Human-Environment Interactions 10

Marcel Bradtmöller
Sonja B. Grimm
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Noa Lavi *Editors*

Under Pressure?

Living with Climate Change and Environmental Hazards in the Past and Now

Springer

Human-Environment Interactions

Volume 10

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Editors

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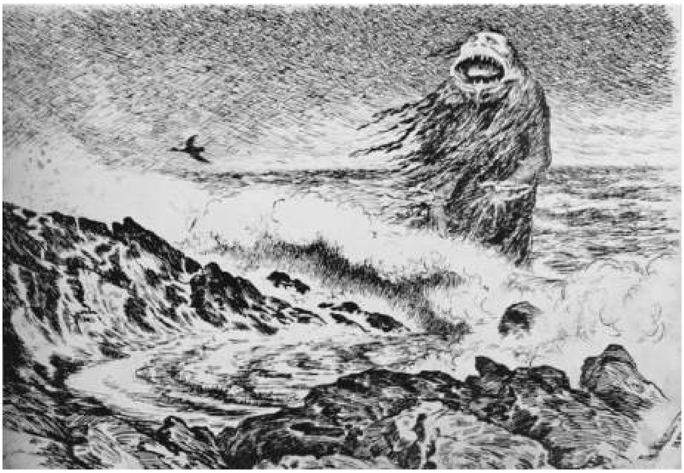
ISSN 2214-2339 ISSN 2452-1744 (electronic)
Human-Environment Interactions
ISBN 978-3-031-85347-0 ISBN 978-3-031-85348-7 (eBook)
https://doi.org/10.1007/978-3-031-85348-7

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland




DON'T
PANIC!

Preface

Growing up in the Global North in the 1980s, we were part of a period and world that managed to end a cold war, witnessed the end of apartheid, and fought for a global fair-trade system. Furthermore, countries came together and took climate action, stopped a hole in the ozone layer, reduced acid rain and subsequent forest decline, and introduced recycling systems for rare resources. The future was bright, embraced by the idea that when large parts of the world work together, we can challenge any global problem. However, we had to learn how fragile our interconnected human societies are when natural hazards strike, such as the 2004 Indian Ocean tsunami, the volcanic eruption of Eyjafjallajökull in Iceland in 2010, and the COVID-19 global pandemic in 2020. Geo-events and pandemics may be short-term and/or single events, but with occasionally long-lasting impact and severe consequences. Affecting whole societies, nation states or individuals, the impact of the various hazards can be significant and result in disasters, or long-term and substantial change.

In this book, you will find chapters contributed by researchers spanning the fields of anthropology ethnography, geography, and archaeology. The point of departure has been papers given at conferences and sessions held in 2022. The first of these conferences, called *Under Pressure? Disasters–Climate Change–Societies (Past/Now)*, was organized at the Museum of Archaeology, University of Stavanger in Norway. The second was the Conference on Hunting and Gathering Societies (CHAGS) organized by the International Society for Hunter-Gatherer Research (ISHGR) and the University College Dublin in Ireland. In this conference, the co-editors of this book joined forces in the session *Living well with natural hazards? Investigating patterns of hunter-gatherer-fisher resilience*. Finally, at the annual meeting of the European Association of Archaeologists in Budapest, Hungary 2022, authors in this book and members of the Palaeolithic and Mesolithic community (PaM) hosted the session #375 "*The societal impacts of climate changes in the past—what can hunter-gatherer archaeology contribute to the current debate?*".

We are grateful to the researchers who made their conference talks and papers into chapters for this book. We also appreciate researchers who did not take part in the mentioned conferences, and still responded to our invitation to contribute.

Furthermore, we thank the many peer-reviewers, the Series editor, and the staff at Springer for making the book possible.[1]

We hope that this volume shows that, although hazards may be "normal" in an unpredictable world, if hazards turn into disasters this has roots in how the societies are rigged. Thereby, learning more and sharing knowledge about what makes various societies and groups vulnerable or resilient will hopefully enable us to live well with hazards, including climate change.

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December 2024

[1] Publishing this book Open Access was made possible by the generous funds of the University of Rostock, Germany (Open Access Publication Fund), the Museum of Archaeology, University of Stavanger, Norway, and the (former) Centre for Baltic and Scandinavian Archaeology (ZBSA; now part of the Leibniz-Zentrum für Archäologie as LEIZA-ZBSA) in the Schleswig-Holstein State Museums Foundation Schloss Gottorf, Germany. Work on the book and the conference Under Pressure? Disasters–Climate Change–Societies (Past/Now) is also part of the designated output for the FRIPRO research project "The Storegga tsunami c. 6150 BC—a wave of destruction or transformative disruption for a prehistoric society?" For short, Life After the Storegga Tsunami (LAST). This project was funded by the Norwegian Research Council (project number 302858; 2021–2024). Furthermore, work on the book as well as the organisation of the sessions at CHAGS Dublin 2022 and EAA Budapest 2022 was also made possible by the subproject B1 "Pioneers of the North" of the Collaborative Research Centre 1266 "Scales of Transformation—Human-environmental interaction in prehistoric and archaic societies" funded by the German Research Foundation (DFG, project number 2901391021-SFB 1266).

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Chapter 1
Under Pressure? Living with Climate Change and Environmental Hazards in the Past and Now

Sonja B. Grimm, Marcel Bradtmöller, Noa Lavi, and Astrid J. Nyland

Rising sea levels, melting ice, floods, droughts and landslides caused by our time's dramatically accelerating climate change are increasingly recognised as influencing life on this planet. Affected by global pandemics and sudden large-scale geological events, like volcanic eruptions, earthquakes and tsunamis, the pressure on the world's populations is rising. Consequently, the volume of research into risk reduction, disaster and conflict management is increasing (e.g., Swain and Öjendal 2018; Kelman et al. 2017; Kelman 2020), as well as the number of related institutes and "think tanks" such as the UNDRR (UN Office for Disaster Risk Reduction).

Since being under pressure is not new for human societies, investigations of disasters, conflict/risk management and resilience have also trickled into archaeology and anthropology research. This is well reflected in a growing number of conference sessions, papers and books (e.g., Izdebski et al. 2016; Bradtmöller et al. 2017; Dawson et al. 2017; Temple and Stojanowski 2018; Kohler and Rockman 2020;

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_1

Riede and Sheets 2020; Burke et al. 2021; Erdkamp et al. 2021; Nyland et al. 2021; Smith 2021; Jacobson 2022; Silva et al. 2022; Riris et al. 2024).

Most of the contributors to this book met and discussed the theme during four scientific events. At all of them, the theme of human–environment relations was discussed to increase our understanding of the impacts of geological events and environmental changes on human life in the present and the past (cf. Collings et al. 2023; Gjerde 2024; Hoebe et al. 2023; 2024; Lundström 2023; Riris et al. 2024; Sánchez-García et al. 2024). A recurring point was whether understanding deep-time developments and insights into adaptive strategies of past societies holds answers that might help humanity deal with current challenges. Furthermore, which specific implications could be learned from small-scale societies, which were the focus of most presentations. Another recurring point was whether archaeology and anthropology could contribute to the "universal call to action" from the United Nations in 2015 through their 17 Global Goals for Sustainable Development for a habitable world for all to live in.[1]

Research and engagement on multiple levels across scientific disciplines are necessary if these goals are to be achieved, and within this book, several of the aims and aspects are engaged with. Goal number 11, *making communities and human settlements inclusive, safe, resilient and sustainable*, is the point on which most chapters of this book pivot. Furthermore, other chapters also touch upon goals number 3, *good health and well-being*, number 13, *climate action*, number 14, *life below water* and number 15, *life on land*.

The following chapters are written by researchers with backgrounds in archaeology, anthropology, ethnography and sociology. They focus on social sciences, humanities and modern disaster studies, applying theories and methods spanning from the natural sciences to science fiction. Therefore, the book is a melting pot of perspectives, fields of research, discourses and methods. All contributors have engaged with the question of how societies may or can live with or through natural hazards, climate change, disasters or crises of different scales and magnitudes. However, in an interdisciplinary setting, consideration of the utilised terms, phrasing and words is required to avoid potential misunderstandings.

1.1 Terms and Scales Matter

With many of the authors coming from the field of archaeology, several case studies focus on prehistoric[2] people who were formerly identified as "hunter-gatherers", "foragers" or "hunter-fisher-gatherers" (Chap. 5, 7, 10, 11,12, 13, and 14). We consciously write *formerly identified* because the term "hunter-gatherers" has been a contested term in anthropology for decades (e.g., Barnard 1983, 2004; Bird-David 1990; Headland 1997; Kehoe et al. 1981; Kusimba 2005; Lavi, Rudge and Warren 2024; Lavi and

[1] https://www.undp.org/sustainable-development-goals.

[2] Note, by "prehistoric" we mean the time period before written sources.

Friesem 2019; Lee 1992; Pluciennik 2004, 2014; Solway et al. 1990; Warren 2021; Wilmsen et al. 2009). Furthermore, although the “surprise over complex hunter-gatherers” may have faded (Sampson 2023, 1), there is still an implicit binary notion of “simplicity” that can taint hunter-gatherer studies. Therefore, since we are still applying the category of hunter-gatherers, we want to stress that our use of the category still acknowledges the variability of such communities and that categorising a society based on their subsistence strategy embeds a definite bias.

Comparable to hunter-gatherers, the term “small-scale society” needs clarification, especially when applied to mobile societies that do not necessarily have a stable group size. Groups can also roam wide territories and can, therefore, be connected across large areas with similar groups (Bird et al. 2019). Moreover, groups can be large or small depending on the time of year if groups, for instance, join for festivities or separate to execute special tasks. When approaching the question of how to identify a small-scale society, the number of people in a group, their territorial size, or whether it is population density in a demarcated area that is key to their behaviour need to be clarified. But, how do we define the boundaries of a society with wide-ranging social networks? Does “small” in “small-scale” characterise the level of social hierarchies or inequalities? In this book, most authors use “small-scale” when referring to societies with low population densities (Kilhavn Chap. 12; Mangalasseri et al. Chap. 8; Piper et al. Chap. 6; Riede et al. Chap. 13; Walker Chap. 5), although there are also single references to geographically localised groups (Bradtmöller and Lübke Chap. 11) and non-industrial groups organised by cultural institutions (Stutz Chap. 14). Hence, we hope it comes across that the term is not used or understood diminutively nor to deprive groups of their social complexity and multiple connectedness.

This sensitivity to bias or prejudices when categorising societies based on their subsistence or scale also acknowledges that the kind and causes of risks, as well as experienced vulnerabilities, will vary over time and between regions. One objective of this book is to heighten awareness and recognise the value of local decision-making in resilience dynamics. Such awareness of potential research bias also relates to the current context of decolonialisation and the implementation of post-colonial theory in academia, anthropology and archaeology (e.g., Lydon and Rizvi 2010; Spangen et al. 2015; Finlayson and Warren 2017; Porr and Matthews 2017, 2019; Warren 2021; Elliot and Warren 2022, 2023).

Thus, we acknowledge the limitations and problems of these terms. However, we also find the terms hard to escape when in need of a short, pragmatic description of mainly mobile communities with small numbers of people per area and a subsistence system based mostly on marine and terrestrial hunting, fishing, gardening and/or gathering.

As some of the papers in the book demonstrate, it remains a matter of debate as to whether the underlying assumptions about societies and their clear distinction can always be upheld. Many of the papers have attempted to avoid the use of the terms “hunter-gatherers” or “small-scale” by referring to the societies living at the time of their case study as “coastal dwellers” or “societies” with a general description of subsistence modes (e.g., Heitz Chap. 4; Nyland Chap. 7; Bradtmöller and Lübke Chap. 11). Moreover, specifying the societies in question also acknowledges that risks may not affect all societies nor all social strata or groupings in a society, in a similar way. This also comes across clearly in our book, where risks and vulnerabilities of societies living from the Epipalaeolithic in the Levant to modern-day India are discussed and exemplified. Our book thus provides examples covering a broad spectrum of social contexts where people have managed to live with hazards, risks and disasters.

After agreeing that how we use terms matters, we also recognise that most terms and concepts have particular histories because of their development in particular subjects; therefore, they often have tacitly embedded meaning and understanding (Von Meding and Chmutina 2023). Terms such as "resilience", "sustainability", "hazards", "vulnerability", "risk management" and "disasters" are also frequently applied in archaeology and anthropology and are key concepts in this book (see Table 1.1). However, they have been developed in fields such as ecology, disaster management studies, psychology, engineering and the social sciences (e.g., Jacobson 2022). In the transference of such contemporary concepts onto past and modern small-scale societies lies potential discrepancies of use and problematic aspects. Can the fragmented archaeological record provide a good enough foundation for their application? Can we apply knowledge from contemporary indigenous societies—who are often marginalised in their respective countries—to historical events or to mainstream and highly industrialised societies? What do we mean and search for when investigating the characteristics of a resilient society? What makes a natural event a hazard, and what makes a hazard a disaster?

As Table 1.1 shows, the papers of this book apply, define or explore such questions, including local understandings of the concepts rooted in case studies on small-scale societies from both the past and present.

1.2 Book Structure and Technicalities

This volume contains theoretical and methodological debate in the fields of anthropology, archaeology and the social sciences, with case studies and examples from the Palaeolithic/Old Stone Age to the present day.

The book is divided in three parts, preceded by this introduction, in which we have introduced the general theme as a point of departure. In Part I, the chapters comprise theoretical debates where concepts and different terms are discussed and engaged with. These chapters contain anthropological and archaeological case studies. In Part II, the chapters are even more case study based, but also here, the chapter authors discuss concepts, related methods, and apply models to archaeological, anthropological, ethnographical and historical cases. These exemplify storying and navigating environmental and climate change as well as short-term natural hazards.

Part III comprises the editors' "Epilogue". This is a synthesis of elements of the discussions in the chapters, where we also consider the benefits of multidisciplinary studies and conversations, which this book is an attempt at. We also conclude with some thoughts on future aspirations.

Table 1.1 Overview about some interesting parameters sorted after chapters

Chapter	Societies under study	Datasets	Geographical range	Studied timeframe	Scientific terms in use	External drivers	Impact on socieites
2. Barrios	Modern, small-scale indigenous communities	Ethnographic investigations (oral interviews) and national data services	Guatemala Highland, Honduras, U.S. Virgin Islands	Pre-Columbian to modern	– Disaster – Vulnerability – Community resilience theory	– Earthquake – Hurricane	na
3. Chmutina & v. Meding	Small-scale/ marginalised groups	Seminal survey (anglophone literature)	Theoretical discussion	Theoretical discussion	– Disaster – Hazard – Causes of Vulnerability – Coping Strategy – Adaptive Capacity – Resilience	na	na
4. Heitz	Prehistoric small-scale communities	Theoretical discussion	Theoretical discussion	Theoretical discussion	– Disaster – Hazard – Spatio-temporal scales – Mobility turn – Social resilience	diverse	diverse
5. Walker	Small-scale communities	Theoretical discussion with some archaeological data	Norway	9.000–8.000 BP	– Disaster – Hazard – Scales of Hazards – Taphonomy	– Tsunami	Theoretical implications
6. Piper et al.	Small-scale communities	Theoretical discussion	Theoretical discussion	Theoretical discussion	– Narratives – Storytelling	– Current climate change	na

(continued)

Table 1.1 (continued)

Chapter	Societies under study	Datasets	Geographical range	Studied timeframe	Scientific terms in use	External drivers	Impact on socieites
7. Nyland	Mesolithic small-scale communities	Theoretical discussion with some archaeological data	Norway	10.000–5.200 BP	– Capacity – Risk reduction – Hazards as Monsters – Storytelling	– Tsunami	– Social impact of disasters: psychological distress/trauma – Forces to think outside the box
8. Mangalasseri et al.	Modern, small-scale indigenous communities	Ethnographic (group discussion, interviews) and qualitative data	Riverbeds within the Western Ghats, India	Recent times	– Community vulnerability – Risk reduction	– Landslide – Flash floods—Unpredictability of rainfall	– Destroyed roads and resources. Fear – Change of mobility – Less space for humans and wild animals
9. Larsson	Historical small-scale communities	Oral first and second hand descriptions, map data	Norway/Sweden	Seventeenth Century	– Disaster – Disasterscape – Taphonomy – Oral tradition	– Landslide	– Destruction of the valley and the human settlements

(continued)

Table 1.1 (continued)

Chapter	Societies under study	Datasets	Geographical range	Studied timeframe	Scientific terms in use	External drivers	Impact on socieites
10. Temple et al.	Small-scale communities	Archaeological & Anthropological data	Japan & Latvia	5.500 -2300 BP & 9.000–2500 BP	– Resilience of what to what – Mobility – Resilient landscapes	na	Theoretical implications
11. Bradtmöller & Lübke	Mesolithic small-scale communities	Archaeological datasets	Wismar Bay (Germany)	9.600– 6.000 BP	– Disaster – Resilience – Capacity	– Sea-level rise	– Population stability – No direct causalities between environ-mental and human dynamics visible
12. Kilhavn	Mesolithic small-scale communities	Archaeological data	Western and Central Norway	10.000–5.200 BP	– Disaster – Hazard – Taphonomy	– Tsunami	– Lack of settlement sites in specific areas after the Tsunami – Changed perception of risk or demo-graphic downturn?

(continued)

Table 1.1 (continued)

Chapter	Societies under study	Datasets	Geographical range	Studied timeframe	Scientific terms in use	External drivers	Impact on socieites
13. Riede et al.	Mesolithic small-scale communities	Archaeological data	Denmark	Early Holocene (11.000 to 6.000 BP)	– Behavioural ecological theory – Risk Management – Pressure and Release Model – Bad Year Economics	– Climate 8.2 event – Tsunami	– Population decline
14. Stutz	Epipaleolithic small-scale communities	Archaeological data	Levant	Late Pleistocene	– Human adaptive system – Niche construction theory – Future-discounting-cycle model	– Hidden Hazards	– Population decline – Decelerating carrying capacity

The chapters in Part I and Part II are all peer-reviewed by two reviewers. The reviewers were given a choice of whether to make their names known to the authors. Most did and are thanked in the Acknowledgement section of the different chapters. This Introduction and the Epilogue, are not peer-reviewed.

1.2.1 Part I: Influential Terms and New Perspectives

Part II starts with *Ksenia Chmutina* from Loughborough University, England, and *Jason von Meding* from the University of Florida, USA, who provide an overview of disaster studies and practice and ask why disasters actually happen. They argue that framing disasters as "natural", "unexpected", "sudden" or "events" promotes the idea that disasters are tragic but simply inevitable and ignores their social and political origins. They also argue that disasters can only really be understood from the perspective of the prevailing socio-economic system.

Roberto E. Barrios, from the University of New Orleans, USA, equally outlines the key role of social science in understanding of disaster and resilience for living well with hazards. He examines the contribution of ethnographic research in defining resilience and comments on why social-science-informed definitions of disaster have yet to be fully incorporated into public policy. He concludes with a review of the need to update vulnerability theory considering recent advances in analyses of human and material agency.

Caroline Heitz from the University of Bern, Switzerland, equally discusses what makes a natural phenomenon a hazard, what makes a disaster and how to operate these terms in archaeological research. She thereby explores situational vulnerabilities and social resilience to climate change conceptualised through different types of varying mobility (e.g., social or spatial) within and of societies. She concludes with suggestions of how this could be investigated archaeologically.

James Walker now at the University of Bradford, England,[3] uses the Storegga tsunami as an example to explore what he sees as the temptation and pitfalls of reductive and environmentally determinist assumptions when considering prehistoric disasters. He also critically considers the multi-scalar processes that belie such assumptions.

Stephanie F. Piper, from the University of York, England, together with *Sonja B. Grimm*, from the Leibniz Zentrum für Archäologie (LEIZA-ZBSA) in Schleswig, and *Marcel Bradtmöller*, from the University of Rostock, both Germany, discuss the potential of our knowledge about past and present small-scale societies to derive positive climate narratives and how they can be used by storytelling in various forms to open fresh perspectives for our future existence.

Narratives are also prominent in *Astrid J. Nyland's* chapter. Nyland is from the University of Stavanger, Norway, and engages with a tsunami's ontological as well as epistemological aspects but starts with a deconstruction of the phenomenon of a

[3] Former at the University of Stavanger, Norway.

tsunami. By using monsters as a thinking tool, she develops a new understanding of what an encounter with the Storegga tsunami 8200 years ago could have caused and suggests new entries for learning about the social impact of a crisis. She also builds on the concept of post-memory and sees storytelling as a key societal capacity for risk reduction.

1.2.2 Part II: Explorations of Human–Environment Relations

In Part II, archaeological and anthropological case studies tell the stories of societies under pressure by identified natural hazards and long-term processes. The chapters are arranged chronologically, starting with a case study from present-day India and ending with the Epipalaeolithic in the Levant. Geographically, the chapters include case studies from Japan, India, the Levant, Scandinavia (Norway, Sweden and Denmark), Germany and Great Britain.

The section starts with the chapter from *Asish Mangalasseri* and *Ajesh M.* from Keystone Foundation, Nilgiris District, Tamil Nadu, *Vinod Chellan* from Cochin University of Science and Technology, Cochin, all India, and *Noa Lavi* from Haifa University, Israel. They are writing about the importance of community-based ecological monitoring and environmental justice in light of unexpected extreme rainfall, severe floods and landslides caused by climate change. Their case study focuses on small-scale communities from Nilambur, India, and shows how communities combine new and local knowledge to manage stress and enhance resilience. These coping strategies, argue the authors, are both innovative and rooted in communities' practices and values and thus should be taken into account in official decision-making processes.

Landslides are also the focus of *Anton Larsson's* chapter. Anton Larsson is from the University of Stockholm, Sweden. His case study is the Intagan landslide in Sweden in 1648. Using GIS, maps and archival sources, he explores both material and immaterial memories of the disaster. In doing so, his taphonomic analysis shows the limitations of analysing the effects of natural hazards based on archaeological remains.

Daniel H. Temple, from George Mason University, USA, *Gunita Zarina* and *Ilga Zagorska*, both from the University of Latvia, examine the mobility strategies of hunter-gatherer communities from Japan (Jomon period) and Latvia (Zvejnieki) to understand how they maintained resilient landscapes despite ecological changes. By analysing the cross-sectional properties of long bones, the research reveals that Jomon groups had higher mobility rates due to their rugged, mountainous terrain, while Zvejnieki groups were less mobile, living in flatter, lacustrine environments. Both groups shared strong ideological ties to their landscapes, as reflected in their burial practices, which helped sustain the long-term occupation of these sites.

Marcel Bradtmöller from the University of Rostock, together with *Harald Lübke,* LEIZA-ZBSA in Schleswig, both Germany, aim to understand the resilience of Stone Age coastal dwellers and their ability to adapt to natural dynamics such as the 8.2 ka cold event, but most importantly to the rising post-glacial sea level of the Baltic Sea. Their results suggest that these groups maintained socio-economic stability through capacity building via super-regional networks and innovations. However, they also raise more practical questions about appropriate datasets, the necessary data resolution and the spatial scale of investigation for this type of study.

Håvard Kilhavn, University of Stavanger in Norway, takes the Storegga tsunami, 8200 years ago, as a point of departure. By investigating the coastal site location in what he calls Storegga's Mesolithic ground-zero, he discusses sea-level change and shoreline dating of the sites. He aims to provide insights into potential changes in settlement practices that can inform the potential social impact of the tsunami and also discusses the taphonomic implications of the tsunami's impact on the preservation of the material remains.

Felix Riede from the University of Århus, *Kathrine L.D. Andreasen* from Museum Odense and *Peter M. Yaworsky* from the University of Århus, all Denmark, apply a model-based approach derived from disaster risk reduction research and based on the Pressure and Release Model. They investigate whether the combination of two event-like environmental hazards, the 8.2 ka cold event(s) and the Storegga tsunami, led to changes in land-use, subsistence and network strategies among contemporaneous Mesolithic foragers in western Denmark.

Aaron Stutz of the Bohusläns Museum in Sweden asks whether too much resilience is a good or a bad thing. Using a case study from the Epipalaeolithic of the southern Levant, he points to a paradox of the apparently flourishing hunter-gatherer-fisher communities. While maintaining a small-scale foraging world, these groups had grown demographically, for example, by gradually having significant ecological impacts on big game populations. Were there hidden dangers or robustness in hunting, gathering and fishing societies?

1.3 Final Remarks

In this book, the reader will encounter discussions on concepts about resilience, vulnerability, sustainability and disasters, among others. By focusing on modern and prehistoric small-scale societies, it becomes obvious that the chapters discuss the same issues as the current climate change research. A second focus of our contributors is on identifying the socio-economic parameters of resilience and the reasons for their loss. This is challenging because the external impacts, their effects on societies and the human responses to them are sometimes not easy to identify, especially in the past. Aspects of social dynamics are discussed, noting the difficulties of acknowledging how and what we recognise as representing social change. Are changes in material culture necessarily caused by external impacts? Can we prove causality? Does B necessarily follow A? How do we tell if environmental change is relevant to societal change? Can we identify distinct strategies for social safety? What are the required conditions or capacities for successful stress management?

Aspects of social complexity are addressed, taking issues with the labelling of these societies as flexible, immediate return-oriented, egalitarian, non-interdependent or non-complex systems. In these questions, there are also ethical and scientific responsibilities because no matter which terms we apply, they are socially situated and, hence, are political. Can we identify the various arenas in which such terms are activated? This becomes particularly relevant in times in which archaeological research results are politically misused. Can our effort enable academic activism and make our work matter to people today? If not, how can we achieve that? In both cases, how can we prevent socio-politically motivated misrepresentation?

Finally, can generated knowledge of disasters or climate change handling in recent/current societies be applied to understand strategies in past societies? While simple correlations or lessons learnt are complicated to derive, we nonetheless see links between the scientific results of the contributions to our current situation, which we will point out in the final chapter. We may not offer answers to all the above questions, but if they make you curious, we hope you will enjoy the glimpses offered in this book!

References

Barnard A (1983) Contemporary hunter-gatherers: current theoretical issues in ecology and social organization. Annu Rev Anthropol 12:193–214

Barnard A (2004) Hunting-and-gathering society: an eighteenth century Scottish invention. In: Barnard A (ed) Hunter-gatherers in history, archaeology and anthropology. Berg, Oxford, pp 31–43

Bird DW, Bird RB, Codding BF et al (2019) Variability in the organization and size of hunter-gatherer groups: Foragers do not live in small-scale societies. J Hum Evol 131:96–108

Bird-David N (1990) The giving environment: another perspective on the economic system of gatherer-hunters. Curr Anthropol 31(2):189–196

Bradtmöller M, Riel-Salvatore J, Grimm SB (eds) (2017) Adaptive cycles in archaeology. Special issue. Quaternary International 446

Burke A, Peros MC, Wren CD et al (2021) The archaeology of climate change: the case for cultural diversity. Proc Natl Acad Sci 118:e2108537118

Collings P, Ready E, Medina-Ramírez OM (2023) An ethnographic model of stress and stress management in two Canadian Inuit communities. J Cross Cult Psychol 54(3):407–428. https://doi.org/10.1177/00220221231155105

Dawson T, Nimura C, López-Romero E et al (2017) Public archaeology and climate change. Oxbow Books, Oxford

Elliot B, Warren G (2022) Consumers, not contributors? the study of the Mesolithic and the study of hunter-gatherers. Open Archaeology 8(1):787–795. https://doi.org/10.1515/opar-2022-0259

Elliot B, Warren G (2023) Colonialism and the European Mesolithic. Nor Archaeol Rev 53(1):71–89. https://doi.org/10.1080/00293652.2023.2182232

Erdkamp P, Manning JG, Verboven K (2021) Climate change and ancient societies in Europe and the Near East. Diversity in collapse and resilience. Palgrave Macmillian, Cham

Finlayson B, Warren G (2017) The diversity of hunter gatherer pasts. Oxbow books, Oxford

Gjerde JM (2024) Frequency, phases and chronology of rock art: spatiotemporal studies of the Alta rock carvings, northernmost Europe. Oxf J Archaeol 43(2):108–134. https://doi.org/10.1111/ojoa.12293
Headland T (1997) Revisionism in ecological anthropology. Curr Anthropol 38(4):605–630. https://doi.org/10.1086/204648
Hoebe PW, Cohen KM, Busschers FS et al (2024) Early Holocene inundation of Doggerland and its impact on hunter-gatherers: an inundation model and dates-as-data approach. Quatern Int 694:26–50. https://doi.org/10.1016/j.quaint.2024.05.006
Hoebe PW, Peeters JHM, Arnoldussen S (2023) Parsing prehistoric patterns: prospects and limitations of a big radiocarbon dataset for understanding the impact of climate on Late Palaeolithic and Mesolithic populations in northwest Europe (16–7.5 ka calBP). J Archaeol Sci: Rep 49:103944. https://doi.org/10.1016/j.jasrep.2023.103944
Izdebski A, Holmgren K, Weiberg E et al (2016) Realising consilience: how better communication between archaeologists, historians and natural scientists can transform the study of past climate change in the Mediterranean. Quatern Sci Rev 136:5–22
Jacobson MJ (2022) Archaeological evidence for community resilience and sustainability: a bibliometric and quantitative review. Sustainability 14(24):16591
Kehoe A, Asch M, Bernier B et al (1981) Revisionist anthropology: Aboriginal North America [and comments and reply]. Curr Anthropol 22(5):503–517
Kelman I (2020) Disaster by choice. How our actions turn natural hazards into catastrophes. Oxford University Press, Oxford
Kelman I, Mercer J, Gaillard JC (2017) The routledge handbook of disaster risk reduction including climate change adaptation. Routledge, London
Kohler TA, Rockman M (2020) The IPCC: a primer for archaeologists. Am Antiq 85:627–651
Kusimba S (2005) What Is a hunter-gatherer? Variation in the archaeological record of Eastern and Southern Africa. J Archaeol Res 13(4):337–366
Lavi N, Friesem DE (2019) Introduction. In: Friesem DE (ed) Lavi N. Towards a Broader View of Hunter-Gatherer Sharing. University of Cambridge Repository, Apollo, Cambridge, pp 1–11
Lavi N, Rudge A, Warren G (2024) Rewilding our inner hunter-gatherer: how an idea about our ancestral condition is recruited into popular debate in Britain and Ireland. Curr Anthropol 65:1–28. https://doi.org/10.1086/728528
Lee RB (1992) Art, science, or politics? The crisis in hunter-gatherer studies. Am Anthropol 94(1):31–54
Lundström V (2023) Living through changing climates: temperature and seasonality correlate with population fluctuations among Holocene hunter-fisher-gatherers on the west coast of Norway. The Holocene 33(11):1376–1388. https://doi.org/10.1177/09596836231185839
Lydon J, Rizvi UZ (2010) Handbook of postcolonial archaeology. Routledge, Milton Park, New York
Nyland AJ, Walker J, Warren G (2021) Evidence of the storegga tsunami 8200 BP? an archaeological review of impact after a large-scale marine event in mesolithic Northern Europe. Front Earth Sci 9:767460. https://doi.org/10.3389/feart.2021.767460
Pluciennik M (2004) The meaning of "hunter-gatherers" and modes of subsistence: a comparative historical perspective In: Barnard A (ed) Hunter-gatherers in history, archaeology and anthropology. Berg, Oxford, pp 17–30
Pluciennik M (2014) Historical frames of reference for 'hunter-gatherers'. In: Cummings V, Jordan P, Zvelebil M (eds) The Oxford handbook of the archaeology and anthropology of hunter-gatherers. Oxford University Press, Oxford, pp 55–68
Porr M, Matthews JM (eds) (2019) Interrogating human origins. Decolonisation and the deep human past. Routledge, London
Porr M, Matthews JM (2017) Post-colonialism, human origins and the paradox of modernity. Antiquity 91:1058–1068
Riede F, Sheets P (eds) (2020) Going forward by looking back. Archaeological Perspectives on Socio-ecological Crisis, Response, and collapse. Berghahn, New York, Oxford

Riris P, Silva F, Crema E et al (2024) Frequent disturbances enhanced the resilience of past human populations. Nature 629:837–842
Sampson CP (ed) (2023) Fisher-hunter-gatherer complexity in North America. University Press of Florida, Florida
Sánchez-García C, Revelles J, Burjachs F et al (2024) What burned the forest? Wildfires, climate change and human activity in the Mesolithic – Neolithic transition in SE Iberian Peninsula. CATENA 234:107542. https://doi.org/10.1016/j.catena.2023.107542
Silva F, Coward F, Davies K et al (2022) Developing transdisciplinary approaches to sustainability challenges: the need to model socio-environmental systems in the longue durée. Sustainability 14:10234
Smith ME (2021) Why archaeology's relevance to global challenges has not been recognised. Antiquity 95:1061–1069
Solway J, Lee R, Barnard A et al (1990) Genuine or spurious? Situating the Kalahari San in history [and comments and reply]. Curr Anthropol 31(2):109–146. https://doi.org/10.1086/203816
Spangen M, Salmi AK, Äikäs T (2015) Sámi archaeology and postcolonial theory—an introduction. Arct Anthropol 52:1–5
Swain A, Öjendal J (eds) (2018) Routledge handbook of environmental conflict and peacebuilding. Routledge environment and sustainability handbooks. Routledge, London, New York
Temple DH, Stojanowski CM (2018) Hunter-gatherer adaptation and resilience: a bioarchaeological perspective. Cambridge University Press, Cambridge
Von Meding J, Chmutina K (2023) From labelling weakness to liberatory praxis: a new theory of vulnerability for disaster studies. Disaster Prev Manag 32(2):364–378. https://doi.org/10.1108/DPM-10-2022-0208
Warren G (2021) Is there such a thing as hunter-gatherer archaeology? Herit Soc 4(2):794–810. https://doi.org/10.3390/heritage4020044
Wilmsen E, Barnard A, Biesele M et al (2009) To see ourselves as we need to see us: Ethnography's primitive turn in the early Cold War years. Crit Afr Stud 1(1):20–95. https://doi.org/10.1080/20407211.2009.10530743

Part I
Concepts and Theoretical Debates

Chapter 2
What is a Disaster? an Overview of (Contested) Disaster Concepts

Ksenia Chmutina and Jason von Meding

> In 1879, after three years without rain, the Indians number nine million fewer. It is the fault of nature: "These are natural disasters," say those who know. But in India during these atrocious years, the market is more punishing than the drought. Under the law of the market, freedom oppresses. Free trade, which obliges you to sell, forbids you to eat.
> Eduardo Galeano

Abstract Disasters have been catching the attention of politicians, news reports, academics, and many others for centuries; yet the way that disasters have been framed changes significantly depending on who is talking about them and to whom. This chapter demonstrates that disasters cannot be understood without untangling unequal and often oppressive social, political, and economic systems. We argue that framing disasters as "natural", "unexpected", "sudden", and "events" promotes the idea that disasters are tragic but simply inevitable and ignores their social and political origins. We discuss the concepts most widely used—and contested—to define disasters and explain why these concepts can be so problematic and indeed can often only be understood within the contextual framework of the prevailing socio-economic system.

Keywords Disasters · Hazards · Vulnerability · Capacity · Concepts

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_2

2.1 Introduction

People have lived with—and suffered from—the threats and impacts of hazards for centuries; disaster has produced, shaped, and broken civilizations and affected our cultures and behaviours. Every day, mass media bombards us with images of floods, heatwaves, typhoons, hurricanes, earthquakes, or volcanic eruptions, and the stories of "unprecedented" "freak" events that destroy livelihoods and cost billions of dollars in recovery and reconstruction. Disasters are thus becoming more and more prominent on political and media agendas as the damages caused by these disasters are on the increase. But what is a disaster, and why does it actually happen? This chapter provides an overview of the current debates in the Anglophone disaster scholarship, some critical, some normative, but important to our understanding of disasters nevertheless. While a lot of scholarship has been produced by non-Western scholars (for instance, the much respected works by the members of LA RED, some of which are cited in Chap. 3 by Roberto Barrios, and publications by scholars from Southeast Asia (e.g. see Bonifacio and Epe's excellent edited volume on the *Disasters in the Philippines* (2023) as well as many others), it is outside the scope of this chapter to provide an extensive overview of all these works. Instead, we will focus on what is considered "seminal" literature—but we strongly encourage the reader to only use this as a foundation for critique and engage with much wider readings inside and outside disaster studies.

Engaging with Anglophone literature is also important for understanding and developing the critique of disasters, as disaster terms—and consequently the problems they are trying to address and frame—are very much grounded in English language hegemony (Chmutina et al. 2020). The use of Anglophone terminology and underlying meaning among governmental and non-governmental organizations, research institutions, and intergovernmental actors enforces power by creating the language norms by which these elite actors get published, win grants, and achieve policymakers' buy-in.

2.2 What is a Disaster?

The word "disaster" derives from the Greek δυσ- (bad) and ἀστήρ (star), a calamity blamed on an unfavourable position of stars or planets. For centuries, its meaning has been related to divine anger (Drabek 1991) and forces of nature, but gradually, as the scientific comprehension of natural phenomena as well as socio-political and technological processes and impacts has increased, the sense of "inevitable" in the interpretation of disasters has been questioned (Alcántara-Ayala et al. 2022).

A disaster is commonly defined as "[a] serious disruption of the functioning of a community or a society at any scale due to *hazardous events interacting with conditions* of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts" (UNISDR 2018, authors' emphasis). This definition suggests that a hazard and a disaster are not the same. In other words, a disaster is not just the occurrence of a hazard: an earthquake that happens in an uninhabited area would not typically be considered a disaster.

The UNDRR (2018) defines a natural hazard as "[a] natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation", with an annotation that "[s] evere hazardous events can lead to a disaster as a result of the combination of hazard occurrence and other risk factors" (authors' emphasis). The fundamental determinants of hazards comprise location, time, magnitude, and frequency; risk factors are related to the threshold determined by the combination of the lowest limit at which physical forces can cause damage (Alexander 2000). It is also important to recognize that risk is a complex notion. While risk is traditionally defined as a combination of an impact and a likelihood, a political will to deal with risks, a capacity to map and assess the frequency of hazard events, susceptibility to loss across a range of population groups and sectors, and a capacity to take actions to prepare and to mitigate, to monitor the results of actions, to learn from successes and failures, and to maintain vigilance and foresight through more quiescent periods, when public interest will decrease (Wisner 2018), play an even more important role in how the risk is created (and by whom). These elements are summed up in an equation-like mnemonic (Wisner et al. 2012: 19–21):

$$R \approx [H \times (V/C) - M],$$

where R stands for disaster risk, H for the specific hazard probability, V for vulnerability, C for localized and individual capacity for self-protection and recovery, and M for social protection provided by the state, ideally complementing and supplementing C and never blocking or diluting it (which in reality happens quite often!). These variables are dynamic and are affected by global economic and geopolitical change and climate instability, national political and economic cycles and other abrupt changes, as well as local context.

This demonstrates why the interaction between a hazard and these "conditions of exposure, vulnerability and capacity" emphasized in the UNDRR definition is significant for our understanding of disasters. Oliver-Smith (1986) explains this well in his definition of disasters: "[disaster] is a collectivity of intersecting processes and events, social, environmental, cultural, political, economic, physical, technological, transpiring over varying lengths of time". This definition highlights the fact that risk is *socially constructed*, encouraging us to think beyond the theories, concepts, and methods commonly used in the study of disasters in the hope that they might be universal in their relevance and application to understanding the unique and diverse experiences of millions of people across very different cultures.

While disasters are often portrayed as unexpected external and natural shocks and are frequently framed as tragic but simply inevitable, the anthropological evidence—and body of knowledge in disaster anthropology, alongside many varied knowledges—helps us to recognize that disasters are never simply natural. If disasters were inevitable, it would follow that humans should strive to adapt and we should devote maximum effort and resources to this. But is this really the case, and what does the answer mean for disaster risk reduction strategy and action?

This argument that disasters are not natural—and are thus avoidable—is not new: in a letter to Voltaire in 1756, Rousseau reflected on the 1755 Lisbon earthquake, describing it as something more than an earthquake, noting “that nature did not construct twenty thousand houses of six to seven stories [...], and that if inhabitants of this great city were more equally spread out and more lightly lodged, the damage would have been much less and perhaps to no account” (in Master and Kelly 1992: 110). This argument has been further highlighted and discussed over the years (Ball 1975; Cannon 1994; Chmutina and von Meding 2019; Hewitt 1983; O’Keefe et al. 1976; Oliver-Smith 1986; Smith 2005). When disasters are described as “natural”, they are perceived to be caused by hazards of natural origin (such as extreme weather, geophysical phenomena, or epidemics) —and by calling disasters “natural” we are putting the responsibility for failures of development on “freak” natural phenomena or “acts of God”, which is never the case. Disasters are a product of economic, social, cultural, and political processes.

A hazard cannot be prevented, but it does not have to lead to disaster. Earthquakes, droughts, floods, storms, landslides, and volcanic eruptions are hazards, but deaths and damages—i.e. the impacts of disasters—are due to human acts of omission and commission rather than acts of nature. A hazard becomes a disaster because its impact threatens the lives and livelihoods of people, and this does not happen unless people and cities are vulnerable due to marginalization, discrimination, and inequitable access to resources, knowledge, and support. Furthermore, vulnerabilities are too often enhanced not because the information about dealing with hazards does not exist, but because decision-makers (and those responsible for the development of the built environment) do not use this information appropriately (or at all).

There is, however, a tendency in literature to differentiate between “natural” and “technological” disasters (Chmutina and von Meding 2019). In the 1980s, Allen et al. (1980) attempted to provide a categorization of disasters as “sudden” (e.g. hurricanes, earthquakes, volcanic eruptions), “creeping” (e.g. droughts, epidemics), “deliberate man (sic)-made” (e.g. civil wars), or “accidental”. The two latter categories have been perceived as disasters that “could have been avoided”, with “accidental” deriving from harmful technological, industrial, and infrastructure settings, procedures, and failures, such as gas explosions or nuclear radiation. In other words, a human (as opposed to a natural phenomenon) often plays a central role in triggering a threat, which implies that “technological disasters” can be avoidable through correct human behaviour.

In current practice, there is a clear (although perhaps often unspoken of) delineation between these categories: the “sudden” and “creeping” categories are a subject of disaster risk management (with the Sendai Framework for Disaster Risk Reduction (UNDRR 2015) at the forefront), whereas the “deliberate man-made” category is a subject of international humanitarian law, and the “accidental” category is a subject of risk management (which is often addressed in various ISOs). The UNDRR, however, has been calling for integration: “Paragraph 15 of the Sendai Framework for Disaster Risk Reduction 2015–2030 leaves no doubt about the need to address hazards comprehensively as it applies to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by both natural and man-made hazards as well as related environmental, technological and biological hazards and risks" (UNDRR 2018, 2).

However, we would argue that regardless of the source of hazard or threat, *all* disasters are avoidable because *all* disasters are a product of economic, social, cultural, and political processes and require an understanding of vulnerability, which in turn involves the recognition of root causes and the drivers of disaster risk. In other words, disasters do not cause effects; the effects are what we call a disaster (Dombrowsky 1998).

2.3 What is Vulnerability?

As noted earlier, vulnerability is one of the core conditions that turn a hazard into a disaster; it is also one of the most contested concepts in disaster scholarship (see, for example, Bankoff and Hilhorst 2022; von Meding and Chmutina 2023). The UNDRR (2018) defines vulnerability as "the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards". Vulnerability is a complex characteristic derived from socio-economic factors (Cannon 1994) that expose people to harm and limit their ability to anticipate, cope with, and recover from harm. Understanding vulnerability is the key to understanding why disasters occur—and why disasters do not affect all communities and societies equally: for instance, women die more frequently than men in coastal storms and tsunamis; they also suffer domestic violence and other forms of gender violence and insecurity after disasters. Understanding vulnerability reveals that disaster impacts are disproportionately felt by the poor and/or other social groups that have been pushed to the margins of society and lack access to resources and the means of protection available to those with higher levels of socio-economic or political power. Vulnerability thus reflects how power and resources are shared within society.

The elements of vulnerability are complex and intertwined; they change over a person's life cycle. Vulnerabilities may emerge, change, compound, and persist over long periods, passing from generation to generation, and driving inequalities deeper into a society. Thus, each individual, household, social group, or community becomes more or less vulnerable over the course of time (due to a change in season, life cycle, or economic or political cycle). They are also more or less vulnerable to a wide variety of everyday risks such as crime, violence, ill health, and unemployment as well as to less frequent large-scale events such as civil war or epidemics. The interaction of everyday and large-scale threats in a temporal context of multifaceted change demands an understanding of people's situation, not their category. It is impossible to assert that "women" or "indigenous people" or "disabled people" are a vulnerable group or should be considered "at risk" in an absolute sense—patterns of vulnerability are far too complex and dynamic to support such sweeping generalizations (Jacobs 2021; Wisner 2016).

The *vulnerability approach* to disaster became prominent in the 1970s (see Bankoff 2019), shifting the focus from hazards to the conditions that made communities unsafe, and emphasized not only the exposure to hazards but, more importantly, people's capacity (as will be discussed in the next section) to recover from loss. The social critique was unequivocal: colonial heritage, unequal power relationships, unfair developmental policies, and neoliberal interests make some communities and individuals less able to deal with disasters, leaving them at risk. Vulnerability thus offered a way to understand how disasters were shaped by developmentalism, capitalism, consumerism, materialism—and all other "-isms" that have become prominent in showing "economic progress". While achievement according to these measures was often used to "assess" the progress of various nations, the same "improvement" was at the same time the root cause of many vulnerabilities.

Let us look more closely at the root cause of vulnerabilities. Simply put, it is the extent to which a particular social order puts people at risk. This is perhaps best described by Wisner et al. (2004) in the Pressure and Release Model, which explains how vulnerability is produced and reproduced over time, showing how disasters are directly linked not only to a natural hazard but largely to the extent to which a society is put at risk. Inequality, poverty, political ideology, class, and power relations are the root causes of vulnerabilities that turn natural hazards into disasters, making some more vulnerable than others. In other words, vulnerability represents the political, economic, physical, or social susceptibility of a person/group of people to damage from natural hazards. A series of extreme—but often permanent—conditions exist that make livelihood activities extremely fragile for certain social groups (Cardona 2003). The socio-economic, political, and cultural and historic causes are intertwined and interdependent:

1. *Socio-economic causes of vulnerability:* Inequality increases the exposure to risk; this is reflected in power distribution in terms of class, gender, ethnicity, sexuality, disability, and so on. It is a process of feedbacks, which serve to further entrench and ingrain certain people/groups in a cycle of disadvantage, when pre-existing conditions are exacerbated rather than created by a natural hazard. Poverty is an important factor that determines vulnerability. Low-income urban settlements often have limited social resources, i.e. a lack of extended family structure, established networks of contacts, or strong relationships of trust (Sanderson 2000). Thus, inequality is manifested through an access to basic—but not only economic—needs (i.e. goods, services, and cultural satisfactions that are needed for adequate survival). If a livelihood merely provides (or does not provide) sufficient basic needs, then the provision of self- or social protection is highly unlikely, leading to an increase in vulnerability. However, what turns hazards into disasters is not simply a question of money and resources; vulnerability is not the same as poverty. Although livelihood and self-protection are strongly linked to wealth and income, a person's gender or ethnic roots, for instance, may

alter their self-protection capacity despite having a reasonable livelihood (e.g. Bradshaw and Fordham 2013; Donner and Rodriguez 2008; Dunn 2016).

2. *Political and institutional causes:* Vulnerability is a result of power-laden social relations and processes (Sun and Faas 2018). The political system allocates resources for structural preparedness for, and mitigation of, hazards—yet the process of decision-making and implementation is often technocratic and reactive and does not consider the needs of many people (and in fact, often benefiting just a few; see Cheek and Chmutina 2021). Many disaster risk management activities are embedded in international agendas, but peripheral status in the global political economy of some countries, as well as the consequences of long-term conflict and battles for power and the desire to "develop", lead to increasing ecological and social neglect. State power is also closely linked to the impacts of policies and legislations, as the abuse of state power often leads to neglect of governmental functions, such as enforcement of building and safety codes, provision of basic infrastructure, as well as corruption. It is important to consider political causes because people who are spatially isolated (e.g. living in "informal" settlements), or are poor in terms of depleted ecological legacy or livelihood resources, frequently have limited "voice" and access to formal institutions, which makes them politically marginalized. Political marginality is interconnected with the social; it often reflects favouritism practised by ruling parties and historically developed divisions of national territory (Wisner 2010).
3. *Cultural and historical causes:* Contemporary vulnerability often originates from historic governance, i.e. the processes of invasion, conquest, and colonization that subsequently provided the structure for later development models and social hierarchies in postcolonial societies that reproduce colonial patterns of displacement, dislocation, and disadvantage. They reproduce vulnerability by perceiving indigenous communities as inherently vulnerable and ignoring important environmental knowledge and a nuanced understanding of hazards to which the "vulnerable" populations are exposed (Sun and Faas 2018). Furthermore, the continuing influence of foreign powers (think of Haiti, for instance!) results in a state that is geared towards serving the political, social, and business elite rather than the best interests of the public (Schuller 2016). Vulnerability is also further exacerbated by corruption and a lack of governmental leadership accompanied by a missing legal framework and weak law enforcement.

Vulnerability is a multifaceted phenomenon reflecting a range of social, cultural, political, demographic, and economic conditions interacting in complex ways. A single dimension of the social structure is hardly ever responsible for vulnerability. But it is also important to remember that vulnerability is a Western concept—often employed to portray certain localities and groups of people as fundamentally unstable, unsafe, and in need of intervention (Bankoff 2001; Marino and Faas 2020). But people living with risk should not be seen as "those who need help" but instead as "powerful claimants with rights, rather than poor victims or passive recipients" (Heijmans 2004, 127). Children, elderly people, and those living with disabilities have valuable knowledge, experience, and skill to contribute to social protection and risk reduction; the potential for building on such local knowledge and skill can be missed. Of course, local potentials should also not be romanticized. But exclusive focus on vulnerability (rather than capacity as will be discussed in the next section) is misleading because it does not allow for information about the ways that local people are proactive in protecting themselves to come to light and it creates the perception of people as victims (Wisner 2016).

We should also remember that vulnerability is something we all have in common. We have started to see more calls for it to be treated as a condition with a potential for positive transformation as well as resistance (von Meding 2021). Vulnerability gives us the basis for exchange and reciprocity—we cannot come into being, flourish, and survive if our existence is not connected to the existence of others, which means that vulnerability can be the basis for solidarity and mutuality. We can organize collectively and cater to the needs of groups and communities, not just those of individuals (ten Have 2018; von Meding and Chmutina 2023). We can take strength in our connectedness and interdependence, especially when some of us are targeted under conditions of systemic oppression. The ability to stay connected and open to each other can be the basis of resistance.

2.4 What is Capacity?

Another condition (and another contested term) that helps us to understand disasters is capacity. Capacity, defined by the UNDRR (2018) as “the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience”, is probably one of the most overlooked concepts in disaster studies (although a popular one among disaster practitioners, ostensibly because it is practical and has tangible short-term action associated with it!). Capacity demonstrates how individuals and communities make gradual adjustments to cope with environmental changes caused by natural hazards without modifying the fundamentals of their social organization (Gaillard 2007).

Capacity as a concept became prominent in the 1980s (largely thanks to Anderson and Woodrow (1989), who offered “guidelines” for developing coping strategies in a disaster) as a way to demonstrate that labelling people as “vulnerable” (i.e. victims or helpless) underplays their skills, knowledge, and resources that are reliable, familiar, and accessible and thus are the first “go-to” resources when facing a disaster. This also showed that local/indigenous peoples should lead capacity development, because they understand their context best. This approach challenged the traditional technocratic approach to disaster risk reduction that was prominent at the time (and, sadly, remains prominent now) and promoted the idea that people, including the most marginalized, should be at the forefront of development because they are knowledgeable and resourceful (Freire 1970).

Capacities are both an individual and a collective set of diverse knowledge, skills, and resources that people can claim, access, and resort to in dealing with hazards.

Everyone possesses a unique set of knowledge that, when combined in community, becomes diverse. Capacities allow active prevention to avoid an occurrence of hazards, to foster preparedness in facing impending hazards as well as to respond to disasters, and to cope with, and recover, from the impacts of disasters (Gaillard et al. 2019).

Capacity development has been identified as one of the main ways of substantially reducing disaster losses as through it, society can foster change and enhance resilience (Hagelsteen and Burke 2016). But often the opportunity to harness the powerful capacities of local community is missed through ignorance or reluctance on the part of key decision-makers to give up power. There is often a lack of analysis of the relevant risks and initial capacities. The division of roles, responsibilities, and ownership is sometimes understood differently by different partners, leading to confusion. External experts, instead of harnessing capacities, apply ready-made solutions and leave before any institutional memory is created. Harnessing capacities to reduce the risk of disaster requires people's genuine participation in assessing and enhancing their existing knowledge, skills, and resources (Gaillard et al. 2019). It also implies a shift in power and gradual empowerment, the process "by which people, organizations, and communities gain mastery over their lives" (Rappaport 1984, 3). Ignoring established systems, strategies, and capacities can only result in the creation of parallel structures and processes (Hagelsteen and Becker 2014).

Sometimes capacities are referred to in terms of coping or adaptation. In the context of disaster risk, coping is generally a response to an experienced impact, and the ability to survive amidst an adverse environment. *Coping capacities* are thus usually affected by, and evolve because of, physical and temporal characteristics of a natural hazard. For example, communities that live in a flood-prone area could develop different coping strategies, depending on the intensity and the duration of the inundation. Coping capacities are thus retrospective by nature, as they are based on the experience of past events; but they are flexible and respond to changes in economic, social, political, and institutional conditions over time (Smit and Wandel 2006). For instance, resource depletion may gradually reduce coping capacity of a community. *Adaptive capacity* is the ability to adapt to environmental change; it is the process of adjusting to change (both experienced and expected), which is longer term. These changes may be small or large, punctual, or long-lasting. Adaptive capacity has a prospective dimension as it builds around the ability to anticipate future changes in the environment.

Often, people rely upon and develop both coping and adaptive capacities. Coping capacities, for instance, are important during a disaster, as local people are invariably the first responders (Quarantelli and Dynes 1972). Often these capacities are the only available resources for marginalized people, whose rights and needs are overlooked by those with more power (Gaillard et al. 2019). However, in the long run, coping capacities—since usability and effectiveness may be limited or even gradually decrease because of values, processes, and power relations in society (Adger et al. 2009)—should be transformed into adaptive capacities aimed at transforming the structure, functioning, and organization of a system (Berman et al. 2012).

It is important to note that capacity and vulnerability are not the opposites of each other: reducing vulnerability does not always enhance capacity, nor the other way around (Davis et al. 2004). The majority of people—even the most marginalized—have some capacities (although these are often underappreciated), and no one should be labelled as a helpless victim (which the interpretation of vulnerability often leads to). Capacity is often grounded in resources that are local and endogenous to community; vulnerability, on the other hand, is often about the structural constraints on access (such as unequal redistribution of wealth, political systems, market forces, etc.). In other words, people have more control over capacities than vulnerabilities, as they often have little or no control over external factors that create vulnerability. In practical terms, it is easier to develop and enhance capacity than to reduce vulnerability (Wisner et al. 2012).

2.5 The Political Narratives of Disaster

Portraying people as "vulnerable" can be a pretext for intervention, a way to attract donor sympathy and therefore resources. This is one of the reasons why disaster risk reduction efforts focus on addressing the "weakness" instead of emphasizing the "strength". However, in reality, these efforts often target capacity enhancement without changing the root causes of disasters, i.e. the cultural, political, and social systems. Vulnerability is rarely impacted significantly through capacity building. Are the "vulnerable" labelling and associated paternalism "worth it" in order to provide harm reduction? This is a long-standing and unresolved debate in our field.

Meanwhile, capacities also take diverse forms: often those who are seen as the most marginalized and vulnerable can make up for their lack of access to economic and political resources by relying upon strong social and human resources. Thus, it is important to understand that capacities are people- and context-specific. The recognition of diverse capacities from a diverse range of communities gives primary importance to utilizing local resources and emphasizing the overarching contribution of local communities in facing natural hazards. It is also important to remember that having capacities does not imply that people can rely on their knowledge, skills, and resources whenever they need to. Structural barriers and temporary impediments, ranging from state ideologies and political decisions to physical impairments, technological failures, and environmental constraints, are the challenges that may stop people from using their capacities (Wisner 2016).

The desire to enhance one's capacity is a moral quandary, built on Western ideas of inclusion and participation and often driven, or expected, by government actors and donors. In this context, enhancing capacities may mean challenging the established traditional norms. This creates an ethical dilemma: is it OK for an outsider to challenge the cast norms in India by empowering lower casts, for instance? Is it OK to intervene when the situation seems unjust from a Western perspective? Should a community based on reciprocity and collectivity have values and ideologies of individual "freedom" imposed on it? Are inclusions and modes of participation ethical?

These questions are not new: the issue of respecting culture and—at the same time—working in the interests of the most marginalized is a classic humanitarian dilemma; but the answers are still not clear. Neither should people's capacities be overestimated nor romanticized; too often, people's capacities have been interpreted as "resilience" —another heavily debated and critiqued concept, often as "a panacea for a spectacular variety of contemporary social and environmental ills" (Zebrowski 2020, 73).

In the context of disasters, in a normative sense, it is argued that resilience can be both a desired outcome and a process leading to a desired outcome, and with the definitions largely focusing on the ideas of the ability to self-organize and the capacity to learn, to change, and to adapt, its understandings are nebulous and malleable (see Alexander 2013; Gaillard and Jigyasu 2016; Mayena 2006, who all provide an excellent insight into the evolution of the concept). Some argue that a concept of resilience is also contradictory as well as meaningless in non-Anglophone contexts: Chmutina et al. (2020) and Lizarralde et al. (2020), for instance, show that the usage of "resilience" too often does not consider local contexts, and this being the case, it can instead reinforce quasi-imperialist impositions of ideas. Many authors also point out that the current use of the concept is predominantly driven by neoliberal ideas of "growing the wealth of the poor" (Bracke 2016, 52) and using it as a pathway to (re)build the capacity of financial systems and national economies in the aftermath of disasters, thus reinstating the pre-disaster conditions (Cheek and Chmutina 2021). Amo-Agyemang (2021) further demonstrates that resilience discourse is rooted in colonial knowledge, subjectivity, and power.

Resilience—and its ability to "resolve" all contemporary issues—has become a useful neoliberal narrative to explain anything from how individuals should act and cope with hazards, risks, and disasters to a mainstreamed approach to development. Portrayed as something "good", resilience has become an important goal that needs to be achieved no matter what. Under neoliberal conditions, resilience therefore can be interpreted as the ability to survive under the conditions of destitution. Such resilience is profitable because "resilient" people can, as sociologist Sarah Bracke (2016, 61) notes, "absorb the impact of austerity measures and continue to be productive". As such, the resilience message essentially tells the most oppressed that they should work on themselves to rebound more quickly from every setback; they should get better at coping because the world isn't fair. It is thus important to emphasize that otherwise neutral words like "resilience", when used in the context of disasters, become laden with political meaning, because disasters are a political process.

Current approaches to disaster risk reduction too often see disasters as a one-off "event" rather than as a socio-political process. This is reflected in DRR measures that can displace the disaster temporarily but leave the underlying factors that created the disaster unaddressed (Chmutina et al. 2021). Those who are most marginalized in our day-to-day existence are those who are most harmed by disasters. For the marginalized, a disaster is not a new, sudden, or unexpected danger. It is a continuation of everyday harm inflicted on those relegated to the margins of society. Disasters don't simply bring about suffering—they expose it. For those who have no voice in decision-making, no claim to an official place to live, or a livelihood tied to meagre natural resources, trauma, suffering, and displacement are not unique to a disaster event.

Disasters also expose the contradictions of neoliberalism: disasters are grounded in the underlying inequalities in society, while neoliberal capitalism relies on the maintenance of those same inequalities (Cheek and Chmutina 2021). Disasters taking place within the neoliberal paradigm are disastrous spectacles of neoliberalism as a process. Within this dynamic lies a fundamental tension: disasters can be a threat to the state, yet neoliberalism drives the production of vulnerabilities. Neoliberalism exacerbates the tendency for governments to create risk in the pursuit of growing their economies. The state (often its people through taxes) subsidizes risky or unsustainable development from which the most wealthy and well-connected benefit. This kind of uneven development (see Smith 2010) leads to a retrenchment of the problems that created such risk in the first place.

2.6 Conclusion

There is overwhelming scientific knowledge across many fields that helps us to understand why hazards occur—but why do disasters occur? In order to answer this question, it is important to answer many other “whys”: why do many poor people live in hazard-prone areas? Why is the coping capacity of some groups of people more limited than that of others? Why are power and access to resources not distributed equally? Why are health and wealth disparities allowed to become normal in our societies? These and other “whys” help us explore the underlying causes that turn a hazard into a disaster. Similar hazards (in terms of intensity) may have very different outcomes: one may turn into a disaster (in terms of loss of life and assets as well as disruption to livelihoods and future well-being), whereas another would cause minor disruption with easy recovery.

These “whys” also show us that disasters are neither inevitable nor natural. By blaming nature for creating disasters, we allow ignorance, carelessness, and greed to be masked by focusing on natural processes (Chmutina and von Meding 2019). Disasters occur not because of nature but because of us, human beings—and to paraphrase Heijmans (2001), they will keep occurring until our governments stop ignoring their social and political origins. In other words, disasters are not unexpected events but long-term political processes.

It is also important to note that all the concepts discussed here—disasters, vulnerability, capacity—are highly problematic and often contested. The meaning of vulnerability has been shaped at a particular historic juncture by a particular historic perspective; this signifies that it can only really be understood from the perspective of the prevailing socio-economic system (Bankoff 2019; Gaillard 2019). The current definition of disasters is based on Western science and English language hegemony. Most disaster scholars would agree that disasters are a social construct (as demonstrated in the adoption by the UNDRR and discussed in the earlier sections of this chapter). This encourages us to focus on vulnerability and marginalization, as noted earlier with regard to risk or impact reduction. However, is it truly possible to find and challenge the root causes of disasters by only using Western theories, concepts, and methodologies that we consider universal and roll them out across very different cultures and societies around the world? Perhaps not, because Anglophone meanings that represent Western imaginings are limited. Lizarralde et al. (2020) show how the use of disaster concepts, when treated as a-political and universal, creates challenges rather than contributing to disaster risk reduction. First, it may introduce problems or concerns that do not actually exist in local communities. Second, it can distort messages that are voiced by local communities and citizens. Third, it can help produce solutions that do not actually address the needs and expectations of local residents. Fourth, this tendency perpetuates a body of knowledge that fails to capture the reality that it is trying to explain. And finally, it increases the gap between academic work and the problems people face. In the meanwhile, aspects that are required for social change (such as people's expectations and aspirations to improve social status) get masked.

Gaillard (2022) demonstrates the limits of arguing that disasters are a social construct while at the same time largely relying on Western ontologies and epistemologies; this is what he calls "epistemological nonsense" that reflects the injunction of the project of modernity that created a "man vs. nature" dichotomy, and that made it possible to tame the threats that nature poses, and thus develop and flourish freely (see, for example, writings on Hegel's dialectical search for reason). As a result, contemporary discourses on disaster are firmly grounded in the ontological assumption that such disasters sit at the interface between nature and society, i.e. hazard and vulnerability. This is why, although the dominant definition importantly highlights the interaction between hazard and the conditions of vulnerability, it may not serve everyone's purpose when reducing disaster risks, because the experiences of disasters vary for different cultures and peoples (Faas 2022). Disasters—similarly to their definitions, understanding, and experiences—are not universal, and the assumptions that drive our understandings of disasters need to be further challenged (Gaillard 2023).

The vast majority of the current framings of disasters—and consequently, disaster risk reduction initiatives—continue to promote Western discourses, which need to be challenged if we are to achieve a more grounded, genuine, reciprocal, and meaningful understanding of disasters. The understanding of disasters must be grounded in praxis between technical problem-solving and commitment to humanity (Chmutina and von Meding 2022). Disasters cannot be understood without untangling unequal and often oppressive social, political, and economic systems. This is not about just the technical skills or geographical setting; culture, politics, power, and our role as experts in those are more important. This can only be done through dialogue, empathy, and humility. We must recognize our collective ties and interconnections; we are all dependent on each other.

Reducing disaster risk means a collaborative and decentralized effort that challenges the long-established systems and ideological structures of neoliberalism, neocolonialism, patriarchy, racism, and so on. When we speak about disasters, when we make decisions about risk reduction, we need to talk about the systemic root causes grounded in oppression and marginalization. What we say and do when it comes to disaster risk reduction should be about ethics, equity, power, and responsibility—and not about hazards, measurement of losses, or economic growth. We must generate new ideas, values, and commitment that take the place of the capitalist logic that continues to recreate violence, oppression, and disaster risk.

References

Adger WN, Dessai S, Goulden M et al (2009) Are there social limits to adaptation to climate change? Clim Change 93(4–5):335–354
Alcántara-Ayala I, Gomez C, Chmutina K et al (2022) Disaster risk. Routledge, London UK
Alexander D (2000) Confronting catastrophe. Terra Publishing, London UK
Alexander D (2013) Resilience and disaster risk reduction: an etymological journey. Nat Hazards Earth Syst Sci Discuss 1:1257–1284
Allen ME, Sibahi Z, Sohm ED (1980) Evaluation of the office of the united nations disaster relief. JIU/REP/80/11. https://www.unjiu.org/sites/www.unjiu.org/files/jiu_document_files/products/en/reports-notes/JIU%20Products/JIU_REP_1980_11_English.pdf
Amo-Agyemang C (2021) Decolonising the discourse on resilience. Int J Afr Resist Stud 16(1):4–30
Anderson MB, Woodrow PJ (1989) Rising from the ashes. Lynne Rienner Publisher, Boulder USA
Ball N (1975) The myth of the natural disaster. Ecology 5(10):368–369
Bankoff G (2001) Rendering the world unsafe: 'vulnerability' as western discourse. Disasters 25(1):19–35
Bankoff G (2019) Remaking the world in our own image: vulnerability, resilience and adaptation as historical discourses. Disasters 43:221–239
Bankoff G, Hilhorst T (2022) Why vulnerability still matters. Routledge, London UK
Berman R, Quinn C, Paavola J (2012) The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. Environ Dev 12:86–100
Bonifacio G, Epe RB (2023) Disasters in the Philippines. Bristol University Press, Bristol UK
Bracke S (2016) Bouncing back: vulnerability and resistance in times of resilience. In: Butler J, Gambetti Z, Sabsay L (eds) Vulnerability in resistance. Duke University Press, Durham NC and London, pp 52–75
Bradshaw S, Fordham M (2013) Women, girls and disasters. A review for DFID. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/236656/women-girl/s-disasters.pdf
Cannon T (1994) Vulnerability analysis and the explanation of 'natural disasters'. In: Varley A (ed) Disasters, development and environment. Ch.4. Wiley and Sons, UK
Cardona OD (2003) The need for rethinking the concepts of vulnerability and risk from a holistic perspective: A necessary review and criticism for effective risk management. In: Bankoff G, Frerks G, Hillhorst D (eds) Mapping vulnerability: disasters, development and people. Earthscan Publishing, London, pp 37–51
Cheek W, Chmutina K (2021) 'Building Back Better' is neoliberal post-disaster reconstruction. Disasters 46(3):589–609
Chmutina K, von Meding J (2019) A dilemma of language: 'natural disasters' in academic literature. Int J Disaster Risk Sci 10:283–292
Chmutina K, von Meding J (2022) Towards a liberatory pedagogy of disaster risk reduction among built environment educators. Disaster Prev Manag 1(5):521–535
Chmutina K, Sadler N, von Meding J et al (2020) Lost (and Found?) in translation: key terminology in disaster studies. Disaster Prev Manag 30(2):149–162

Chmutina K, von Meding J, Sandoval V et al (2021) What we measure matters: the case of the missing development data in Sendai Framework for Disaster Risk Reduction monitoring. Int J Disaster Risk Sci 12:779–789
Davis I, Haghebeart B, Peppiatt D (2004) Social vulnerability and capacity analysis. In: Discussion paper and workshop report. ProVention Consortium, Geneva
Dombrowsky W (1998) Again and again: is a disaster what we call a disaster? In: Quarantelli EL (ed) What is a disaster: Perspectives on the question. Routledge, USA, pp 19–30
Donner W, Rodriguez H (2008) Population composition, migration and inequality: the influence of demographic changes on disaster risk and vulnerability. Soc Forces 87(2):1089–1114
Drabek TE (1991) The evolution of emergency management. In: Drabek T E, Hoetmer G J (eds) Emergency management: principles and practice for local government. ICMA, p 3–29
Dunn L (2016) Integrating men and masculinities in caribbean disaster risk management. In: Enarson E, Pease B (eds) Men Masculinities and Disasters. Routledge, New York, pp 209–218
Faas AJ (2022) In the shadow of Tungurahua. Rutgers University Press, New Brusnvick NJ
Freire P (1970) Pedagogy of the oppressed. Bloomsbury, New York
Gaillard JC (2007) Resilience of traditional societies in facing natural hazards. Disaster Prev Manag 16(4):522–544
Gaillard JC (2019) Disaster studies inside out. Disasters 43:7–17
Gaillard JC (2022) The invention of disaster. Routledge, UK
Gaillard JC, Cadag JR, Rampengan MMF (2019) People's capacities in facing hazards and disasters: an overview. Nat Hazards 95:863–876
Gaillard JC, Jigyasu R (2016) Measurement and evidence: whose resilience for whom? Working paper #11, Resilience Development Institute
Gaillard JC (2023) The Tout-Monde of disaster studies. Jàmbá 15(1):a1385
Hagelsteen M, Becker P (2014) Forwarding a challenging task: seven elements for capacity development for disaster risk reduction. In: Proceedings of the 4th international disaster and risk conference IDRC, 26–30 August, Davos, Switzerland
Hagelsteen M, Burke J (2016) Practical aspects of capacity development in the context of disaster risk reduction. Int J Disaster Risk Reduct 16:43–52
Ten Have H (2018) Disasters, vulnerability and human rights. In: O'Mathúna DP, et al. (eds) Disasters: core concepts and ethical theories. Advancing Global Bioethics Ch.11:157–174
Heijmans A (2004) From vulnerability to empowerment. In: Bankoff G, Frerks G, Hilhorst D (eds) Mapping vulnerability: Disasters, development and people. Earthscan, London, pp 115–127
Heijmans A (2001) Vulnerability: a matter of perception. Working Paper 4. Benfield Greig Hazard Research Centre, UCL, London
Hewitt K (1983) Interpretations of calamity from the viewpoint of human ecology. Allen and Unwin, Boston
Jacobs F (2021) Beyond social vulnerability: COVID-19 as a disaster of racial capitalism. Sociologica 15:55–65
Lizarralde G, Páez H, Lopez A et al (2020) We said, they said: the politics of conceptual frameworks in disasters and climate change in Colombia and Latin America. Disaster Prev Manag 29(6):909–928
Marino E, Faas AJ (2020) Is vulnerability an outdated concept? after subjects and spaces. Ann Anthropol Pract 44(1):33–46
Master RD, Kelly C (eds) (1992) The collected writings of Rousseau, vol 3. The University Press of New England, Hanover USA
Mayena SB (2006) The concept of resilience revisited. Disasters 30(4):434–450
O'Keefe P, Westgate K, Wisner B (1976) Taking the naturalness out of natural disasters. Nature 260:566–567
Oliver-Smith A (1986) The Martyred city: death and rebirth in the Andes. University of New Mexico Press, Albuquerque
Quarantelli EL, Dynes RR (1972) When disaster strikes: it isn't much like what you've heard and read about. Psychol Today 5(9):66–70

Rappaport J (1984) Studies in empowerment: introduction to the issue. J Prev Interv Community 3(2–3):1–7
Sanderson D (2000) Cities, disasters and livelihoods. Environ Urban 12(2):93–102
Schuller M (2016) Humanitarian aftershocks in Haiti. Rutgers University Press, New Jersey USA
Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Chang 16(3):282–292
Smith N (2010) Uneven development. Verso, UK
Smith N (2005) 'There's No Such Thing as a Natural Disaster'. Understanding Katrina: Perspectives from the Social Sciences. http://understandingkatrina.ssrc.org/Smith
Sun L, Faas AJ (2018) Social production of disasters and disaster social constructs: An exercise in disambiguation and reframing. Disaster Prev Manag 27(5):623–635
UNDRR (2015) Sendai framework for disaster risk reduction. UN, Geneva
UNDRR (2018) Words into action: implementation guide for man-made and technological hazards. https://www.undrr.org/publication/words-action-guideline-man-made/technological-hazards
UNISDR (2018) Terminology. https://www.unisdr.org/we/inform/terminology#letter-d
Von Meding J (2021) Reframing vulnerability as a condition of potential. The Arrow 8:48–54
Von Meding J, Chmutina K (2023) From labelling weakness to liberatory praxis: a new theory of vulnerability for disaster studies. Disaster Prev Manag 32(2):364–378
Wisner B (2016) Vulnerability as concept, model, metric, and tool. Oxf Res Encycl Nat Hazard Sci. https://doi.org/10.1093/acrefore/9780199389407.013.25
Wisner B, Blakie P, Cannon T, Davis I (2004) At risk, 2nd edn. Routledge, USA
Wisner B, Gaillard JC, Kelman I (2012) Framing disaster: theories and stories seeking to understand Hazards, vulnerability and risk. In: Wisner B, Gaillard JC, Kelman I (eds) The Routledge handbook of hazards and disaster risk reduction. Routledge, USA, Ch.3
Wisner B (2010) Marginality. In: Bobrowky P (ed) Springer Encyclopedia of natural hazards. Entry 226. Springer, Berlin
Wisner B (2018) Core elements of natural hazard mitigation: natural hazard mitigation and preparedness practices. In: Gerber BJ (ed) Oxford encyclopaedia of natural hazards governance. Ch.38
Zebrowski C (2020) Acting local, thinking global: globalizing resilience through 100 resilient cities. New Perspect 28(1):71–88

Chapter 3
Disaster and Resilience: Some Observations for Living Well from the Vantage Point of the Social Sciences

Roberto E. Barrios

Abstract During the past five decades, the terms disaster and resilience have undergone significant transformations in the ways they are defined in the social sciences and disaster management. In this period, disaster has been redefined from an unavoidable and temporally limited impact of "nature" on society to a temporally prolonged politico-ecological process. At the same time, resilience was adopted from materials science and systems ecology to denote a community's ability to recover (and even thrive) in the aftermath of a hazard impact. This chapter reviews the contributions anthropology and other social sciences have made towards the understanding of disaster and resilience. In the case of the former concept, these contributions have proposed (a) the understanding of disaster as a process that is not solely natural in which human practices play a key role in giving it shape and magnitude and can therefore be mitigated and (b) the recognition of power and political economic relations at global, regional, national, and local levels in the making of disasters. In the case of the latter concept, social scientists have expressed concern that use of the resilience concept has drawn attention from disaster risk reduction as it assumes disasters are unavoidable and that it has also been deployed alongside neoliberal discourse and policy, removing disaster risk reduction responsibilities from government agencies.

Keywords Resilience · Disaster · Prevention · Vulnerability · Social science · Anthropology

3.1 Introduction

Over the last five decades, social scientists have drastically redefined the concepts of disaster and resilience (O'Keefe et al. 1976; Oliver-Smith 1999; Walker and Cooper 2011). At the same time, these terms have also become prominent in the lexicon

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_3

of governmental and intergovernmental organization policy frameworks across the globe (Evans and Reid 2014). Beyond circles of academic researchers and policymakers, disaster and resilience have also become popular concepts through which the public at large narrates its experience of catastrophic events and imagines how to live well in a world that is increasingly hazard-prone in the context of anthropogenic climate change. Unfortunately, in many cases, practitioners and policymakers have been slow and even resistant in incorporating the contributions of social scientists to enhance our understanding of these concepts into their practice (Hoffman and Barrios 2019). In this chapter, I review the history of scholarly and popular definitions of these two concepts, paying specific attention to the debates and critiques over competing definitions that have animated it. I do this by focusing primarily on one region of the world, Central America (with a brief tangent to the Caribbean), which has been foregrounded by disaster researchers as an exemplary case study of disaster and its root causes.

Exploring the history of disaster and resilience through the lens of Central America sheds light on the practices and policies necessary to reduce—if not altogether prevent—disasters. Interestingly enough, these policies and practices also have implications for living well beyond disaster mitigation and delve into themes of historically contextualized social justice. With regard to disaster mitigation, the chapter emphasizes the established maxim of many disaster researchers in Latin America that socio-economic inequity reduction *is* disaster risk reduction. Moreover, informed by political ecological approaches in anthropology, the chapter recognizes that disaster-prone sites and communities come to be so in broader contexts of extractive political economy (i.e. colonialism, global capitalism, imperialism). Disaster risk reduction, then, must be a practice that transforms political economic systems (the underlying causes) and not merely socio-spatial arrangements in disaster-affected sites (the symptoms).

This chapter will also argue that the realization of disaster resilience requires the addressing of broader political economic and power-laden relationships that often extend well beyond the boundaries of disaster-affected sites. Moreover, resilience-making must involve the critique and transformation of social fractures along lines of race, class, gender, and national identity that often undermine a community's ability to weather and recover from the impact of a hazard; the key message here being that disaster-affected sites, communities, nations, and even regions are not neatly bound entities that fully determine the socio-environmental conditions that lead to catastrophe. Instead, they are often nodes within broader systems of development and resource exploitation that inequitably distribute risk and well-being. Consequently, disaster and mitigation must be addressed in terms of these broader networks and connections. Finally, a note to the reader: this chapter is primarily structured as a theoretical discussion that draws from abridged ethnographic examples (but not full-blown case studies) from my last 25 years of disaster research. Readers interested in more detailed versions of the ethnographic examples presented are encouraged to examine my other publications that contain more detailed ethnographic data (e.g. Barrios 2017).

3.1.1 Disaster: The Anthropological Vantage Point

The term "disaster" is derived from the Old Italian terms *dis* and *astro*, which, when combined, convey the idea that a misalignment of astronomical bodies results in calamity for humans. One example of such an understanding of disaster is the depiction of severe droughts by the Post-Classic Yucatec Maya as cloven-hooved beasts sent from the sky by Planet Mars to assail humanity. These droughts are represented thus in the *Dresden Codex*, one of four surviving pre-Columbian hieroglyphic books written by the Maya in the twelfth century C.E. More specifically, these images represent a catastrophic drought period that took place in the ninth century C.E., which, when combined with high population densities and an agricultural system that was stretched to the limit of its carrying capacity, brought about the socio-environmental disaster known as the "Central Maya Lowlands Late Classic Period collapse" (Bricker and Bricker 2020). This representation is accompanied by the hieroglyphic inscription *kin tun haabil*, which translates from Yucatec Maya to English as "hot sun year" (Bricker and Bricker 1997, 2020). Furthermore, this section of the *Dresden Codex* is known among Mesoamericanists as "the Mars tables", and it is a detailed accounting of the movements of the red planet in the night sky. Maya astronomers noticed that the intensification of a devastating drought coincided with the retrograde motion of Mars, a period in the planet's orbit when it shines brighter due to its relationship with Planet Earth and the sun (Bricker and Bricker 1997, 2020). In Maya cosmology, stars, planets, and the moon were manifestations of deities, and their movement corresponded to mythological stories that stipulated ethical behaviour (Tedlock 1996). Environmental calamities were therefore also associated with moral or ethical transgressions on the part of humans and ensuing divine punishments. This opens the possibility of interpreting the representation of drought in the *Dresden Codex* as a divinely sent punishment.

Such interpretations of disaster among the Maya continued until the 15th-century colonization of Mesoamerica by Spanish forces and their indigenous allies from Central Mexico. In *Popol Vuh*—a book written in the early colonial period to document the pre-Columbian history and mythology of the K'iche Maya in the Guatemalan Highlands—floods are also featured as a punishment meted out by creator deities to the predecessors of humanity for mistreating animals and their possessions, and for not praying to the gods (Tedlock 1996). The Spaniards who colonized the Maya Highlands employed similar divine interpretations of disaster, albeit through patriarchal Christian morality. In 1541, the original capital city of the Captainship of Guatemala was destroyed by a lahar that descended from the Agua Volcano, known as "Junajpu" by the local Kaqchikel Maya. The catastrophe occurred directly following the appointment of Beatriz de la Cueva to the Governorship of the colonial province, a political event that required shrewd manoeuvring on her part to be chosen over several men also competing for the position. De la Cueva's appointment came following the death of her husband, Pedro de Alvarado, the ruthless Spanish colonizer who waged several scorched-earth campaigns against the K'iche and Kaqchikel Maya in the early sixteenth century. Many Spanish colonial settlers interpreted the disaster as a punishment by the Christian God for the appointment of a woman to the Governorship, a position normally reserved for men (Petit-Breuilh Sepúlveda 2004). To this day, Kaqchikel residents of the area also narrate their version of this catastrophe. In this instance, the lahar was a punishment from God instigated when De la Cueva cursed him following the death of Alvarado.

In the Eurocentric history of disaster studies, the interpretation of disasters as divine punishment or astronomical calamity endured until 1755, when an earthquake, tsunami, and urban fire devastated the city of Lisbon. Eighteenth-century Enlightenment philosophers such as Immanuel Kant who visited the city observed that the devastation was too widespread, indiscriminate, and arbitrary to be attributed to a punishment from the Christian deity and proposed that the disaster be credited to the sublime power of nature. Hence, the concept of "natural" disasters was born (Evans and Reid 2014) (see Chmutina and Von Meding, Chap. 2).

The attribution of disaster to an emerging concept of nature in the 18th-century signals the growing influence of modern epistemology at the time. Modern epistemology itself emerged in the seventeenth century as a means of ascertaining matters of fact that were thought to be true everywhere and unencumbered by cultural prejudices (Shapin and Schaffer 1985). At the heart of this way of thinking was the idea that a modernist thinker was able to separate objects (things in themselves, i.e. "nature") from subjects (cultural values, i.e. divine interpretations of disaster) and observe and narrate laboratory experiments in a language that was detached from cultural context (Bauman and Briggs 2003; Haraway 1997; Latour 1993). While the quest for a way of observing and narrating the world in an objective manner was a worthy cause, philosophers of science have recently questioned whether such an epistemological feat was in fact ever accomplished (Haraway 1997; Latour 1993). Alternatively, they have proposed that the power of modern epistemology is not so much its wielders' ability to separate objects from subjects but to claim to do so while not actually doing so (Latour 1993).

The modernist idea that disasters were caused by—and could be reduced to—agents of "nature" (i.e. natural hazards such as earthquakes, cyclones, landslides, floods) remained the dominant way of understanding disasters for two centuries. From this perspective, disasters were inevitable and people's agency in relation to them was limited to preparing to respond to them once they occurred (Oliver-Smith and Hoffman 1999). At the same time, the modernist naturalistic interpretation of disasters did not completely replace divine or animistic explanations, which also continue to be enunciated in the twenty-first century.

Naturalistic explanations of disaster would remain dominant until 1976 when critical geographers Phil O'Keefe, Ken Westgate, and Ben Wisner published an article in the journal *Nature* titled "Taking the naturalness out of natural disasters". In this publication, O'Keefe, Westgate, and Wisner conducted a comparative analysis of disasters at a global level, tabulating disaster impacts and hazard magnitudes. Their conclusion: Hazard magnitude alone did not determine whether an earthquake, hurricane, or other geophysical force caused a disaster. Instead, socially conditioned factors such as socio-economic inequity, environmentally destructive land use practices, and poor urban planning played a principal role in converting a hazard into a disaster. Another key observation made by these geographers was that there was also a pattern to the global distribution of disasters. Those that were most materially destructive and socially disruptive occurred in areas and nation states that were former colonies and part of what we call the "Global South" rather than in the "developed" countries of North America and Europe. Taking their analysis further, O'Keefe et al. made the case that the environmental and social impact of colonial and postcolonial extraction by imperial powers were greatly to blame for creating the conditions that precipitated disasters when natural hazards presented themselves.

Currently, social scientists who research disasters consider O'Keefe et al.'s article to be a foundational piece in what came to be called "vulnerability theory". Vulnerability theory proposed two key changes in the way researchers and the public should think about disasters. First, this analytical framework challenged existing ways of thinking about the temporality of disasters. Naturalistic interpretations of disaster that conflated disasters with natural hazards assumed that disasters began with the manifestation of hurricanes, earthquakes, floods, etc., and ended when their direct physical impacts subsided. In contrast, vulnerability theory analysed disasters as much more temporally prolonged processes that often began long before a hazard's manifestation and continued long beyond its impact (Garcia-Acosta 2020; Maskrey 1993; Oliver-Smith and Hoffman 1999). Second, vulnerability theory insisted that disasters were, to a great extent, of humanity's making and were therefore primarily of a social ontology, not a natural one (Maskrey 1993). This intervention also opened the door for researchers, policymakers, and the general public to believe that, if disasters were primarily social and of human making, then it was possible to minimize or prevent them altogether.

3.1.2 Applying Vulnerability Theory in Central America

A case that highlighted the merits of vulnerability theory in O'Keefe et al.'s article was the earthquake that devastated Guatemala in 1976. This earthquake, which measured 7.5 on the Richter scale, claimed at least 23,000 lives and disproportionally impacted economically marginalized and predominantly indigenous rural communities (Olcese et al. 1977). Vulnerability theory's logic proposed that, had this earthquake manifested in a nation state where seismic-resistant building codes were rigorously implemented, socio-economic inequities were reduced, and urban planning ensured equitable access to housing areas minimally affected by natural hazards, the earthquake would not have detonated the catastrophic phase of a disaster. Instead, the 1976 earthquake manifested in a country in which nearly 500 years of colonial and postcolonial societal and governmental practices had systematically marginalized indigenous populations and the urban and rural poor, devastated natural environments, and encouraged the construction of buildings and housing structures that were not properly adapted to a seismic environment. The earthquake was the last, and possibly the least critical, of the disaster's ingredients.

How did Guatemala's specific political ecological arrangement of people, landscapes, and resources come to be? In the pre-Columbian period, the indigenous states that occupied the region allowed farmers to use the best agriculturally productive river valley land to grow subsistence crops as well as crops meant for trade and tribute. Indigenous states were not egalitarian utopias. They were stratified societies in which commoners owed tribute to the members of elite ruling lineages, and militarily defeated elite groups from one city state were required to pay tribute to the leaders of another. Nevertheless, this political ecological arrangement allowed for the development of high population densities in the highlands of Central America. It is estimated that the combined population of all Maya people in the region reached two million prior to the arrival of the Spanish invaders (Few 2020).

The arrival of Spanish forces and their indigenous allies from Central Mexico in 1524 upset existing arrangements among people and between people and their environments in the Guatemalan Highlands in a way that would give form and magnitude to unprecedented disasters during the next five centuries. The Spanish soldiers who embarked with Hernán Cortés in Cuba bound for Central America and Mexico in 1519 were motivated by the prospects of personal enrichment by forcing the indigenous communities they encountered to trade gold for glass beads and other less valuable goods (Diaz 1963). Early into their expedition, members of this Spanish force became disillusioned with the relative scarcity of gold they could procure from indigenous communities along Mexico's eastern coast. Upon hearing from the Maya people they encountered about a wealthy kingdom in the inner country known as Mexico, they disembarked and began a land excursion into the interior lands. In Central Mexico, they arrived at Tenochtitlan, the capital city of the Mexica people, one of the three city states that comprised the Aztec triple alliance. There, they found a city similar in many respects to those of the Iberian Peninsula at the time—a city with markets, class hierarchy, botanical gardens and zoos, temples and plazas, a system of communal labour that built and maintained a system of canals, causeways, and levees that allowed the city to exist in the middle of Lake Texcoco, professional armies, and a well-established tribute payment system (Diaz 1963).

Within a few months of the military defeat of the Mexica through an alliance Cortés made with the rival kingdom of Tlaxcala, Spaniards realized that the true wealth of the Mesoamerican region was the presence of dense populations from whom they could extract tribute and labour and whose land they could be appropriate. Through the *encomienda* and *hacienda* systems, Spaniards claimed land previously used to grow food for the general population and transformed it to cattle pasture for elite consumption and export crop production and demanded indigenous populations pay excessive tributes and provide free labour in exchange for their Christianization. Spaniards also transformed urban and rural landscapes by concentrating people who previously lived in rural areas into *reducciones*, dense towns where they could be more easily controlled. The result was widespread food insecurity, malnutrition, and forced labour that, when combined with dense settlements and the rapid spread of newly introduced communicable diseases like smallpox, caused the largest slow biological disaster in the region's history. In the Maya Highlands alone, a population of two million people was reduced to fewer than 200,000 in less than a century—that is, a 96% reduction in the region's population (Few 2020; Lovell and Lutz 1996).

The environmental injustice and violence of the first century of colonization in Highland Guatemala were just the beginning of a five-century process of systematic theft of indigenous lands by Spanish, Criollo (Spanish people born in the New World), and Ladino elites (descendants of Europeans and indigenous people who primarily identify with the former). The appropriation of indigenous agricultural land for cattle ranching and plantation agriculture forced Maya farmers into mountainside agriculture, promoting deforestation and soil erosion that increased landslide risk. During the twentieth century, several civil conflicts ignited by profound socio-economic inequities and 36 years of U.S.-supported military dictatorships also forced many people to flee the countryside and settle in hazard-prone areas of Guatemala City (Way 2012). By the eve of the 1976 earthquake, all the ingredients of a disaster had been painstakingly put in place; all that was needed was for the earth to shake.

One of the key messages of the vulnerability approach is that disaster mitigation is not a neatly compartmentalized endeavour that is independent of other societal concerns such as socio-economic inequity and social justice issues. In fact, vulnerability theory advocates in Latin America often point out that inequity reduction *is* disaster risk reduction and that disasters are routinely given form and magnitude by the injustices (if we define justice through the notion of giving all members of a society their equitable due) of colonialism, ethnocentrism, racism, and classism. Engaging in disaster mitigation, then, is a matter of ensuring there is an equitable distribution of the means for living well (i.e. livable wages, equitable access to hazard-free housing, disaster-mitigating urban planning) in any given society. Unfortunately, in many postcolonial societies of the Global South, such declarations are denounced and violently repressed as revolutionary by conservative elites, as has historically been the case in Guatemala.

Nearly 50 years after the birth of vulnerability theory, its adoption as a matter of national development policy remains an ephemeral fantasy in many parts of Central America. In 2020, 49% of Guatemala's population lived below the World Bank's poverty line (World Bank 2020) and, in 2021, the country's per capita GDP was $5,025 (compared to the U.S.'s $65,118) (World Bank 2021). In terms of disaster mitigation, preparedness, and response, two recent disasters give the country failing marks. On June 3, 2018, Volcán de Fuego (the Fire Volcano) produced its most deadly and socially disruptive eruption known to date. The death toll estimates from the volcano's pyroclastic flow vary from 70 to 200 lives and up to 300 missing. In the days preceding the eruption, vulcanologists from the National Institute of Seismology, Volcanology, Meteorology, and Hydrology (INSIVUMEH) communicated the presence of an imminent risk of eruption to the political appointees in charge of the National Coordinator of Disaster Reduction (CONRED). Knowing the volcano was home to several farming communities, INSIVUMEH scientists emphasized the need for an immediate evacuation order in the area. Negligence on the part of CONRED's leadership to issue the evacuation orders in a timely manner converted the pyroclastic flow into a disaster (Lakhani 2018).

More recently, the COVID-19 pandemic underscored the existing gap between Guatemala's socio-economic conditions and vulnerability theory's vision of preventive disaster mitigation. When the virus first arrived in 2020, the country struggled with a fragmented and deficient healthcare system (Martinez-Folgar et al. 2021), which, when combined with a high poverty rate and a non-existent social security system, made Guatemala a prime example of vulnerability. Available excess mortality data indicate the country suffered a 73% increase in excess mortality at its pandemic peak, twice that of England (37%) and Spain (38%) (Martinez-Folgar et al. 2021). Compared to other Central American nations like Costa Rica over a longer time span (January 2020 to December 2021), Guatemala suffered a mortality rate per 100,000 population that was nearly 2.5 times (174.7 for Guatemala, 70 for Costa Rica) that of its neighbouring country, Costa Rica (COVID-19 Excess Mortality Collaborators 2022). Costa Rica is known for having a well-funded and efficiently managed public healthcare system (Fantin et al. 2023) and the second-highest per capita GDP in Central America, both of which are direct outcomes of the country's efforts to reduce inequality following its 1948 Civil War.

3.2 Matters of Ontology

As I have previously mentioned, people have interpreted disasters as divine punishment, acts of nature, and socially constructed processes over the course of recorded history. All three of these interpretations of disaster are culturally particular statements about the ontology of disaster—that is, claims about what a disaster *is*. In epistemological terms, the first (divine punishment) could be said to be an interpretation based on a non-modern epistemology—that is, a system of knowledge-making in which people do not separate objects (e.g. geological fault lines, earthquakes, volcanos) from subjects (e.g. offended deities, gender). The second and third, in contrast, are interpretations of disaster that became possible through the emergence of modern epistemology in the seventeenth century—that is, a way of making knowledge that claims superiority over others through its ability to successfully separate subjects (e.g. cultural values, myths, ideology) from objects (things in themselves) and therefore objectively represent disasters.

The development of modern epistemology is often traced to the 17th-century Restoration in England. In this historical context, philosophers debated and reflected upon different mechanisms of establishing assent among learned observers concerning matters like the nature of sovereign power. One proposal came from Robert Boyle, who recommended the development of specific practices of seeing, speaking, and writing about laboratory experiments that would help natural philosophers replicate each other's work and agree on matters of fact upon which governance practices could be based (Shapin and Schaffer 1985). At the heart of Boyle's methodology was the figure of the modest witness: an upper-class, English male who was considered capable of seeing and narrating experiments without cultural bias (Haraway 1997). Also, central to Boyle's scientific method was the desire to create a way of speaking and writing that was removed from any cultural context and, therefore, objective (Bauman and Briggs 2003).

The outcomes of Boyle's proposals are what are today called the "scientific method" and "modern epistemology" (the separation of objects from subjects). While Boyle's intentions may have been noble, several philosophers and historians of science have recently noted that they were never actually achieved. Specifically, ideas about gender, class, capital, authorship, intellectual property, nationalism, and ethics, all of which are culturally contingent, were never successfully kept out of the laboratory or scientific practice (Haraway 1997; Latour 1993). While wielders of modern epistemology have historically claimed to possess a superior way of knowing and representing the world, the power of modern epistemology lies in claiming to do so while not actually doing so. In fact, the work of science and laboratory work is to proliferate connections between objects (materiality) and subjects (socially situated meanings, values, and desires).

Another outcome of the emergence of modernist epistemology was the division of academic labour between the social, natural, and physical sciences. In the context of disaster studies, this division has presented a few analytical difficulties as the process of disaster genesis involves practices that entangle politics, social practices, and materiality. Indeed, as Ksenia Chmutina (personal communication) has noted, such a division also pretends disasters are a-political and can therefore be studied objectively. Once again, Guatemala is a case in point. The disaster triggered by Volcán de Fuego's eruption in 2018 was not the result of an absence of scientific knowledge on the part of state vulcanologists. It was the result of the inaction by political appointees who failed to heed the warnings issued by INSIVUMEH staff. In this instance, political elements played a key role in the unfolding of the disaster's catastrophic phase. Meanwhile, the separation of political power from scientific knowledge instituted in Guatemala's governance practices leaves vulcanologists powerless to issue evacuation orders and diminish the eruption's social impacts. Likewise, modern epistemological approaches to disasters, which encourage the separation of objects from subjects, nature, and society, inhibit the recognition of the intimate and inseparable relationship between the two in disaster-making. Put simply: disaster studies require another language beyond the dichotomy of nature and culture to effectively apprehend the disaster process, and disaster risk reduction necessitates a questioning of the compartmentalization of scientific, sociological, and anthropological knowledge about disasters from political decision-making power.

3.3 Resilience: Towards an Ethnographically Informed Definition

Coinciding with the emergence of vulnerability theory in the 1970s was the effort within the field of systems ecology to develop a framework for thinking about a biological population's ability to survive in the aftermath of a predatory or extractive event—a quality ecologist named “resilience”. The term “resilience” is derived from the Latin *resiliere*, to spring forth. Questions such as “how much of a particular species of animals or plants can be extracted from a specific ecosystem before they become extinct?” were foremost in these researchers’ minds. Ecologists themselves had borrowed the term from material physicists, who used it to denote a material’s ability to absorb an impact and to then return to its prior state (Holling 1973).

For ecologist Crawford S. Holling (1973), a major limitation of the materials physics-borrowed definition of resilience was that it focused on a singular quantitative measure: the magnitude of the impact received. While such a measure may have been sufficient for physicists’ purposes, ecologists, he argued, needed a much more nuanced understanding of resilience. As Holling went on to detail in his 1973 article “Resilience and Stability of Ecological Systems”, the survival of species is not solely determined by the impact of a predatory or extractive event (e.g. how many individuals of a species are hunted or harvested) but is also contingent on interspecies relationships with other populations that share the same ecosystem.

During the 1970s, economists were also debating what role, if any, centralized governments should play in the making of social well-being. A key concern was the involvement of the state in establishing the prices of commodities and subsidizing production to limit unemployment. One emerging perspective championed by Friedrich Hayek (1989) was that market economies were extremely complex systems that could not be known in their entirety and that intervening in them with limited information—as in the case of state involvement in helping set commodity prices—could only do more harm than good. To make his case, Hayek drew from environmental studies, naturalizing human economies and likening them to hydrological systems composed of many tributaries that were best left to regulate themselves (Walker and Cooper 2011). Hence, the political economic perspective known as “neoliberalism” was born.

Today, some social scientists define neoliberalism as the political philosophy that market liberalization will lead to optimal social ends (di Leonardo 2008), while others understand it as the idea that all dimensions of human experience are best thought of in terms of fiscal cost–benefit analysis (Povinelli 2010). In the context of the USA, neoliberalism has been operationalized by political leaders and financial elites in the form of environmental, labour, and fiscal deregulation, and the cutting back of public services provided by government institutions (i.e. public education, public housing, public hospitals). At the same time, political leaders have adjusted the country’s tax tables to dramatically reduce the federal taxes paid by the wealthiest 400 households from 70% in the 1950s to less than 23% in 2018 (Leonhardt 2019). These policy changes have resulted in a growth in the wealth gap between the wealthiest Americans and the middle and working classes as well as a parabolic increase in the cost of education and healthcare. Also of concern is the manifestation of fiscal and technological catastrophes that resulted from the lack of regulatory oversight such as the economic recession of 2008 and the East Palestine, Ohio, train derailment in 2023.

Over the past two decades, resilience has emerged as a key concept in disaster risk reduction and response. Unfortunately, the term has remained poorly defined in disaster studies and its use threatens to undo decades of work on the part of vulnerability theorists who have made significant efforts to recognize the role of social practices in giving disasters form and magnitude. Ultimately, resilience, like disaster, is first and foremost a word, and words can have varied and shifting meanings. In the field of community psychology, for example, researchers have defined resilience as the qualities and capacities that allow communities to recover in the aftermath of an impact (Norris et al. 2008; Sherrieb et al. 2010). Scholars in this field have focused on the concept of social capital as the most adequate indicator of community capacity—social capital being the benefits an individual can derive from their social relations.

The community psychology definition draws heavily from the materials physics understanding of resilience in the 1970s. It focuses on an entity (a community), an impact (a natural hazard), and a singular measure (social capital) to assess a social unit's ability to suffer and recover from adversity. This definition of resilience is deficient in two critical ways. First, it makes several assumptions about what a community *is* that are not supported by empirical ethnographic evidence. Second, it ignores various extra-community factors that are also empirically proven to play an important role in determining how a community recovers in the aftermath of disaster. To explore these issues, I now turn to a case study from my own research in Choluteca, Honduras in the aftermath of Hurricane Mitch between 1999 and 2003.

3.4 Resilience in Post-Mitch Choluteca, Honduras

Hurricane Mitch impacted Honduras in late October 1998. The torrential downpour from the Category 4 storm interacted with five centuries of land use and urbanization patterns that promoted widespread deforestation and poor management of river valleys. The result was landslides and severe flooding throughout the nation, causing the loss of 35,000 homes and 70% of the country's GDP (PAHO 1998). In the country's southernmost department of Choluteca, floods from the Choluteca River destroyed 3,000 homes in the region's main city, forcing thousands of families to seek refuge in nearby unflooded homes, vacant schools, and warehouses. When I arrived in the area to conduct 13 months of dissertation fieldwork in June 2000, I found half of these displaced Cholutecans living in two separate housing reconstruction sites 7 kms away from the city.

The larger of the two sites, Limón de la Cerca, was home to 900 families, and its residents were struggling with significant social and infrastructural challenges. In the time since its founding in early 1999, the site had earned a reputation as a place of crime and gang violence, a reputation that was confirmed by gang graffiti that marked public buildings and abandoned homes as territory of the Mara Salvatrucha, one of two major transnational gangs operating in Honduras. Key infrastructure projects like public lighting that were amply funded by foreign governments remained without completion, and 300 of the 1200 homes built with the assistance of international NGOs remained vacant, many of them damaged by the strong thunderstorms that occurred frequently in the area. Residents often reported security concerns related to gang violence and delinquency and the inadequacy of the housing structures to withstand the environmental stresses of the site.

Displaced Cholutecans living in Limón also observed that the constructed houses and the land parcels they were located on were inadequate for their housing needs. The houses measured 25 square metres in size, lacked internal partitions to delimit living spaces, and were located on 140 square metre lots. The median household size was seven people and disaster survivors found their new homes to be cramped and unsafe. Working-class Cholutecans were also accustomed to supplementing their household diet and income by raising pigs, chickens, and vegetable gardening, but the land parcels their homes and latrines were located on greatly limited their ability to do so. Women, in turn, reported deep gendered impacts, noting that the absence of childcare and the distance to the city forced many to abandon their pre-hurricane occupations (e.g. housekeeping in private homes, food vending in the local market) and become primarily financially dependent on their male partners.

Meanwhile, a mere 200 m away along the Pan-American Highway, the second community, Marcelino Champagnat, was demonstrating dramatically different outcomes 19 months after the storm: gang graffiti was absent from community walls; constructed houses were significantly larger, featured internal partitions, and were in 280 square metre lots; and public projects like potable water and lighting had been successfully completed before I arrived. Residents of Marcelino reported feeling safer in their homes and explained that a group of neighbourhood elders had managed to restrict the activities of gang members in the community, monitoring and subjecting the latter to weapons searches.

Struck by the differences between the two sites, I conducted a series of structured ethnographic interviews with NGO housing programme managers and staff, local government officials, and grassroots disaster survivor leaders, inquiring whether they recognized differences in reconstruction outcomes between the two sites and, if so, why they thought these differences had manifested in less than two years. Local government officials and NGO programme managers and staff responded that the differences between the two communities were an expression of disaster survivor qualities. From their perspective, disaster survivors in Limón de la Cerca were marginal urban people who were already caught in a cycle of aid dependency to begin with, expecting everything to be given to them and being infiltrated by a criminal element. In contrast, NGO programme managers and local government officials claimed that the residents of Marcelino Champagnat were of a rural provenance and manifested rural practices of community organizing that had proven essential to the site's successful construction.

The explanation of the different outcomes between the two reconstruction sites fits very well within the community psychology conceptualization of resilience. The qualities of a human population before a disaster explain its post-disaster recovery outcome. The rural community, with its assumed tightly integrated structure and social capital, was able to recover faster than the members of urban neighbourhoods, who were assumed to be dependent and potentially criminal. The data I collected during my year-long ethnographic study, however, did not support this explanation of recovery outcomes. The results of 160 randomly selected household surveys (N = 110 in Limón, N = 50 in Marcelino) indicated that the residents of these two sites came predominantly from the urban neighbourhoods of the City of Choluteca and both had similarly low percentages of residents who originated from rural communities. Moreover, the survey data indicated that disaster survivors did not originate from two distinct pre-disaster communities but were all residents of nearly 30 different localities prior to the hurricane (for more details, see Barrios 2014, 2017).

Continued ethnographic interviews with disaster survivors and their grassroots leaders also provided a different perspective on the causes of different recovery outcomes. In late 1998, the catastrophe overwhelmed the operating capacities of what was already a deficient and untransparent municipal government and, by January 1999, disaster survivors were still living in schools and warehouses turned into temporary shelters. Facing pressure from school administrators and warehouse owners to vacate their premises, the future residents of Limón and Marcelino organized around a group of established neighbourhood and religious leaders who took the initiative of searching for a long-term relocation site. Through their scouting efforts, they identified the land where Limón was eventually constructed. They favoured this site because its low land value would allow families to buy lots that were large enough to accommodate their animal husbandry and horticultural practices. Hoping to put pressure on the municipal government to intervene on its behalf with the land's owning bank, disaster survivors moved from their temporary shelters to the edge of the site adjacent to the Pan-American Highway in early 1999.

Unfortunately, the partial land invasion did not move the municipal leadership to action. Frustrated with the delay, disaster survivors staged a protest and blocked the city's major bridge crossing the Choluteca River. This brought unwanted attention to the municipality's ineffective response, and the local police department responded by arresting the grassroots leaders involved in organizing the protest. From this moment on, the municipality became more involved in the land acquisition but excluded grassroots leaders from the process. The land purchase was conducted without transparency, and disaster survivor leaders were not informed of the final sale price. The municipal government then formed a land commission that also excluded the most proactive grassroots leaders. The land commission cut the individual household land parcel size to half of what disaster survivors had planned for, distributed the land parcels among disaster survivors through a raffle, and excluded protest organizers from the distribution of land. In response to the municipal government's actions, excluded leaders organized a new land invasion, seceded from Limón, and founded Marcelino with 600 families that accompanied them.

Going forward, international NGOs working in Limón constructed 1200 homes whose dimensions were not suited to the needs of Cholutecan families and whose structural design was not adequate for the environmental stressors of the site. The random distribution of land parcels also effectively fractured social relations between families that were essential for household security and childcare. Before the hurricane, people who had known each other for many years in urban neighbourhoods felt solidarity and trust with each other and collaborated to confront delinquents who burglarized properties. Women relied on other female neighbours whom they trusted to provide childcare for each other so they could work outside their homes. The raffle distributed former neighbours across the large reconstruction site and created conditions of anonymity among new neighbours. The fracturing of these key social relations created a vacuum in community organization that was quickly filled by gangs.

As the reconstruction progressed, residents of Limón became increasingly disappointed with the municipality's land commission and the Mayor of Choluteca, voicing their displeasure with his performance during political campaign visits to the site. Seeking retribution, the Mayor refused to sign a tax exemption that was required for the completion of the community's electrification. Over the year I conducted my ethnographic fieldwork, disaster-displaced Cholutecans were forced to live in darkness for their political misconduct. Meanwhile, in Marcelino, proactive community organizers who were excluded from land distribution in Limón worked together to limit gang activity through informal community policing and negotiated housing construction programmes with NGOs that were better suited to disaster survivor needs. Circumventing the municipal government and working directly with NGOs, this community leadership also facilitated the effective completion of vital infrastructure projects.

3.5 Theorizing Resilience Ethnographically

The microhistory of Limón de la Cerca and Marcelino Champagnat elicited through ethnographic interviews and the residential data collected from household surveys presents an alternative explanation of the sites' reconstruction outcomes and challenges community psychology conceptualizations of resilience. First, the people of Limón and Marcelino did not originate from two neatly delimited communities that existed prior to the catastrophe with markedly different levels of social capital. Instead, disaster survivors lived in one of nearly 30 different neighbourhoods or rural communities. It was the destruction triggered by Hurricane Mitch that forced these Cholutecans to share the experience of being disaster-displaced and to have a sense of a common stake in the recovery process (the reconstruction of their homes and lifeways). Social scientists who study communities recognize that shared experience and a sense of solidarity are key elements in community formation. Following this logic, disasters may be recognized as community-forming contexts, and such was certainly the case for Limón and Marcelino.

Once the hurricane had created a situation that brought people from multiple urban neighbourhoods and rural communities together through a shared experience of displacement, grassroots organizers from pre-disaster neighbourhoods emerged as the leaders of a newly formed macro-community. When these leaders challenged the political authority of municipality officials, they were met with an excessive use of police force by the latter. The purposeful exclusion of grassroots leaders by the municipality land commission then effectively denied the residents of Limón their core social organizers, leaving them vulnerable to the imposition of inadequate housing designs by NGOs and the politicization of infrastructure projects by the Mayor.

In terms of community resilience theory, the case of housing reconstruction programmes in Southern Honduras indicates that communities are by no means static entities that pre-exist an impact, experience an impact, and then recover from an impact. Communities, instead, are entities that exist prior to an impact but can disband and reconstitute with different actors as an effect of a catastrophe and will continue to change over the course of disaster recovery. Put simply, communities are emergent entities, and the catastrophic phase of a disaster can be a critical factor in their emergence. If communities are not static in their composition, then their qualities and capacities may be emergent as well. Finally, a community's ability to act coherently and effectively towards mitigation and recovery in the aftermath of a disaster is not solely determined by its pre-existing internal qualities (i.e. social capital) but by the broader political economic network it exists in—that is, its relationship with external actors who wield control over resources and policies that either constrain or enable its possibilities. The possibility of living well in the aftermath of Hurricane Mitch for Cholutecans was greatly influenced by their broader relations with international NGOs and municipal government.

The above-listed ethnographic insights into resilience resonate with Holling's observation that a species' ability to survive an extractive event is contingent on multiple relations with other species within an ecological context and cannot be reduced to a single measure, be it magnitude of impact or social capital. Furthermore, these insights are also applicable on a larger scale. In 2019, I was invited with anthropologist Antoinette Jackson to help researchers from the University of the Virgin Islands draft the five-year hazard and community resilience plan for the U.S. Virgin Islands. Our research revealed that this U.S. territory's ability to recover manifested within a broader context of political economic relations with the U.S. mainland.

The USA purchased the Virgin Islands from Denmark in 1917 following more than two centuries of colonial plantation economies that relied on African slave labour. Following declining plantation revenues and the emancipation of slaves in 1848, Denmark ceded its colony in exchange for 25 million U.S. dollars. As part of this exchange, Danish residents of the colony were allowed to choose between repatriating to Denmark or remaining in the territory while descendants of African slaves were not. As one interlocutor shared with us, "we were sold with the land". The transition between Danish and U.S. rule did not readily translate into improved socio-economic conditions for Afro-descendants. In the context of U.S. state-sanctioned segregation, African Americans in the U.S. mainland were systematically forced to make do with deficient public education, limited opportunities for home ownership, and workplace discrimination. The Afro-descended residents of a U.S. territory, in turn, were relegated to an even more marginalized status.

The interests of the U.S. in the Virgin Islands were purely strategic. Its location in the Caribbean made it ideal to safeguard its control over the Panama Canal. From the mainland perspective, the territory also came to be seen as a space of recreation and federal investment focused accordingly at the expense of the lifeways and socio-economic well-being of local Afro-descended populations. On the Island of St John, the U.S. Park Service established a national park in 1956. Park policies forbade Afro-descendants, whose ancestors had lived on the island long before it became a U.S. territory, from engaging in foraging, agricultural, and fishing practices they had carried out for generations, igniting tensions between them and park staff. As the twentieth century progressed, the territory became a customary stop for Caribbean cruise ships. The increasing popularity of the territory brought golf courses and seaside resorts, but the economic benefits of these development initiatives remained poorly distributed among historically marginalized Afro-descendants. In 1972, building tensions over inequitable tourism development boiled over in what is now known as the "Fountain Valley Massacre" when a group of local Virgin Islanders killed eight tourists and staff at a golf resort in St Croix. In the 1970s, the territorial government approved the opening of an oil refinery on the southern coast of St Croix and, while the refinery did provide employment for many Afro-descended people across the West Indies, it also brought severe pollution that resulted in the refinery's closure in 2021.

On the eve of the dual impacts of Hurricanes Maria and Irma, the U.S. Virgin Islands were a deeply socio-economically divided community. Residents who moved from the mainland for employment opportunities in the region's financial, tourism, or energy sectors enjoyed a high quality of life and spatially distanced themselves from historically marginalized Afro-descendants. The latter were confined to low-income housing and subjected to dysfunctional public health and education systems. The territory's extractive economic relationship with the U.S. mainland and its class and race structure effectively limited the possibility of a territory-wide sense of community among the islands' residents. As in the case of housing relocation sites in Southern Honduras, the Virgin Islands' ability (or lack thereof) to recover from the impacts of hurricanes cannot be understood without careful consideration of broader Danish colonial and U.S. Imperial political ecological relationships it has existed in during the last three centuries.

3.6 Conclusion: Reflections on Living Well

This review of the recent history of the disaster and resilience concept in the Latin American context tells us much about how the mitigation of the former and realization of the latter have implications for living well. With regard to disaster, disaster risk reduction requires addressing social inequalities in access to hazard-free living areas, urban planning focused on addressing class, race, and ethnicity-based disparities, and overall diminishing of socio-economic inequities—all actions that have implications for the improvement of quality of life that extend well beyond disaster risk. Similarly, in producing resilience one must be critically mindful that a community's ability to rebound from a catastrophic impact requires more than bolstering qualities such as social capital within it. Producing resilience also necessitates developing inclusive and collaborative and supportive relationships with local, regional, and national governmental and non-governmental agencies that do not reproduce historic race-, class-, and ethnicity-based inequities.

Reducing disaster risk and producing disaster resilience are haunted by a social paradox: making them a reality is both simple and incredibly challenging. These tasks are simple in the sense that it is relatively easy to call for inequity reduction, and yet such calls have a long history of being resisted by politically dominant classes and the ideologies they develop to maintain the status quo, especially in postcolonial societies like Guatemala, Honduras, and the USA. This challenge is intensified by the fact that, over the past five decades, neoliberal ideology has become a core principle of governmental policy in the USA and the Global South, only increasing pre-existing socio-economic inequities. While mitigating disaster and producing resilience are, in principle, quite simple tasks, they remain nothing short of being radically socially transformative in many disaster-prone societies.

References

Barrios RE (2014) Here, I'm not at ease: anthropological perspectives on community resilience. Disasters 38(2):329–350

Barrios RE (2017) Governing affect: neoliberalism and disaster reconstruction. University of Nebraska Press, Lincoln

Bauman R, Briggs C (2003) Voices of modernity: language ideologies and the politics of inequality. Cambridge University Press, Cambridge

Bricker HM, Bricker VR (1997) More on the mars table in the Dresden codex. Lat Am Antiq 8(4):384–397

Bricker HM, Bricker V (2020) A comparison of historical evidence for droughts in the pre-columbian maya codices with climatological evidence for droughts during the early and late classic periods. Ethnohistory 67(1):97–126

di Lenoardo M (2008) Introduction: global and American landscapes of inequality. In: Collins JL, di Leonardo M, Williams B (eds) New Landscapes of Inequality: Neoliberalism and the erosion of Democracy in America. School of Advanced Research Press, Santa Fe, pp 3–20

Diaz B (1963) Conquest of new Spain. Penguin Books, London

Evans B, Reid J (2014) Resilient life: the art of living dangerously. Polity Press, Malden

Fantin R, Barboza-Solís C, Hildesheim A et al (2023) Excess mortality from COVID 19 in costa rica: a registry based study using poisson regression. The Lancet 20(2023):1–11

Few M (2020) Epidemics, indigenous communities, and public health in the COVID-19 era: views from smallpox inoculation campaigns in colonial Guatemala. J Glob Hist 15(3):380–393

García-Acosta V (2020) Introduction: anthropologists studying disasters in Latin America: why, when, how? In: García-Acosta V (ed) The Anthropology of Disasters in Latin America: State of the Art. Routledge, London, pp 1–21

Haraway DJ (1997) Modest_Witness@Second_Millenum. Female Man_Meets_OncodMouse: Feminism and Technoscience. Routledge, New York

Hayek FA (1989) The Pretense of knowledge. Am Econ Rev 79(6):3–7

Hoffman SM, Barrios RE (2019) Disaster upon disaster. Exploring the gap between knowledge, policy and practice. Berghahn, New York

Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4(1):1–23

Lakhani N (2018) Guatemala volcano: at least 62 killed and 300 injured after Fuego erupts. The Guardian. https://www.theguardian.com/world/2018/jun/04/guatemala-fuego-volcano-erupts-dead-missing

Latour B (1993) We have never been modern. Harvard University Press, Cambridge, Translated by Catherine Porter
Leonhard D (2019) The rich do pay less taxes than you. The New York Times. October 6. Accessed August 30, 2023 https://www.nytimes.com/interactive/2019/10/06/opinion/income-tax-rate-wealthy.html
Lovell WG, Lutz C (1996) A dark obverse: Maya survival in Guatemala 1520–1994. Lat Am Geogr 86(3):398–407
Martinez-Folgar K, Alburez-Gutierrez D, Paniagua-Avila A et al (2021) Excess mortality during the COVID-19 pandemic in Guatemala. Am J Public Health 111(10):1839–1846
Maskrey A (ed) (1993) Los Desastres No Son Naturales. Red de Estudios Sociales en Prevención de Desastres en América Latina
Norris F, Stevens SP, Pfefferbaum B et al (2008) Community resilience as a metaphor, theory, and strategy for disaster readiness. Am J Community Psychol 41(1–2):127–150
O'Keefe P, Westgate K, Wisner B (1976) Taking the naturalness out of natural disasters. Nature 260:566–567
Olcese O, Moreno R, Ibarra F (1977) The Guatemala earthquake disaster of 1975: a review of its effects and of the contribution of the United Nations family. UNDP, Guatemala
Oliver-Smith A, Hoffman S (eds) (1999) The angry earth: disaster in anthropological perspective. Routledge, New York
PAHO (Pan American Health Organization) (1998) Impact of hurricane mitch on central America. Epidemiol Bull 19(4):1–13
Petit-Breuilh S, Eugenia M (2004) La Historia Eruptiva de los Volcanes Hispanoamericanos (Siglos XVI al XX): El Modelo Chileno. Cabildo Insular de Lanzarote, Arrecife
Povinelli E (2010) Shapes of freedom: an interview with Elizabeth A. Povinelli. Alterities 1:88–98
Shapin S, Schaffer S (1985) Leviathan and the air pump: Hobbes, Boyle, and the experimental life. Princeton University Press, Princeton
Sherrieb K, Norris FH, Galea S (2010) Measuring capacities for community resilience. Soc Indic Res 99(2):227–247
Tedlock D (1996) Popol Vuh: the definitive edition of the Mayan book of the dawn of life and the glories of gods and kings. Simon and Schuster, New York
The World Bank Group (2020) Poverty and equity brief: Guatemala. Site accessed April 20, 2023. https://databankfiles.worldbank.org/public/ddpext_download/poverty/33EF03BB-9722-4AE2-ABC7-AA2972D68AFE/Global_POVEQ_GTM.pdf
The World Bank Group (2021) Guatemala. Climate Change Knowledge Portal. Site accessed May 1, 2023. https://climateknowledgeportal.worldbank.org/country/guatemala/vulnerability
Walker J, Cooper M (2011) Genealogies of resilience: from systems ecology to the political economy of crisis adaptation. Secur Dialogue 42(2):143–160
Way JT (2012) The Mayan in the mall: globalization, development, and the making of modern Guatemala. Duke University Press, Durham

Chapter 4
Mobility, Vulnerability, and Resilience. A Theoretical Framework for Studying Social Response to Climate-Related Hazards and Disasters in the Past

Caroline Heitz

Abstract This article proposes a theoretical framework for examining the vulnerabilities and resilience capabilities of prehistoric social groups to climate-related natural hazards and disasters using the material remains of the past. It is argued that different forms of spatial mobility related to social configurations should be considered to gain a deeper understanding of the diversity of responses. Mobility and immobility are taken as two poles of a continuum, between which subjects oscillate in the course of their lives. Accordingly, past societies were neither exclusively sedentary or mobile. Rather, different forms of spatial mobility constituted their respective socio-spatial and economic configuration. Related social practices provided resilience but also created situation-specific vulnerabilities. I suggest, therefore, that research on responses to climate-related natural hazards and disasters in the past should take the following aspects into account: the spatiality and temporality of the respective natural hazards and disasters, the threatened or impacted subjects, and their different mobility-related socio-spatial configurations. Furthermore, I suggest that the subjects' resilience capabilities and vulnerabilities are related through memory and learning based on already experienced hazards and disasters and thus are socially constructed.

Keywords Climate archaeology · Social archaeology · Materiality · Disaster risk reduction

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_4

4.1 Introduction

Perceiving and responding to hazards and disasters form part of all communities in the past, present, and future of humanity. Since the beginning of human history, climatic changes have fundamentally influenced the conditions of life. The possible interrelations between climatic changes and societal transformations harbour a great research potential that remains underexplored. The archaeology of climate change (e.g. Burke et al. 2021) is currently a rapidly emerging field of research. However, there is still a lack of archaeological theoretical approaches to climate-related hazards and disasters that take the situation-specific vulnerabilities and resilience capabilities of social groups into account as well as their different regimes of spatial mobility and respective socio-spatial configuration.

In this article, I argue that spatial mobility is not only fundamental to socio-spatial configurations in general but also one of the most important resilience capabilities for mitigating risks before and limiting impacts during and after disasters. The ability to be mobile, or in other words, the potential of spatial mobility as a resilience capability of subjects, depends on their cultural, economic, and socio-spatial configurations. The connection between spatial mobility, vulnerability, and resilience is thus particularly interesting. Accordingly, mobility is a worthwhile epistemological access point to a deeper understanding of the situation-specific vulnerabilities and resilience capabilities of past societies. Here I will develop a theoretical framework that can be used in future archaeological case studies. To this end, it is essential to conceptualize the terms "hazard", "disaster", "mobility", "vulnerability", and "resilience" in such a way that they can be used to study archaeological finds. To outline the different temporalities of climate-related hazards and disasters, I will draw mainly on concepts from climate science (Pfister and Wanner 2021) and disaster risk reduction research,[1] but also from other disciplines (Meriläinen and Koro 2021; Williamson and Courtney 2018). For the conceptualization of the other terms, approaches from the social sciences and humanities are appropriated for archaeological theory building. They all belong to the paradigm of relational theory. Accordingly, subjects—e.g. individuals or social groups—are conceptualized as material-discursive entanglements.[2] For the notion of mobility and its relation to socio-spatial configurations, I will draw on theories of the so-called "mobility turn" (e.g. Glick Schiller and Salazar 2013; Salazar 2016). The conceptualization of vulnerability and resilience is informed by relational theories from sociology, social geography, and social anthropology (e.g. Christman and Ibert 2012; Keck and Sakdapolrak 2013). The illustrative examples, which for reasons of space have been given as short vignettes, are taken from my

[1] "*Sendai Framework Terminology on Disaster Risk Reduction*" of the United Nations Office for Disaster Risk Reduction (UNDRR), https://www.undrr.org/drr-glossary/terminology (accessed 13.6.2023).

[2] On the material-discursive construction of subjects: all living and non-living things are meaningful knots in the lines of life but are not understood as self-contained entities as they are only discerned, objectified, or subjectivized as such for the sake of perception, orientation, identification, and inquiry (Heitz 2021).

field of research: the prehistoric lake dwellings around the Alps (e.g. Heitz et al. 2021a, b).

4.2 Temporalities of Climate-Related Hazards and Disasters

4.2.1 Hazards and Disasters

According to the "Sendai Framework Terminology on Disaster Risk Reduction" of the United Nations Office for Disaster Risk Reduction (UNDRR), a "hazard" is "a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation".[3] In principle, such a conceptualization of a hazard refers to a phenomenon that has the potential to be harmful in the future while there is an awareness of it in the present. However, hazards do not necessarily cause any destruction (Meriläinen and Koro 2021, 161). In appropriating "hazard" as a concept that could be used to study archaeological evidence, two aspects need to be clarified: the causality and the spatiotemporal extent of hazards.

In terms of causality, it is tempting to distinguish between anthropogenically and naturally caused hazards. However, this runs the risk of falling into a Cartesian ontological trap of an untenable divide between "nature" and "culture". With the concept of socionatural hazards, the "Sendai Framework Terminology" seems at first glance to overcome this problem:

> Hazards may be natural, anthropogenic or socionatural in origin. **Natural hazards** are predominantly associated with natural processes and phenomena. **Anthropogenic hazards,** or human-induced hazards, are induced entirely or predominantly by human activities and choices [..]. Several hazards are **socionatural,** in that they are associated with a combination of natural and anthropogenic factors, including environmental degradation and climate change.[4]

The idea of "purely natural hazards" is too short-sighted: while it may be true that some events can occur independently of human activity, such as volcanic eruptions, it is humans who perceive them as hazards. Relational thinking, which takes into account the social perception and construction of hazards, recognizes this condition (Meriläinen and Koro 2021, 158). Hazards—whatever their cause—must first be recognized as such. This applies equally to natural, anthropogenic, and socionatural hazards. Consequently, the hazards of the past studied by archaeologists are not objectively given but are defined by researchers. Whether these events were also perceived as hazards by the subjects concerned in the past can be examined by

[3] https://www.undrr.org/terminology/hazard (accessed 13.6.2023).

[4] https://www.undrr.org/terminology/hazard (accessed 13.6.2023). Risks of "*armed conflicts and other situations of social instability or tension*" are excluded in this definition.

analysing written and pictorial sources and the materiality of targeted risk reduction measures. The latter include, for example, dams and fascines to protect settlements from flooding and tents to protect subjects from the effects of extreme weather conditions.

In terms of spatiality and temporality, hazards may be single, sequential, and/or combinational in their effects. The sequential occurrence of hazards, e.g. the fear that a potential flood could be accompanied by an epidemic, is referred to as “multi-hazard framework”, in which several interrelated hazards overlap in time and/or space (De Angeli et al. 2022, 2). This aspect is particularly useful for archaeology, as space and time are analytical categories that can be explored very well. It also raises awareness of the fact that hazards can have spatial and temporary intermediate effects, as well as long-term and far-reaching consequences. Thus, hazards can be characterized by their potential spatial and temporal extent, their expected intensity or magnitude, and their frequency and probability of occurrence.

In contrast to hazards, disasters are phenomena where a potentially hazardous situation has become a harmful event and is perceived as such (Meriläinen and Koro 2021, 161). Like “hazard”, “disaster” is a relative term (Williamson and Courtney 2018, 6). Whether something is experienced as a “disaster” is a matter of the perspective of those involved in the situation: be it the emic perspective of those affected by disasters or the etic perspective of those studying them (Meriläinen and Koro 2021, 163–164). In the “Sendai Framework Terminology”, disasters are defined as follows:

Disasters are "a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to one or more of the following: human, material, economic and environmental losses, and impacts [..]”. The effect of the disaster can be immediate and localized but is often widespread and could last for a long period of time. The effect may test or exceed the capacity of a community or society to cope using its own resources and therefore may require assistance from external sources, which could include neighbouring jurisdictions, or those at the national or international levels.[5]

Disasters may have very different spatial and temporal dynamics. Disasters related to hazardous events like fires, earthquakes, landslides, avalanches, hurricanes, or floods may have a very sudden and violent direct impact in a limited spatial–temporal frame. In contrast, droughts, famines, and epidemics may have slow, sometimes even unnoticed phases of development, the onset of which is difficult to pinpoint. Such disasters spread over larger spatial scales and longer periods of time, such as months or even years (Williamson and Courtney 2018, 5–8).

Although disasters can be perceived as events (Meriläinen and Koro 2021, 162) unfolding spatially and temporally confined, the preconditions that facilitated their expansion might have been created beforehand. In the case of a blaze, for example, a settlement is affected immediately by a short-term fire. However, house constructions made from combustible materials, too dense settlement layouts, insufficient

[5] https://www.undrr.org/terminology/disaster (accessed 13.6.2023).

firefighting strategies, and also previous phases of droughts and wildfires are conditions that expand the temporality of the disaster into the past long before the onset of the hazardous event. Turning to the aftermath, disasters might expand long beyond the impactful event itself. Those who lost their homes in the fire might continue to suffer from the loss of their property as well as from temporary unideal housing conditions (Meriläinen and Koro 2021, 162). Furthermore, preparing better for future hazards expands the temporality of disasters into the ongoing present and imagined future. Accordingly, in social anthropology and environmental history, disasters are not understood as discrete events but as processes where causality is embedded in the deeper timescale of a community (De Angeli et al. 2022, 2; Meriläinen and Koro 2021, 162). Disasters are the result of long-lasting interrelations between communities and their environments (Williamson and Courtney 2018, 5–6). Furthermore, future disasters are imagined in the context of current hazards by drawing on the experience of past disasters in order to mitigate or reduce potential risks (Compton 2020, 2). The temporal linearity of the disastrous events themselves is replaced by a cyclical temporality where past, present, and future are interrelated. Such nested temporalities are also typical for climate-related hazards, as will be shown in the next section.

4.2.2 Climate, Weather Patterns, and Weather

Like hazards and disasters in general, those related to climate encompass different temporalities and spatialities too. The climate-related processes themselves are driven by different aspects of the climatic system that have different temporal and spatial scales. For example, clouds that might lead to disastrous storms can emerge within minutes or hours and are very mobile, but glaciers, which could cover settlements and pastures as well as triggering ice slides, landslides, and floods, grow up to 70 m a year over decades to centuries and are spatially much more restricted (Pfister and Wanner 2021, 25, 337–338). Here the conceptual distinction between "climate", "weather", and "weather pattern" is important.

The term "weather" refers to the state of the atmosphere (the troposphere) and all associated processes at a particular location or in a small region over a short period of time, usually one day. Weather includes phenomena such as clouds, winds, and precipitation from rain to snow (Pfister and Wanner 2021, 24). "Weather patterns" are large-scale weather phenomena that can last from hours to a few days (Pfister and Wanner 2021, 25). What is referred to as "climate", finally, is the statistics of weather phenomena that were measured over days, months, seasons, and years as climate variables. A standard climatic period of observation is about 30 years (Pfister and Wanner 2021, 25).

Among the most basic climate drivers are the three different dimensions of the orbital movements that follow quasi-periodic rhythms (see Fig. 4.1; Pfister and Wanner 2021, 29–31).

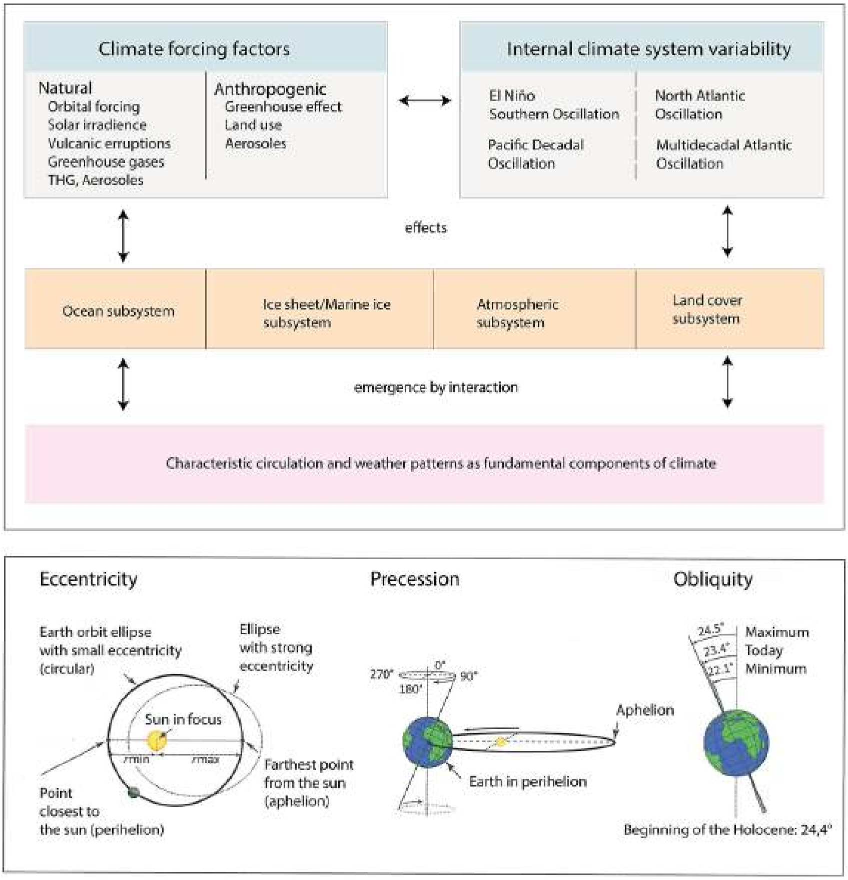

Fig. 4.1 Basic factors and processes influencing the climate (**a**) and the three quasi-periodic orbital movements causing variations of the solar insolation known as "Milankovitch forcing" (**b**) (hereafter: Pfister and Wanner 2021, Figs. 1.6 and 1.8)

- The "eccentricity": the changing shape of the Earth's yearly orbit around the sun from a rather circular to an elliptical path takes ca. 100,000 years.
- The "precession": the tumbling direction of the Earth's axis of rotation with a periodicity of 23,000 years.
- The "obliquity": the angle of the Earth's axis that is tilted with respect to Earth's orbital plane changes from 22.1° to 24.5° over a time span of ca. 41,000 years.

The three quasi-periodic orbital movements, the so-called "Milankovitch cycles", lead to a variation in solar insolation and thus the regional energy balance and long-term mean values of the ground-level running temperature. Accordingly, Milankovitch forcing is responsible for most of the long-term temperature fluctuations (Pfister and Wanner 2021, 27–28). In addition, there are also short-term forcings, such as volcanic eruptions, of which massive ones within the tropical zone have the biggest impact. If aerosols enter the stratosphere, they can lead to one to three years of cold summers with a lot of precipitation. Such eruptions can trigger, for example, crop failure and the danger of famine as well as glacier advances (Pfister and Wanner 2021, 35–36, 62–72). Holocene cold phases could be triggered by volcanic eruptions that coincided with phases of a reduced number of sunspots. Both had the effect that less solar irradiance reached the Earth's surface, causing lower temperatures (Pfister and Wanner 2021, 185–266, 329). The periodic change of sunspot patterns follows different cycles: the Schwabe cycle (ca. 11.1 years), the Geissberg cycle (ca. 90 years), and the Suess cycle (ca. 120 years) (Pfister and Wanner 2021, 31, 36).[6]

With regard to the internal system variability, the "North Atlantic Oscillation" (NAO) and the "Atlantic Multi-decadal Oscillation" (AMO) are the most significant sources of internal variability of the climate system for the European Northern Hemisphere. The NAO is driven by the nonlinear and thus stochastic interaction of the atmospheric and the oceanic circulations influenced by pressure differences between the Icelandic Low and the Azores High as well as the polar ice caps. The NAO changes between two modes: a positive mode (NAO+ index) that, due to strong westerly winds, leads to warm and humid winters in Northern Europe and dry conditions in Southern Europe; and a negative mode (NAO– index) that leads to fewer westerly winds and thus a stronger influx of cold and dry air from the polar regions, which leads to cold and dry winters in Northern Europe and humid winters in Southern Europe. Although the NAO indices might change daily, long-term patterns of both modes can last for more than ten years.

The AMO is a cyclical fluctuation in the circulation of ocean currents in the North Atlantic, which is said to bring about a change in sea surface temperatures throughout the North Atlantic Basin. Its influence on the atmosphere shows a rhythm of around 70 years (Pfister and Wanner 2021, 38–39, 157, 160–161, Figs. 1.17, 1.18, 6.10). The AMO is a correlation of air temperatures and rainfall in summer in the Northern Hemisphere as well as variabilities in spring snowfall over the Alps and the advance and retreats of glaciers (Pfister and Wanner 2021, 161, Fig. 6.10).

4.2.3 Climate-Related Hazards and Disasters

Climatic changes with their different temporal scales from years to millennia are a complex interplay between forcings and cycles. With reference to the UNDRR definition of hazards mentioned in Sect. 2.1, I define "climate-related hazards" as

[6] Beside these planetary drivers, anthropogenic forcings, e.g. changes in land use and the emissions of greenhouse gas, can also trigger climatic changes. The latter have been particularly impactful since the turn of the twenty-century BC (Pfister and Wanner 2021, 343–376).

follows[7]: weather-related temporal deviations from the norm of weather characteristics in a particular region, in a particular season, and in a particular period. They have the potential to impact subjects, their resources and infrastructures, their livelihoods, and the environment in a disastrous way. In relation to what is known as normal, such anomalies might be perceived as extreme events.

Their unpredictability due to their irregular, nonlinear, or just rare occurrences makes them hazardous to the potentially impacted communities (Kislov and Krenke 2010). In contrast to sudden-impact disasters, long-term changes in the annual mean temperature were probably never perceived as hazards by prehistoric communities.

From an etic perspective, those anomalies "exceeding one, one and a half or two standard deviations in long-term observational series" might be considered potentially hazardous events. To approach long-term climatic changes and their potential hazardous effects, the trends in mean values of temperature or precipitation spanning decades, centuries, and millennia need to be considered (Kislov and Krenke 2010). The European Environmental Agency (Crespi et al. 2020)[8] has identified 16 climate-related hazards based on 32 indices that are grouped into six hazard types. The latter are hazards related to hot and cold conditions, wet and dry conditions, wind, snow, and ice on the mainland, but here they are also coast- and ocean-specific ones (Fig. 4.2).

Too much or too little rainfall, especially in spring and summer, can lead to disasters, since much of one's life and livelihood—ecosystems in general, but also agriculture and thus food security, water supply, and settlement security—depends on "rain falling at the right time and in the right amount".[9] Heavy precipitation in terms of too much rain in a too short period of time can lead to river floods and short-term lake level rises. Changing temperature and precipitation patterns can lead to aridity—an increased long-term average dryness of a region.[10] The consequences are low water contents in the soil, soil erosion, salinization, and land degradation affecting ecosystems and agriculture. Short-term increases in temperature and evaporation accompanied by a decrease in precipitation can lead to droughts that last from weeks to several years.[11] Furthermore, soaring temperatures, dry forests, and strong winds increase the risk of wildfires, which are mostly triggered by human activity but occasionally also by lightning, spontaneous combustion, or volcanic activity.[12] Long-term changes in mean air temperature can impact ecosystems, agriculture, human

[7] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1 (accessed 13.6.2023).

[8] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1 (accessed 13.6.2023).

[9] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/wet-and-dry-1 (accessed 13.6.2023).

[10] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/wet-and-dry-1/wet-and-dry-aridity (accessed 13.6.2023).

[11] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/wet-and-dry-1/wet-and-dry-drought (accessed 13.6.2023).

[12] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/wet-and-dry-1/wet-and-dry-fire-weather (accessed 13.6.2023).

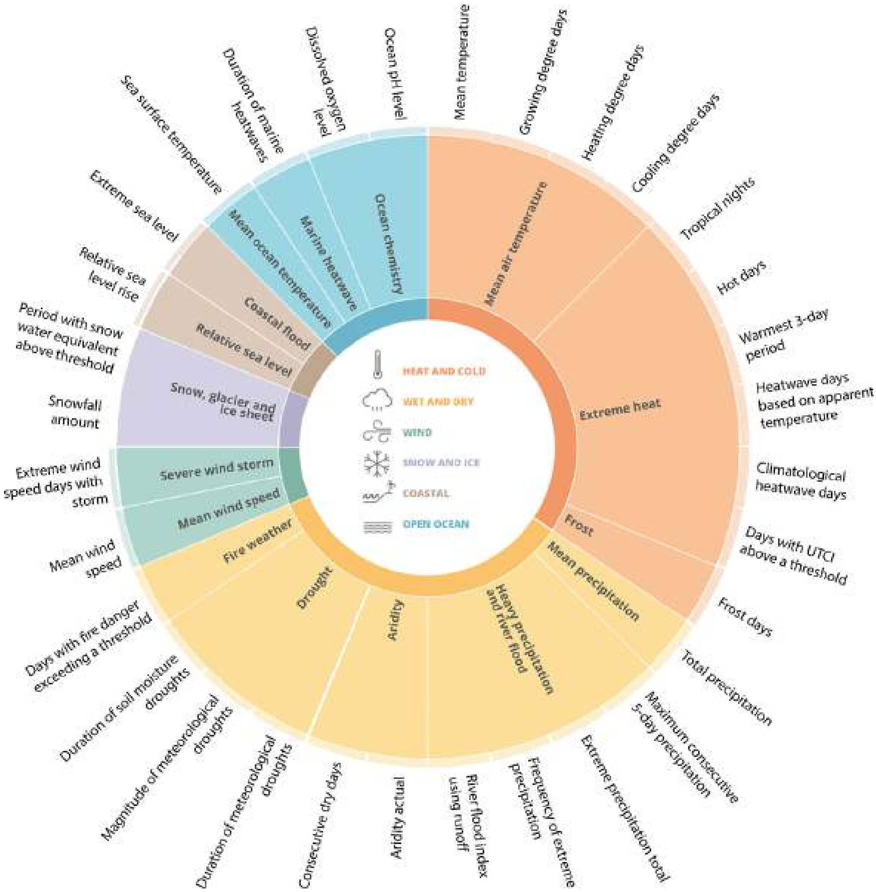

Fig. 4.2 Overview of Europe's 16 hazards with their 32 indices grouped into six hazard types as identified by the Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report (hereafter: European Environment Agency 2021)

health, and well-being. Heatwaves—short extreme temperature heights—can lead to higher death rates and increase the likelihood of wildfire outbreaks in combination with aridity and droughts.[13] Frost days and periods of extreme cold at unfavourable times during the growing season can affect seasonal farming and cropping cycles.[14]

For archaeological case studies, specific climate-related challenges need to be approached through the modelling and/or reconstruction of climate variations using simulations and paleoclimatic proxy data, as well as environmental and archaeological evidence.

[13] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/heat-and-cold/heat-and-cold-extreme-heat (accessed 13.6.2023).

[14] https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1/heat-and-cold/frost-days (accessed 13.6.2023).

4.3 Mobilities of Social Groups

To examine the potential impact of climate-related hazards and disasters, a deeper understanding of differences in socio-spatial configurations of past communities is indispensable. Their vulnerabilities but also resilience capabilities are strongly related to their socio-economic ways of life, which in turn is related to different regimes of spatial mobility. As a starting point, one can hypothesize that moving away from hazardous situations like wildfires or following prey in phases of rapidly emerging cooling periods was one of the biggest resilience capabilities of forager communities. Accordingly, they would be less vulnerable to such aspects of climatic changes. In contrast, sedentary crop-growing communities facing the same climate-related hazards might be more vulnerable because settlements and fields cannot be moved quickly. Cold spells could have a delicate effect on crop yields. It would be far too simplistic, however, to view foraging and farming communities as either mobile or sedentary, respectively. Instead, the focus should be on the diversity of different mobility regimes, how they relate to economic diversities and socio-spatial configurations, and how this influences the vulnerability and resilience of communities to climate-related hazards.

4.3.1 The Mobility Turn

Scholars of the "mobility turn" in social science and humanities argue that mobility is fundamental to all communities, regardless of their economic strategies or more general ways of life (Cresswell 2006; Faist 2013; Hannam et al. 2006; see also Salazar 2013; Sheller and Urry 2006). Cultural and social phenomena can thus be understood "through the lens of movement" (Salazar 2016, 2–3). The wide range of different forms of mobility can be studied in all kinds of social configurations, beyond the dichotomy of mobile foragers versus sedentary cultivators (Heitz and Stapfer 2017, 23–24; Leary 2014, 16).

4.3.2 Mobility from a Social-Archaeological Perspective

As I have outlined elsewhere (Heitz 2023a; Heitz and Stapfer 2017, 2021), I suggest conceptualizing "movement" as a physical activity that takes place in a changing spatial and temporal extension, as opposed to "immobility" or "stasis". From a social-archaeological perspective, "mobility" can be understood as a particular kind of movement that involves a change between different units of a context (see also Burmeister 2013, 36–37). Concepts such as "here" and "there", "self" and "other", and "foreign" and "familiar" make it clear that such categorical units, and their

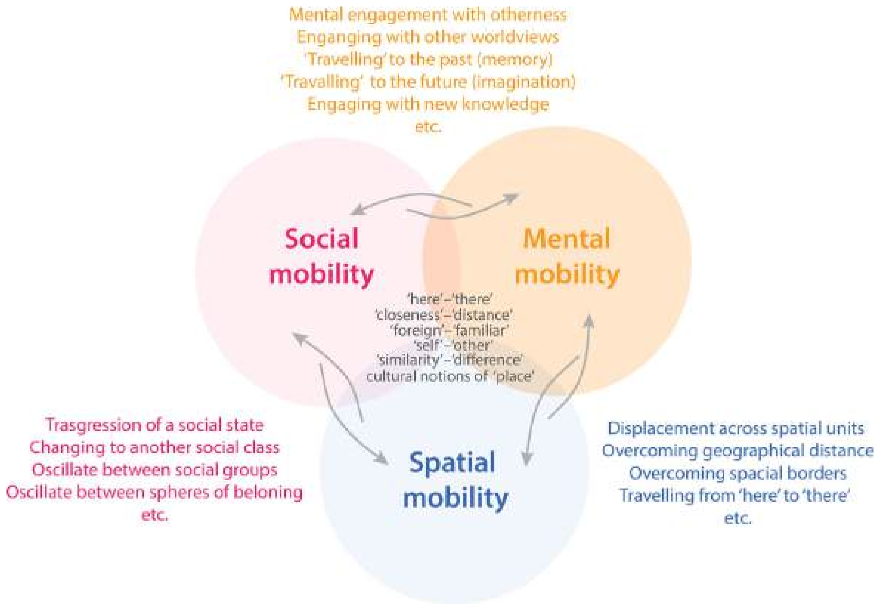

Fig. 4.3 Three intersecting spheres of mobility (Heitz and Stapfer 2021, Fig. 8.4)

boundaries, can be socially constructed and vary according to emic perspectives (Appadurai 1996, 179; Frello 2008, 27–32).

These concepts all refer to three different spheres of mobility (Fig. 4.3), which may overlap in specific situations (Heitz and Stapfer 2021, 122–123):

By "social mobility" I mean the crossing of a social boundary and the transgression of a social state, such as moving up or down into another social class (vertical social mobility), moving into another social milieu, or oscillating between different social group affiliations such as gender, kinship, or residential groups (horizontal social mobility in stratified forms of social organization).

By "mental mobility" I mean mental engagement with what is perceived as "new", "foreign", "different", and "unknown" with the past and the future in the present. This can involve overcoming familiar ideas, engaging with new knowledge, different world views, or mental journeys into the past (memory), into the future (imagination), or to other mental places (e.g. by listening to stories or looking at pictures). Mental mobility also involves putting oneself in another person's cultural and social situation (empathy) or reflecting on what one has experienced in the past and what one can learn from it for the future (cf. Frello 2008, 28–29; Hannam et al. 2006, 14; Sheller and Urry 2006).

With "spatial mobility" I refer to any movement in space, from one defined "place" to another, and thus to the overcoming of geographical distances. As with mental mobility, spatial mobility is also a basic condition of human life (Burmeister 2013, 36–37; Frello 2008, 26, 28; Glick Schiller and Salazar 2013, 185, 187; Salazar 2016, 1–2; Salazar and Smart 2011, 1–2).

Forms of spatial mobility may be more directly amenable to archaeological analysis than social and intellectual mobility. Well-established methods for detecting spatial mobility in archaeology include the analysis of means of transport and routes, the distribution of finds, including the typological and material analysis of non-local objects, and the strontium isotope analysis of human and animal remains (Gregoricka 2021; Heitz 2017).

These three spheres of mobility can be interrelated: leaving for another place (spatial mobility) requires a pre-existing imagination of the destination and a mental map and imagination of the landscapes along the way—regardless of whether one has been there before or not, or whether one has any knowledge of what to expect on the journey ahead. Accordingly, before leaving, one travels there mentally (mental mobility) long before the bodily departure. Travelling and arriving at a place may involve encounters with what is known and familiar, as well as encounters with what is unfamiliar and unknown. Engaging with the unknown requires mental flexibility because it means learning about the new place—or the already known but changed place—and learning means being mentally mobile. Thus, spatial mobility leads to encountering and engaging with similarity and difference, with the familiar and the unknown, and is thus related to mental mobility (Heitz and Stapfer 2021, 113). Having arrived in a new place, in what is likely to be a different cultural environment, one's social status and role may also be different from the place of departure. Social positions can therefore change in the course of the journey. The new arrivals might be perceived as "strangers", "travellers", "traders", "migrants", "visiting neighbours", etc. Being spatially mobile in such cases involves overcoming or oscillating between social states and thus social mobility too (Heitz 2017, 276–277).

The oscillation between movement and stasis and the resulting enormous variety of patterns and rhythms of mobility raise many questions (Heitz and Stapfer 2021, 112–113): who is mobile? What are the ranges, directions, and speeds of mobility? Is it long or short term? Does it involve stopovers? Is it frequent or infrequent? Is it permanent spatial displacement or only sporadic temporal displacement? What are the economic, political, social, and cultural contexts? (Bell and Ward 2000, 98–100; Glick Schiller and Salazar 2013, 184; Kelly 1992, 44–51, 57). Mobility, on the one hand, is strongly related to economically and socially based spatial configurations of communities and their ways of conducting their daily lives, but also to incidences like hazardous events or disasters beyond what is perceived as normality.

4.3.3 Mobility and Socio-Spatial Economic Configurations

Different regimes of mobility are fundamentally related to the variety of economic forms and their socio-spatial configurations. The degree of spatial mobility has been linked to a community's position on the "evolutionary ladder" throughout the history of archaeological research. According to this view, which is rooted in the problematic paradigm of evolutionism, foragers were associated with nomadism and agriculturalists with sedentarism, the former way of life being seen as an inferior stage of development to the latter (Kelly 1992, 43–50; Scharl 2017, 9–10; Wendrich and Barnard 2008, 10–15, 48–50). In such an untenable dichotomic view as will be shown below, foragers would need to follow the seasonal movements of their animal resources and seek out their gathering grounds and thus adopt a basically mobile lifestyle. In contrast, agriculturalists seem to be bound to the clod by their need to maintain their garden patches and fields throughout the growing cycles and thus live in permanent settlement the whole year round.

Ethnographic, archaeological, and historic examples show that the relation between economic, social, and spatial configurations and thus regimes of spatial mobility are far more complex. On the one hand, there are various examples of sedentary or semi-sedentary lifestyles of foraging communities, e.g. in cases where marine, aquatic, or plant resources are available in a confined space the whole year round (Scharl 2017, 9–10). On the other hand, there are various mobility regimes on different temporal and spatial scales in farming communities, from the seasonal transhumance of herders, to the decadal shifting cultivation of agriculturalists, up to the regular residential mobility of households or whole residential communities (Scharl 2017, 11–12). Accordingly, spatial mobility regimes might include a great variety of case-specific occasions and reasons, temporalities, and spatialities (Salazar 2013, 553; Salazar and Smart 2011, 2). However, there are some fundamental tendencies in residential mobility regimes of prehistoric foraging and farming communities (Scharl 2017, 12):

Foragers move their camps on a yearly, seasonal, weekly, or daily basis, which is largely dependent on the availability of resources while the temporal rhythm of the cultivators' residential mobility encompasses cycles of years or decades.

While the mobility pattern of foragers may have been primarily dependent on the spatial distribution of their resources, the mobility regimes of cultivators could have been more strongly influenced by increasingly densely populated landscapes as well as territorial claims and relations of politics and power that go hand in hand with more sedentary lifestyles.

As a tendency, different regimes of mobility (and immobility) are linked to socioeconomic configurations, and the latter influence the situational vulnerabilities and resilience capacities of communities in the face of climate-related hazards.

4.4 Vulnerabilities and Resilience Capabilities

In exploring how communities dealt with climate-related hazards in prehistory, I will argue from a social-archaeological perspective that the conceptual relation between resilience and vulnerability should be reconsidered: it is not helpful to understand them as two mutually exclusive states of a community, in the sense that communities are either vulnerable or resilient. Rather, resilience and vulnerability should be understood as relational, as phenomenologically interrelated concepts. To move beyond ecological system-theoretical approaches that run the risk of underestimating situational, socially creative human problem-solving (cf. Heitz et al. 2021a, b), I will draw on relational conceptualizations of resilience and vulnerability derived from sociology, social anthropology, and geography (Christman and Ibert 2012; Keck and Sakdapolrak 2013). Acknowledging the social construction of both terms, they recentre agency in the complex entanglements of social subjects. I therefore propose a conceptualization of resilience and vulnerability that is open to the diversity of temporalities and spatialities of climate-related hazards and that takes into account the historicity of landscapes and communities with their social and economic configurations.

4.4.1 Vulnerability and Vulnerabilities

According to the UNDRR's Sendai Framework, vulnerability is defined as a condition:

> The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.[15]

Understanding vulnerability as a pre-existing condition neglects the dynamics of evolving hazards and disasters: as they unfold over time and space, new forms of vulnerability may emerge (Williamson and Courtney 2018, 5). The "multi-hazard framework" and "multi-exposure" concepts also emphasise that (Kelman et al. 2015, 23). Furthermore, in disaster risk reduction and environmental research, it is generally agreed from an etic perspective that vulnerability is driven by exposure, sensitivity, and response to a hazardous event (Kelman et al. 2015). What is missing here is that vulnerability—as much as hazards and disasters—is perceived, experienced, and evaluated as such from emic perspectives of communities in the first place and that their ability to respond is heavily dependent on that. Accordingly, vulnerability, but also resilience, call for both quantitative and qualitative approaches. They are as much as an etic objectified as a subjective emic category (see also Kelman et al. 2015, 22–23). In the following I will outline an alternative approach to vulnerability:

1. Vulnerability (lat: *vulnus* = wound)[16] is not the same as being wounded. It is the potential to be wounded. While being wounded may be a temporary state that can even lead to death, vulnerability is a basic, permanent potential of all life.
2. Vulnerability is a concept that refers to a basic human experience as "perceiving and dealing with endangerments from part of the history of human society" (Christman and Ibert 2012, 260).
3. Drawing on relational thinking, vulnerability concerns social configurations and assemblages of practices far beyond one individual life, including technical

[15] https://www.undrr.org/terminology/vulnerability (accessed 10.7.2023).

[16] https://www.etymonline.com/word/vulnerable (accessed 15.6.2024).

systems and entire landscapes of living and non-living things and their animated, entangled, temporary coexistence (Heitz 2021, 3).

4. Vulnerability as an ontological phenomenon occurs as relationally emergent, situation- and context-specific vulnerabilities. While vulnerability is something fundamentally given (see 1–3), it is the various vulnerabilities of subjects under study in their plurality that need to be examined (Heitz 2021, 4). In the practice of case study-oriented research, it is paramount to specify which analytically determined entity is vulnerable in which of its aspects in what situation and relation (Heitz 2021, 3). It should be asked: whose vulnerabilities,[17] from what, and in relation to what?
5. From emic but also etic perspectives, vulnerabilities are situation-specific assessments of possible harm. They are socially constructed—but not objectively given. As Christman and Ilbert (2012, 267) have put it: "[..] *in the context of social action under conditions of uncertainty, [vulnerabilities] denote practices of collectively assessing and negotiating situations of endangerment. [This] involves any kind of entity—be it a subject, a group, an organization, a technical or ecological system or a territory—which is defined (and thereby also delimited), identified as valuable and worthy of being preserved and set at the centre of an analysis.*"
6. Vulnerabilities can be studied from a subject-involved (emic) and a non-involved (etic) perspective as well as with qualitative and quantitative methodologies. The two perspectives[18] do not have to be congruent, although both are socially constructed.

The finding that vulnerabilities can be studied through disaster risk reduction practices leads us to *resilience* as a concept and how it is related to vulnerability.

4.4.2 Social Resilience

The concept of resilience in the UNDRR's Sendai Framework draws on the resilience theory of Gunderson and Holling (e.g. Gunderson and Holling 2002; Holling 1973) that was already used in archaeology (e.g. Peters and Zimmermann 2017; Redman 2005). There, resilience is defined as:

> [t]he ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.[19]

[17] The same set of questions was suggested for resilience by Obrist et al. (2010, 289) and Keck and Sakdapolrak (2013, 8).

[18] For social anthropology, Meriläinen and Koro (2021, 163–164) emphasize that researchers might also become entangled with a disaster place in terms of participant observation; however, that does not apply for archaeology.

[19] https://www.undrr.org/terminology/resilience (accessed 24.5.2023).

As I have argued elsewhere (Heitz et al. 2021b), such a concept for archaeology runs the risk of deterministic thinking, deductionist reasoning, and the neglect of agency. It also fails to address the relationship between resilience and vulnerability in terms of social learning and risk reduction management. Vulnerability seems to be strongly related to the awareness and thus the predictability of the possibility of being affected by hazards. The question of how to reduce vulnerability, how to prevent harm, or how to overcome it seems to require a counter-concept, for which I propose "resilience":

1. Resilience is not the opposite of vulnerability. The proper opposite of vulnerability would be invulnerability. But its absolute, finite connotation roots the latter rather in the realm of myth and shows the unsuitability of the term for a conceptualization in research. Vulnerability is a probable possibility; invulnerability is a fait accompli (Heitz 2021, 5).
2. "Resilience" is not an oppositional but a complementary term to "vulnerability". Both terms draw on complementary aspects of experience: while vulnerability can be understood as the assessment of possible hazards that could turn into harmful events, resilience can be understood as the emerging potential and capability (Arponen et al. 2016) to respond sustainably.
3. Resilience and vulnerability are related through experience, learning, and memory (Assmann 2011; Keck and Sakdapolrak 2013). Experiencing repeated (similar) threats helps subjects to learn how to cope with them, to be protected from them, or even to prevent them from happening. Accordingly, "social resilience" means learning from the past to respond to challenging situations in the present to sustain in the future.
4. If I conceptualize vulnerability as a retro-prospective assessment of a potential threat related to experience as part of autobiographic, social, cultural memory (Assmann 2011), social resilience, accordingly, is: the capability to respond in terms of action and social practice (learning) to mitigate the risk of becoming harmed (protection), to prevent or reduce harm from happening (prevention), to buffer or counteract the impact of threats (resistance), and to cope with and overcome them (effectful related transformation).

Social resilience thus is not only about "bouncing back" (lat: *resilire*[20]) but about "going forward by looking back" (Riede and Sheets 2020), which emphasizes the sustainability inherent in social resilience (Kelman et al. 2015, 22). Social resilience is rooted in experience, memory, and learning for the future and thus reducing vulnerability (Keck and Sakdapolrak 2013, 9).

[20] https://www.etymonline.com/search?q=resilience (accessed 15.6.2024).

4.4.3 *The Materiality of Climate-Related Vulnerabilities and Resilience Capabilities*

Archaeologically, past communities' vulnerabilities and resilience capabilities can be studied by drawing on the materiality of both climate changes and their environmental consequences (paleoclimatic proxies), as well as action and social practices of response (archaeological finds). Material traces can be approached by mixing quantitative and qualitative methods from archaeology, environmental, and climate sciences and focusing on different temporal and spatial scales (Heitz et al. 2021b, 159–161).

One of the most challenging issues lies in the temporal and spatial correlation between the dynamics of paleoclimatic and social changes—or climate-related hazards and disasters with forms of social response, respectively. Quantitatively, the significance of correlation can be tested using time series statistics (Heitz et al. 2021a, b: 178–185). For example, a centennial minimum in a time series of a paleoclimatic proxy indicating summer precipitation may be significantly correlated with a corresponding minimum in the time series of settlement frequency in a given study area. However, correlation does not prove causation.

Qualitative methods can be used to validate findings from quantitative approaches or to complement them. As explained in Sect. 4.2, it was perhaps short-term, severe climate-related hazards and disasters that were experienced and assessed as such by prehistoric communities: flash floods due to heavy precipitation and/or rapid snow or glacier melt, forest and settlement fires triggered by hot spells and drought, cold summers caused by volcanic eruptions, etc. Their impact on communities can be studied on a local scale, on a specific site, or within a confined region by using stratigraphy-based methods from archaeology and environmental or climate science. They might reveal layers of destruction and abandonment or even reconstruction. In particular, micromorphological analyses make it possible to gain an understanding of site formation processes including anthropogenic and climate-related factors (e.g. Ismail-Meyer et al. 2020, 2022), while sedimentological and hydrological analyses can be used to detect, for example, tephra, floods, and tsunamis related to climate, earthquakes, or landslide (e.g. Anselmetti et al. 2020; Schaller et al. 2022; Wilhelm et al. 2022).

As mentioned in Sect. 4.1, vulnerability can be modelled by calculating indices from an ecological perspective. Disaster risk reduction research has developed several vulnerability indices that measure a community's sensitivity to hazards and "its ability to respond to and recover from the impacts" (Cutter and Finch 2008, 2301). However, the absolute metrics may neglect proportional impacts as well as contextual or local differences when transferring the indices from one case study to another (Kelman et al. 2015, 23). Nevertheless, the calculation of such indices could be worthwhile in order to transfer to archaeological research what has not yet been done.

Adopting a subject-involved (quasi-emic) perspective using qualitative methods, vulnerabilities assessed by past communities themselves can be understood through the materiality of their resilience practices, as will be shown below (Heitz 2021, 8). Using a relational ontology, the geographers Christman and Ibert (2012) have proposed a methodological framework that can be appropriated for archaeology. Disaster risk reduction and mitigation are understood as "rearrangement" in the "material-discursive entanglement" of social worlds (Christman and Ibert 2012, 267): "The intention is to implement more or less far-reaching changes within the relational web in order to reduce the vulnerability of the centrally placed entity [the subject] by protecting its vital functions and ensure its overall integrity". The authors define six dimensions of resilience-related actions and practices, which I have adapted for archaeological research using floods and fires as examples of hazards:

- Manipulation: The surroundings, understood here as an entanglement, can be modified to reduce the vulnerability of the threatened subject. For example, the earth around a settlement could be piled up to form a dam to protect it from flooding, or firebreaks could be cut out to prevent forest fires from spreading to the settlement.
- Addition: Protective measurements can be added in such a way that the subject's exposure to the hazard is reduced or prevented. For example, settlements can be protected from flooding by erecting fences with closely spaced boards, and the impact of settlement fires can be reduced by introducing fire-extinguishing practices.
- Removal: Threatening entities can be removed in hazardous situations. Water can be drained from settlements in the event of flooding, or combustible building materials can be removed from houses in the event of fire.
- Mobility: To reduce the level of exposure during hazardous events, subjects could be moved away from the threatening situation. Compared with, for example, tents in camps, it may not be possible to move fixed houses quickly enough, so the occupants may have to flee, taking some of their belongings with them (see below).
- Strengthening ties: Relationships that reach outside and beyond the threatening situation can be strengthened. In the event of hazards such as floods and fires, communities can temporarily shelter with neighbours or even be helped to leave the threatened region.
- Changing the valuation: One dimension of resilience is to change the valuation of a subject—or part of it—to make it less valuable if it cannot be saved. In the case of floods and fires, houses may be abandoned to save at least one's own life and those of, for example, animals. The value of immediate survival and food security is temporarily placed above that of shelter.

During hazardous events, which may even become disasters, resilience practices such as those mentioned above may be used simultaneously or sequentially in a dynamically evolving situation—and even after the immediate threat has passed. Most of the measures and actions are related to experience and learning from previous events and the communities' anticipatory capabilities (Keck and Sakdapolrak 2013, 9). Vulnerabilities as retro-prospective assessments thus connect the past, present, and future of communities and are related to the earlier described concept of mental mobility. Hence, a community's capabilities to be resilient are informed by their past experiences, their social practices of disaster risk reduction, but also their resources of everyday practice and their socio-spatial configurations.

4.5 Conclusion and Outlook: Mobility, Vulnerability, Resilience, and Climate-Related Hazards

The aim of this article was to develop theoretical tools. In the following, the main findings are taken up again and supported by some examples. These are intended to make the theoretical considerations more accessible to applied research in the future.

Climate-related hazards are significant deviations in weather characteristics that occur on a particular spatial and temporal scale (see Sect. 4.2). Compared to what is known by experience and memory as normal, such anomalies may have been perceived by prehistoric communities as extreme events and thus as hazards. They can be associated with heat and cold, wetness and dryness, wind, snow, and ice and can be relevant on land, in coastal areas, and in the open ocean. Examples of hazards include short-term and sudden events such as floods, storms, tsunamis, cold snaps, heatwaves, droughts, and wildfires, as well as slowly evolving long-term changes such as an increase or decrease in mean temperature or seasonal precipitation. As such, they have very different temporalities, lasting from hours to years, occurring stochastically or in seasonal, annual, or decadal to centennial cycles. Such hazards have multiple causes and can be socionatural and occur in spatially and temporally evolving multi-hazard situations. Volcanic eruptions are not climate-related in origin but can lead to a significant cooling over two to three years.

Hazards, and even more so disasters, are relational in the sense that they are socially constructed, be it emically by involved subjects or etically by uninvolved observers such as researchers. The assessment of extreme events or long-term changes as hazards is informed by past experiences of vulnerability. Vulnerability draws on the basic human experience of being harmed and is thus an everlasting inherent potential. The potential for vulnerability manifests itself in the form of specific vulnerabilities, which are situational, relational, material, and discursive social constructs. The assessment of vulnerabilities is linked to the assessment of hazards. They are anticipations of the possibility of being harmed. Accordingly, vulnerabilities are retro-prospective assessments based on experience, learning, and memory that are related to past resilience. Social resilience is a complementary phenomenon to vulnerability (see Sect. 4.2): memory as well as learning capacities are built through everyday experiences and social practices. They enhance the capability for risk and disaster readiness and thus a sustainable response. Resilience and vulnerability are to be understood as gradual phenomena, rather than as absolute mutually exclusive states or outcomes. They are potentials that become relevant in emergent hazardous situations that are in turn assessments conducted by social subjects understood as part of material-discursive entanglements. With that, vulnerabilities and social resilience capabilities are part of these material-discursive entanglements just like hazards and disasters themselves. In such a relational perspective, spatial–temporal and environmental dynamics, socio-spatial configurations, and material-discursive practices come into play.

Spatial mobility—which can come along with mental and social mobility (see Sect. 4.3)—is fundamental to the everyday life of all communities and how they organize themselves in time and space. Beside other aspects, economic practices are strongly related to spatial mobility and thus the socio-spatial configurations of communities. There is a great variety of social configurations. The respective regimes of mobility result in different vulnerabilities and resilience capabilities. They influence the positioning of subjects in the spatial and temporal extent of hazards and thus their exposure. Although these relationships need to be studied in specific case studies, some general points should be noted:

As a tendency, immobility seems to increase vulnerability in hazardous situations, as the time of exposure is basically at its maximum. Sedentary lifestyles bring along many aspects of immobility or limited spatial mobility: permanently installed settlements, their houses, and related infrastructure over fields and gardens as well as, for example, places of mineral resources in the landscape through to the spatially bound sense of belonging to a "place". Resilience strategies to reduce the vulnerabilities of such "immobilities" are adding measures of protection or manipulating the surroundings to reduce exposure, to remove the threatening aspect from them. Compared to camps or boats, moving permanent settlements out of the danger zone is not an option in most cases. However, if the architectural features of settlement as such cannot be saved, the inhabitants themselves can flee the hazardous situation, taking valuable movable belongings like animals, stocks, etc., with them. Accordingly, the most direct way to reduce or omit exposure and thus to be resilient as a community is spatial mobility. Translocal social ties in socio-spatial configurations might strengthen this resilience capability even in quite sedentary Neolithic communities (Heitz et al. 2021a, b; Heitz 2023b).

Communities with socio-spatial configurations that involve some degree of residential mobility appear to be resilient to many of the immediate threats of climate-related hazards. Are mobile foraging lifestyles more resilient to climate-related hazards than sedentary agricultural lifestyles? Some archaeological studies at least provide evidence of foraging communities' resilience to climate change (e.g. Blockely et al. 2018; Yamamoto and Seki 2022). However, the long-term consequences of changes in temperature and precipitation may have affected the spatial distribution and availability of food resources, which led to habitat change and the transformation or reorganization of cultural and economic practices, and socio-spatial configuration, including demographic change (e.g. Grimm 2020; Solich and Bradtmöller 2017).

As a general tendency, subsistence strategies, including agriculture, that are dependent on at least partial sedentism lead to a dependency on annual precipitation during the growing cycle. Their food security is vulnerable to cold spells, hail, heatwaves, droughts, floods, etc. The capability of stockpiling, however, increases resilience. Neolithic communities in, for example, Çatalhöyük (Turkey) developed resilience practices using the dynamics of flooding regimes of rivers, utilizing different agroecological niches, diversity in crops, and manuring (Ayala et al. 2022). For the Neolithic transition in the Northern U.S. South-West, it was suggested that a short but extreme cold period followed volcanic eruptions in 536 and 541 AD. This triggered, on the one hand, region-wide large-scale population movements beyond the limits of established networks and difficult conditions for agriculture for those few communities that stayed. On the other hand, favourable agricultural conditions followed, and the previous depopulation enabled a total socio-spatial economic reorganization of local communities that incorporated a shared way of life which in turn enabled farmers to finally spread across much of the landscape (Sinensky et al. 2022, 134–135).

Finally, a focus on climate-related hazards runs the risk of obscuring the positive outcomes of climate change. In addition, future research could bear in mind that vulnerability and resilience capabilities are not necessarily socially equally distributed. Capabilities to respond to climate-related hazards and disasters, as well as vulnerabilities in the first place, may be linked to socio-spatial differences, social inequalities, territoriality, power relations, and politics. Contemporary climate-induced migration also shows that mobility as a resilience strategy can lead to new vulnerabilities for those embarking on unknown journeys. Comparable scenarios and links between climate change, mobility, translocality, resilience, and vulnerability (Sterly et al. 2016) could also be explored more intensively in the future.

Acknowledgements I would like to thank Astrid Nyland and Daniela Hofmann for their helpful comments and advice, and the editors of this volume for their patience. This theoretical work is part of the Ambizione project no. 208840 "RISE—Climate Change Resilience and Vulnerabilities of Bronze Age Waterfront Communities (2200–800 BC)"; see https://data.snf.ch/grants/grant/208840, funded by the Swiss National Science Foundation.

References

Anselmetti FS, Schulte L, Stoffel M (2020) Paleofloods: changes in prehistoric flood occurrence. In: Ruiz-Villanueva V, Molnar P (eds) Past, current, and future changes in floods in Switzerland. Federal Office for the Environment (FOEN), Zurich, pp 11–21. https://doi.org/10.3929/ETHZ-B-000462768

Appadurai A (1996) Modernity at large: Cultural dimensions of globalization. Public Worlds, Minneapolis

Arponen VPJ, Müller J, Hofmann R et al (2016) Using the capability approach to conceptualise inequality in archaeology: The case of the late Neolithic Bosnian Site Okolište c. 5200–4600 bce. J Archaeol Method Theory 23:541–560. https://doi.org/10.1007/s10816-015-9252-0

Assmann J (2011) Cultural memory and early civilization: writing, remembrance, and political imagination. Cambridge University Press, Cambridge, New York

Ayala G, Bogaard A, Charles M et al (2022) Resilience and adaptation of agricultural practice in Neolithic Çatalhöyük, Turkey. World Archaeol 54:407–428. https://doi.org/10.1080/00438243.2022.2125058

Bell M, Ward G (2000) Comparing temporary mobility with permanent migration. Tourism Geopgraphies 2(1):97–107. https://doi.org/10.1080/146166800363466

Blockley S, Candy I, Matthews I et al (2018) The resilience of postglacial hunter-gatherers to abrupt climate change. Nat Ecol Evol 2:810–818. https://doi.org/10.1038/s41559-018-0508-4
Burke A, Peros MC, Wren CD et al (2021) The archaeology of climate change: The case for cultural diversity. PNAS 118:e2108537118. https://doi.org/10.1073/pnas.2108537118
Burmeister S (2013) Migration—Innovation—Kulturwandel: Aktuelle Problemfelder archäologischer Investigation. Mobilität und Wissenstransfer in diachroner und interdisziplinärer Perspektive. Topoi—Berlin Studies of the Ancient World, vol 9. De Gruyter, Berlin, Boston, pp 35–58
Christmann GB, Ibert O (2012) Vulnerability and resilience in a socio-spatial perspective: A social-scientific approach. Raumforsch Und Raumordn (Spat Res Plan) 70:259–272. https://doi.org/10.1007/s13147-012-0171-1
Compton C (2020) The temporality of disaster: Data, the emergency, and climate change. Anthropocenes—Human, Inhuman, Posthuman 1(1):1–14. https://doi.org/10.16997/ahip.24
Crespi A, Terzi S, Cocuccioni S et al (2020) Climate-related hazard indices for Europe. ETC-CCA Technical Paper 1/2020. https://doi.org/10.25424/CMCC/CLIMATE_RELATED_HAZARD_INDICES_EUROPE_2020. Accessed 12 Mon 2023
Cresswell T (2006) On the move: mobility in the modern Western world. Routledge, New York
Cutter SL, Finch C (2008) Temporal and spatial changes in social vulnerability to natural hazards. PNAS 105:2301–2306. https://doi.org/10.1073/pnas.0710375105
De Angeli S, Malamud BD, Rossi L et al (2022) A multi-hazard framework for spatial-temporal impact analysis. Int J Disaster Risk Reduct 73:102829. https://doi.org/10.1016/j.ijdrr.2022.102829
European Environment Agency (2021) Europe's changing climate hazards, EEA report. https://www.eea.europa.eu/publications/europes-changing-climate-hazards-1. Accessed 19 Jul 2023
Faist T (2013) The mobility turn: A new paradigm for the social sciences? Ethn Racial Stud 11:1637–1646. https://doi.org/10.1080/01419870.2013.812229
Frello B (2008) Towards a discursive analytics of movement: On the making and unmaking of movement as an object of knowledge. Mobilities 3(1):25–50
Riede F, Sheets PD (eds) (2020) Going forward by looking back: archaeological perspectives on socio-ecological crisis, response, and collapse. Catastrophes in context. Berghahn, New York
Glick Schiller N, Salazar NB (2013) Regimes of mobility across the globe. J Ethn Migr Stud 39(2):1637–1646
Gregoricka LA (2021) Moving forward: A bioarchaeology of mobility and migration. J Archaeol Res 29:581–635. https://doi.org/10.1007/s10814-020-09155-9
Grimm S (2020) Resilience and reorganisation of social systems during the Weichselian Lateglacial in North-West Europe. An Evaluation of the archaeological, climatic, and environmental record. Monographien des RGZM, vol 128. Propylaeum, Heidelberg. https://doi.org/10.11588/propylaeum.735
Gunderson LH, Holling CS (eds) (2002) Panarchy: understanding transformations in human and natural systems. Island Press, Washington, D.C
Hannam K, Sheller M, Urry J (2006) Editorial: Mobilities, immobilities and moornings. Mobilities 1(1):1–22
Heitz C (2017) Making things, being mobile: pottery as intertwined histories of humans and materials. In: Heitz C, Stapfer R (eds) Mobility and pottery production: Archaeological and anthropological perspectives. Sidestone Press, Leiden, pp 255–289
Heitz C, Stapfer R (2017) Mobility and pottery production, what for? Introductory remarks. Mobility and pottery production. archaeological and anthropological perspectives. Sidestone Press, Leiden, pp 11–38
Heitz C, Stapfer R (2021) Itineraries of pottery. A mixed methods approach to mobility. In: Gibson CD, Cleary K, Frieman CJ (eds) Making journeys. Archaeologies of mobility. Oxbow Books, Oxford, pp 107–119
Heitz C, Hinz M, Laabs J et al (2021a) Mobility as resilience capacity in northern Alpine Neolithic settlement communities. ARC, Archaeol Rev Camb 36(1) (Resil & Archaeol):75–106

Heitz C, Laabs J, Hinz M et al (2021b) Collapse and Resilience in Prehistoric Archaeology: Questioning Concepts and Causalities in Models of climate-induced Societal Transformations. In: Erdkamp P, Manning J, Verboven K (eds) Climate change and ancient societies in Europe and the Near East. diversity in collapse and resilience, Palgrave Studies in Ancient Economies. McMillan, Basingstoke, pp 127–199
Heitz C (2021) On theorizing vulnerability for archaeology. TRAVAS: Theor Resil Vulnerability Anc Stud 1:1–10. https://doi.org/10.5281/ZENODO.5513463
Heitz C (2023a) Keramik jenseits von "Kulturen". Mobilität, Verflechtungen und Transformationen im nördlichen Alpenvorland (3950–3800 v.Chr.). Open Series in Prehistoric Archaeology (OSPA), vol 3. Sidestone Press, Leiden
Heitz C (2023b) From 'communities of practice' to 'translocal communities': a practice-theoretical approach to mobility and socio-spatial configurations of Neolithic groups. In: Heitz C, Wunderlich M, Hinz M et al (eds) Rethinking neolithic societies. New perspectives on social relations, Political organisation and cohabitation, Open Series in Prehistoric Archaeology (OSPA), vol XX. Sidestone Press, Leiden
Holling CS (1973) Resilience and stability of ecological systems. Annu Rev Ecol Syst 4:1–23
Ismail-Meyer K, Vach W, Rentzel P (2020) Do still waters run deep? Formation processes of natural and anthropogenic deposits in the Neolithic wetland site Zug-Riedmatt (Switzerland). Geoarchaeology 35:921–951. https://doi.org/10.1002/gea.21796
Ismail-Meyer K, Pümpin C, Rentzel P (2022) Paludal settings: Wetland geoarchaeology. In: Gilbert AS, Goldberg P, Mandel RD et al (eds) Encyclopedia of geoarchaeology, Encyclopedia of earth sciences series. Springer International Publishing, Cham, pp 1–24. https://doi.org/10.1007/978-3-030-44600-0_158-1
Keck M, Sakdapolrak P (2013) What is social resilience? Lessons learned and ways forward. Erdkunde 67:5–19. https://doi.org/10.3112/erdkunde.2013.01.02
Kelly RL (1992) Mobility/sedentism. concepts, archaeological measures and effects. Annu Rev Anthropol 21:43–66
Kelman I, Gaillard JC, Mercer J (2015) Climate change's role in disaster risk reduction's future: Beyond vulnerability and resilience. Int J Disaster Risk Sci 6:21–27. https://doi.org/10.1007/s13753-015-0038-5
Kislov AV, Krenke AN (2010) Climate-related hazards. In: Kotlyakov VM (ed) Natural disasters I, Encyclopedia of life support systems. EOLSS Publishers, Oxford, U.K., pp 1–19
Leary J (2014) Past mobility. An introduction. In: Leary J (ed) Past mobilities. Archaeological approaches to movement and mobility. Ashgate, Farnham, Burlington, pp 1–18
Massey DB (2005) For space. SAGE, London; Thousand Oaks, California
Meriläinen E, Koro M (2021) Data, disasters, and space-time entanglements. Int J Disaster Risk Sci 12:157–168. https://doi.org/10.1007/s13753-021-00333-x
Obrist B, Pfeiffer C, Henley R (2010) Multi-layered social resilience: a new approach in mitigation research. Prog Dev Stud 10:283–293. https://doi.org/10.1177/146499340901000402
Peters R, Zimmermann A (2017) Resilience and cyclicity towards a macrohistory of the Central European Neolithic. Quatern Int 446:43–53
Pfister C, Wanner H (2021) Climate and society in Europe the last thousand years. Haupt Verlag, Bern
Redman CL (2005) Resilience theory in archaeology. Am Anthropol 107:70–77
Salazar NB (2013) Mobility. Theory in social and cultural anthropology. In: MacGee RJ, Warms RL (eds) Theory in social and cultural anthropology. Sage, Thousand Oaks, pp 552–553
Salazar NB (2016) Keywords of mobility. What's in a name? In: Salazar NB, Jayaram K (eds) Keywords of mobility: Critical engagements, Worlds in motion. Berghahn, New York, pp 1–12
Salazar NB, Smart A (2011) Anthropological takes on (im)mobility. Introduction. Identities: Glob Stud Cult Power 18(6):i–ix. https://doi.org/10.1080/1070289X.2012.683674
Schaller S, Böttcher ME, Buechi MW et al (2022) Postglacial evolution of Lake Constance: sedimentological and geochemical evidence from a deep-basin sediment core. Swiss J Geosci 115(1):7. https://doi.org/10.1186/s00015-022-00412-1

Scharl S (2017) Mobility in prehistoric sedentary societies—an introduction. In: Scharl S, Gehlen B (eds) Mobility in prehistoric sedentary societies: Papers of the CRC 806 workshop in Cologne 26–27 June 2015. VML Verlag Marie Leidorf GmbH, Rahden, Westf, Kölner Studien Zur Prähistorischen Archäologie, pp 9–18

Sheller M, Urry J (2006) The new mobilities paradigm. Environ Plan A: Econ Space 38:207–226

Sinensky RJ, Schachner G, Wilshusen RH et al (2022) Volcanic climate forcing, extreme cold and the Neolithic Transition in the northern US Southwest. Antiquity 96:123–141. https://doi.org/10.15184/aqy.2021.19

Solich M, Bradtmöller M (2017) Socioeconomic complexity and the resilience of hunter-gatherer societies. Quatern Int 446:109–127. https://doi.org/10.1016/j.quaint.2017.06.064

Sterly H, Sakdapolrak P, Ober K (2016) Migration for human security? The contribution of translocality to social resilience. Georgetown Journal of Asian Affairs 3:57–66

Wendrich W, Barnard H (2008) The archaeology of mobility. Definitions and research approaches. The archaeology of mobility. Old world and new world nomadism, Cotsen Advanced Seminar Series, vol 4. Cotsen Institute of Archaeology, University of California, Los Angeles, p 1–21

Wilhelm B, Rapuc W, Amann B et al (2022) Impact of warmer climate periods on flood hazard in the European Alps. Nat Geosci 15:118–123. https://doi.org/10.1038/s41561-021-00878-y

Williamson F, Courtney C (2018) Disasters fast and slow: The temporality of hazards in environmental history. Int Rev Environ Hist 4(2):5–11. https://doi.org/10.22459/IREH.04.02.2018.02

Yamamoto M, Seki O (2022) Impact of climate change on hunter-fisher-gatherer cultures in Northern Japan over the past 4,400 years. Geophys Res Lett 49(5):e2021GL096611. https://doi.org/10.1029/2021GL096611

Chapter 5
Fire Without Smoke? Ancient Hazards and the Allure of Disaster Narratives in Prehistoric Archaeology, with Reference to the Storegga Tsunami (8150 BP)

James Walker

Abstract Despite having lived for most of our history as hunter-gatherers, or some variant thereof, disaster research has overwhelmingly focussed on events from the recent human past. Consequently, research into prehistoric disasters remains a small but growing field of study. This paper explores some of the temptations and pitfalls of reductive assumptions when considering 'natural' disasters from prehistory with a lack of accompanying archaeological data, while also considering some of the advantages of having detailed palaeoenvironmental data pertaining to the event. Striving to avoid normative assumptions and environmental determinism, we may consider the multi-scalar processes that affected both prehistoric people and the archaeological record to which we bear witness. The Storegga palaeotsunami (c. 8150 BP) is reviewed in the light of these considerations. It is suggested that the taphonomic impact of the tsunami, combined with a potentially rapid, if not regionally variable rate of recovery, may explain why it has been difficult to clearly evince the impact (or disaster) relating to the tsunami archaeologically, despite the imposing nature of the phenomenon as inferred from extant palaeoenvironmental data.

Keywords Disaster · Storegga tsunami · Multi-scalar · Normative thinking · Taphonomy

> The real work to be done with respect to definitions of disaster has to do first with conceptualization; one needs to decide what disaster means.
>
> (Perry 2007, 15)

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_5

5.1 Introduction

Living with disasters and the hazards that lead to them has always been a part of the human experience (Quarantelli et al. 2007, 16; Chmutina and von Meding, Chap. 2). Instinctively, we look to lessons from the past to help understand how we may do better in the future, and living with natural hazards is no exception. In the natural sciences, there has been a surge of interest in past hazards and disasters in the wake of various recent encounters with these phenomena. For example, the 2004 Indian Ocean and 2011 Tōhoku tsunamis both spurred tsunami and palaeotsunami science research (Satake 2014; Engel et al. 2020). Archaeology has both contributed to and benefitted from this growth (Goff 2020, 75), with the human consequences of these phenomena among the driving interests (Goff 2023).

Understanding the environmental processes associated with hazardous natural phenomena such as tsunamis, hurricanes, earthquakes, landslides and volcanic eruptions is important for understanding their impact upon landscapes and ecologies (Urabe and Nakashizuka 2016), including humans. Consequently, interest in disasters (if not hazards) has grown across the social sciences (Perry 2018, 9), including archaeology, a field uniquely suited to questions of historical case studies, and particularly those that predate written records (Guidoboni and Ebel 2009, 419; Torrence and Grattan 2002). As this subject receives increasing attention from the archaeological community, it is perhaps pertinent to consider some of the potential pitfalls and traps that may arise from implicit and normative tendencies and attitudes in how we think about disasters and prehistoric hunter-gatherers. In addressing these often implicit tendencies, we should be critical of what may reliably be inferred archaeologically and what must instead be left to reasoned speculation.

5.2 Five Assumptions, Biases and Conceptual Challenges in the Study of Natural Hazards and Disasters in Prehistory

The issues examined below are considered with the intention of illustrating the intuitive ease with which appeals to hazards as causal agents of cultural change may be invoked, even when evidence of impact is not always discernible. Prehistorians are perhaps best suited to understanding disasters through their impact upon traditions of material culture over long time-periods (Torrence and Grattan 2002). They are less well disposed to understanding disasters that leave little detectable impact upon material culture. This makes reconciling evidence of extreme hazards with no obvious evidence of a disaster particularly challenging.

The understanding that disasters may result from extreme environmental phenomena or natural hazards aligns with what Ronald Perry has termed the 'hazards-disaster school' of disaster research, which is a holistic approach that has historically taken its cues from geography and geophysical sciences and sees disasters as 'an extreme event that arises when a hazard agent intersects with a human use system' (Perry 2018, 8). Much like the archaeology (or at least evolutionary archaeology) of prehistoric hunter-gatherers (Bettinger et al. 2015), this approach shares a strong overlap with the study of human ecology (Perry 2018).

As the only social science capable of engaging with the nature of this intersection within the context of deep prehistory, the onus rests largely upon archaeologists to infer disasters or other impacts relating to natural hazards predating the written record. This can, however, leave us reliant upon extrapolations of palaeoenvironmental or geological, rather than cultural, data (Nyland et al. 2021). The shortcomings of relying too heavily upon non-archaeological evidence to derive archaeological inferences are, however, highlighted by an alternative framework within disaster studies that has found favour more recently. This school of thought argues for the decoupling of hazards and disasters as concepts; it stresses that disasters exist purely within the domain of the social. Certainly, this must be true in a humanitarian sense, and as such, this does not necessarily contradict the hazards-disaster school, but does stress the importance of acknowledging that, as fundamentally social phenomena, disasters (however defined) must be understood as contingent upon human communities and the weaknesses and vulnerabilities of their social structures rather than purely in terms of an external causal agent (Quarantelli 2005, 345; Alagona 2006; Perry 2007; Riede 2019). To be clear, disasters must, for an archaeologist at least, be social phenomena, and yet at times the archaeology of disasters in prehistory sits somewhere uncomfortably between these schools. It is from this position that some of the normative ideas critiqued below arise.

5.2.1 A Natural Hazard Results in a Natural Disaster

The first assumption, as already touched upon above, explicitly questions the validity of the 'natural disaster' as a concept (Puttick et al. 2018). This term implies an extrasomatic impetus—an extreme force of nature—to which a human population is subject. The decoupling of hazards from disasters (sensu Quarantelli 2005) should allow a distinction between hazards of different origins without impinging upon our understanding of the disaster that may follow. The idea of a natural disaster implicitly risks the omission or downplaying of the societal, cultural and fundamentally human variable integral to understanding a disaster as a social construct (see Chmutina and von Meding 2019; Chap. 2; Alagona 2006 for discussion). It may implicitly distract or detract from the recognition that it is the failure of a community to cope in a given scenario (in this case with a 'natural' hazard) that leads to a disaster. Indeed, disasters may happen without requiring an obvious hazard or indeed any external cause (Quarantelli 2005, 342).

This issue takes on a new complexion when used in the context of disasters among (particularly prehistoric) hunter-gatherer societies, who have perhaps at times been thought of as somehow more 'natural', in harmony with their environment or as an evolutionary baseline, perhaps as an extension of their apparent simplicity or perceived primitiveness (see, e.g. Sahlins 1972; Kaplan 2000; Kuper 2005; Bettinger et al. 2015 for a discussion). However, the assertion that this may equate to greater 'naturality' without further clarification or qualification is potentially problematic for various reasons, and few anthropologists or prehistorians would be satisfied with the idea that such a state could adequately explain vulnerability or resilience, much less be comfortable with the extended implication of such a Hobbesian or Rousseauian caricature. Thus, the diminishment of the human as (even unintentionally) implied by the invocation of a 'natural' disaster is something worthy of particular caution in the context of hunter-gatherers.

When the 2004 Indian Ocean tsunami hit, it was widely assumed that the tribal communities of Andaman Islanders, who lacked access to any modern warning system, may have been devastated. Yet, seemingly thanks to oral histories, folklore stories, and recognition of signs provided by receding waters, disturbed marine life and agitated sea-birds, these communities had sufficient warning to retreat inland to higher ground and generally avoided higher casualty rates than they otherwise may have (Quarantelli et al. 2007, 30; Kumar and Haider 2007), reminding us that, in this case, while the hazard could reasonably be argued as natural, the avoidance of a disaster, thanks to particular cultural traditions of knowledge, absolutely was not.

5.2.2 The Scale of the Hazard Predicts the Potential for a Disaster

At the end of his book *Climate Change in Prehistory: The End of the Reign of Chaos*, William Burroughs (2005) raises the question of natural disasters of sufficient scale to cause an existential threat to our species and, more specifically, the potential future eruption of the Yellowstone caldera, with reference to previous supervolcano eruptions, such as Mt Toba, around 74 kya. Evidence of the Mt Toba eruption is well attested by widespread tuff deposits that provide a useful stratigraphic dating reference (Williams 2012). The impact it had on ancient populations, however, has been the subject of considerable debate (e.g. Ambrose 1998; Haslam et al. 2010; Smith et al. 2018; Clarkson et al. 2020; Kappelman et al. 2024). Burroughs (2005, 302) notes that if we cannot reliably predict or realistically prepare for or mitigate such an event, 'we might as well stop worrying'. This worst-case scenario exemplifies the notion that a big enough hazard increases the chances (if not also severity) of a disaster.

Hazards of an abnormally large scale, or quick speed, are particularly difficult to prepare for because they exceed anticipation. This is why we fear the so-called 'Big Ones' (Goff 2023, 8; Jones 2018) and why the trope of terrifying freak natural events forms the premise for many films within the disaster movie genre. A group of people living on the coast may learn to live with the hazards of unexpectedly high tides, storm surges and even tsunamis, but an event of relatively unprecedented scale or speed—one that is difficult to prepare for or anticipate—may carry greater risk.

However, as outlined in the case above with those Andaman islanders who survived the 2004 Indian Ocean tsunami (Kumar and Haider 2007), different ways of living and traditions of knowledge may afford different outcomes (see also, e.g. Truedinger et al. 2023; Davies 2002).

A hazard of exceptional scale might effectively make it difficult to avoid its impact, but definitionally such cases are rare, and the relative vulnerability of a human population remains a key variable. A classic example of this within tsunami research is the Lituya Bay tsunami of 1958 in Alaska. Despite being the largest tsunami recorded in modern times (with a run-up of 524 m), only five deaths were reported (Coffman et al. 1982, 108). One could easily imagine that a different coastline setting—or more pertinently, a more densely settled area—may have resulted in a much different outcome. On this basis, not only does a disaster require humans, but for even an exceptionally large force of nature, there must still be the potential for intersection with a human system for it to constitute a hazard (Tobin and Montz 1997, 5). This scenario has been suggested as a possibility for Mesolithic people living in northern Norway (Varangerfjord) at the time of the Storegga tsunami, one late autumn day around 8150 years ago—they may simply have not been present on the affected coastlines at the time the tsunami struck (Blankholm 2020).

Tsunami researchers engaged with questions of scale have come to appreciate that the relationship between scale of magnitude and scale of impact is neither simple nor straightforward (Papadopoulos et al. 2020), and run-up height can vary significantly depending on coastal geomorphology (e.g. Yeh et al. 2015, Fig. 11b). Scales of damage and destruction from tsunamis have been conceived (Papadopoulos and Imamura 2001), but these are generalised in outlook, or rather, they are not geared specifically towards hunter-gatherer societies in terms of how impact is gauged.

Intuitively, we may think that given sufficient scale, speed or surprise, even the most prepared societies may be reduced to the whim and mercy of natural forces. To think otherwise, may risk inviting complacency and hubris (Murayama and Burton 2015), but while there may be small solace in thinking of these phenomena as great levellers, we know from recent examples that such thinking belies underlying differences in socio-economic standing (Elliot and Pais 2006), something that has long been observed in social anthropology. In cases where this is true, we might imagine small-scale societies to be more vulnerable to existential threat. Certainly, low population density hunter-gatherer groups may require time to recover in the wake of depopulation and, in prehistory, may have lacked access to externally supplied aid.

5.2.3 Reaching a Satisfactory Definition of a Disaster

In their volume detailing the discipline of historical seismology, Guidoboni and Ebel (2009, 419) note the difficulties and advantages of integrating disciplinary approaches of overlapping timeframes—instrumental seismology, history, archaeology and palaeoseismology. As mentioned earlier, however, archaeology is unique among the social sciences in accompanying palaeoseismology into the realm of deeper prehistory. In some respects, this means that archaeology can address questions of longer-term changes to lifeways that are less easy or appealing to address in recent history (Torrence and Grattan 2002). Yet understanding recent events is also vital if archaeologists are to understand the kinds of influence that such phenomena may have had upon cultural development in the past (Davies 2002, 28).

The problem for prehistorians, however, lies in the difficulty of providing a definition of what constitutes a disaster that satisfies both etic and emic considerations of the term, without contemporary or historical accounts of the event to serve as a cultural referent. In some cases, it may not be possible to go beyond what we may deem reasonable supposition when it comes to understanding the cultural lens through which particular events of the past were perceived or experienced, and this extends to concepts such as disasters. Much ink has been spilt in attempting to provide satisfactory definitions of disasters and their different types, as well as the different ways in which they are (or are not) understood (Perry and Quarantelli 2005; Quarantelli 2005; Furedi 2007; Aronsson-Storrier and Dahlberg 2022). It is not my intention to settle upon one here, but rather to acknowledge, as the epigraph to this chapter highlights, that this term requires qualification and context.

Cultural ecology offers one approach for assessing impact, but inferring culturally specific frameworks of meaning remains a challenge. We may never truly know (at least not with certainty) how particular communities made sense of these phenomena given the limited data at our disposal. Without being privy to cultural informants or sources of reference, we may only reason as to what *we* perceive would constitute a disaster. In addition to the long-disputed question of 'what is a disaster?', we may also consider 'to (or for) whom, is a disaster?' The eruption of Mt Vesuvius upon the ancient Roman city of Pompeii in AD 79 is perhaps the most iconic disaster caught within the European archaeological record. Yet even the extent to which this was a disaster for the broader region—or the Roman empire more generally—has been questioned (Allison 2002; Grattan 2006).

The issue of clarifying what would have constituted a disaster and understanding the ways in which hazards present themselves to hunter-gatherer societies ties directly to our understanding of cultural meaning and socio-economic structures, particularly in the context of material loss or disadvantage—hence the conjecture that social inequality may 'render agrarian peasants more susceptible to natural catastrophes than any winter camp of Alaskan Eskimo' (Sahlins 1972, 38). The intersection of the hazard and the human system requires careful consideration not just of the hazard, but also the social structure and cultural particulars of the society.

5.2.4 The Projection of Our Own Concerns onto Our Reading of the Past

Following on from the struggle of knowing culturally specific meanings, we may also consider the difficulties of seeing the past without the influence of our own concerns. The archaeology of the Mesolithic in Britain (and elsewhere), for example, has changed since the turn of the millennium as an increased breadth and resolution of data and shifting theoretical developments have allowed for new ideas to grow. Some of what were typically more functionalist research traditions have given way to different perspectives (Young 2000; Spikins 2000; Conneller 2003; 2004; Moore 2003; Milner and Woodman 2005). While this new direction has seen a conscious effort to think of Mesolithic hunter-gatherers as more than just products of their environment and economy, the improved resolution with which we are able to reconstruct palaeoenvironments has remained a huge interpretive asset (Taylor 2018).

For example, our understanding of the submerged palaeolandscape of the southern North Sea, Doggerland, has grown tremendously since the 1990s (Coles 1998; Fitch et al. 2007; Gaffney and Fitch 2022). In a world that is increasingly aware of rising sea-levels, Doggerland, a landscape conspicuous by its current absence, has caught the public imagination (e.g. Gaffney et al. 2009; Leary 2015; Blackburn 2019; Amkreutz and van der Vaartschoof 2022). Some research, justifiably, has been explicitly driven by a desire to know how people dealt with this issue (e.g. Leary 2009; 2011; De Roest 2013; see also Conneller et al. 2016). However, as Caroline Wickham-Jones (2021) has pointed out, we must be cautious regarding the agendas we carry within the narratives we tell. It is one thing to want to know how people dealt with a landscape transformed by sea-level change, but it is also important to be aware of overtly doom-and-disaster-laden interpretations, which are coloured by our own biases and perceptions rather than an actual understanding of people's views in the past (Wickham-Jones 2021). The language we use to describe these events cannot reasonably be expected to be neutral, but we should be particularly cognisant of the (often implicit) reasoning for why we frame the past in the ways we do. Equally, we must be cautious regarding the assumptions we make of disasters in the past if they are implicitly or overly informed by modern anxieties and simplistic analogies (Torrence and Grattan 2002, 4).

This point is particularly noteworthy in the context of studying past hazards and disasters, as not only do we struggle to see them through the cultural lens of prehistoric hunter-gatherers, but, as outlined in the opening of the chapter, the desire to understand them is partly driven by a desire to better understand these phenomena in the light of future potential scenarios. This is a valid motivation, but one that we should be critically aware of, particularly in the light of the different kinds of questions and biases we may face in tackling the deep prehistoric archaeological record, rather than more recent or contemporary phenomena (Torrence and Grattan 2002).

5.2.5 Attributing Causality

One of the reasons for decoupling hazards and disasters while stressing the latter as a social phenomenon is that, in tracing the origin of a disaster, identifying a hazard is not always possible and perhaps in some cases is not even necessary (Quarantelli et al. 2005, 342). If a strength of archaeology is the ability to assess disasters as

Fig. 5.1 Threat of disaster scenario in the wake of a natural hazard, where the Y axis represents the moment at which the hazard intersects with a human system. Threat does not necessarily diminish as time progresses, but the directness with which it may be related to the natural hazard may lessen

causes of cultural change, then establishing a synchronic pattern by which culture change may be related to a natural hazard is both important and, potentially, quite challenging (Torrence and Grattan 2002, 7). Not all hazards, or indeed disasters, are necessarily liable to affect cultural change, and because disasters may arise as a result of multiple convergent factors (e.g. Jørgensen and Riede 2019) even when triggered by an external hazard, characterising cultural change as a result or consequence of a disaster may risk oversimplifying the process(es) behind the pattern. Monocausality may be appropriate in some cases, but a more complex elaboration of events may be necessary in others, particularly if a disaster emerges as a result of the effects of delayed destabilisation rather than the immediate hazard aftermath (Fig. 5.1).

These challenges become even more difficult when attempted further back in prehistory, as attainable resolution of dating decreases and the likelihood of taphonomic impact increases. The long-term perspectives of prehistoric hunter-gatherer archaeology rooted in the functionalist tradition have long been noted as tending towards views of hunter-gatherers as living largely in a state homeostasis throughout much of prehistory (Bettinger et al. 2015). However, this is also partly a result of the sometimes poor spatiotemporal resolution of the data at our disposal, which leaves it unclear whether people were living through periods of stability or whether we are simply unable to nuance these stretches appropriately with the limitations of the available data. This is perhaps why an archaeology of disasters has arguably been more achievable in the more recent past. For archaeologists of prehistory, periods of change or other examples of behavioural variability (e.g. Ruebens 2014) are, understandably, alluring as they allow us to punctuate large spans of time and space with a dynamism and nuance that may otherwise be difficult to tease out. These factors perhaps also help explain the appeal of invoking disaster scenarios from natural hazards in prehistory, as they offer potential points of inflection for societal or cultural change. Appealing to environmental determinism as an explanatory framework seems excusable if we rationalise that an event too extreme to resist acted as some sort of environmental forcing mechanism.

5.3 Normative Thinking and the Allure of the Disaster

There are many areas of overlap in the five issues outlined above, but if there is a common theme that unites them, it is a tendency to relegate the socio-cultural, usually in deference to the environmental. It makes sense that as environmental forces we understand natural hazards through predominantly environmental data. However, disasters effecting cultural change may have occurred in the past without having been stimulated by natural hazards, and equally, disasters caused by natural hazards may not always have resulted in archaeologically observable cultural change. The question of what would have constituted a disaster (and the nature of the impacts a hazard may have had) is clearly an important issue for consideration. It is not enough to assume disasters from environmental data alone, although strategies for living with hazards are an alternative viable prospect for consideration.

Disasters—and indeed, non-disastrous hazards—may affect different groups disproportionately according to existing structural differences within a society (Hartman and Squires 2006). Even a 'simple', relatively egalitarian hunter-gatherer society with comparatively little social stratification does not necessarily avoid differential impacts (or survivability) in a disaster scenario. Natural hazards may expose existing divides within a society, but they may also exaggerate or create new ones. Environmental determinism may seem appealing in the context of a discrete, detectable environmental event of cultural forcing potential, but is rarely a wholly satisfying explanatory framework in isolation (Arponen et al. 2019; Bettinger et al. 2015). Despite this caution, an improved resolution and understanding of palaeoenvironmental data are nevertheless among the most useful means by which we can understand hazardous events from the past.

5.4 Natural Hazards as Agents of Change in Ecosystems and in Archaeological Formation Processes

Having so far focussed on the dangers of conflating hazards with disasters, and overlooking the human element, it is pertinent to reflect upon the utility that archaeologists may gain from accurately characterising the environmental processes entailed by a natural hazard, specifically with regards to understanding ecological impacts and taphonomy.

5.4.1 Recreating the Impacts of a Hazard upon Landscapes and Ecosystems

When natural hazards strike, the crucial impact is often perceived to be the immediate one, which may pose the risk of significant or even unsustainable loss of life, and an outcome we may feel more confidently (although not necessarily correctly) able to characterise as a disaster, for a family, community or population. It is also important to consider, however, an inability to cope with the more extended impacts or ensuant consequences of a natural hazard (Fig. 5.1). Disaster may unfold in the extended wake of an event such as a tsunami, in addition to the immediate risk posed by such a hazard, and this is perhaps simultaneously both more likely to resolve archaeologically, but also more difficult to unequivocally state as monocausal. These phenomena may have lasting impacts upon ecologies and landscapes with the potential to cause severe disruption to human populations that, having survived the initial threat of mortality, set about seeking to recover in the aftermath. Path-dependent rigidity traps (or alternatively, the suitability of an emergent strategy) are of critical importance in such a scenario. The range of viable options to a community and their ability to recognise the need to make change can make the difference in avoiding a disaster beyond the immediate aftermath of a hazard. Equally, significant deviation from pre-hazard lifeways, successful or otherwise, may manifest in noticeable changes to the material record.

Several recent disasters (ecological and humanitarian) have facilitated new research in both these areas, with ecologists investigating how different ecosystems are affected and how long they take to return (assuming they will) to a pre-hazard state (Urabe and Nakashizuka 2016). Human intervention, of course, can have a significant impact on this. Aceh Province, Indonesia, was one of the areas worst affected by the 2004 Indian Ocean tsunami, with devastated settlement infrastructure and approximately 1,642 dead (Doocy et al. 2007). Some aspects of the ecological damage sustained were yet to have fully recovered even as late as 2019 (Affan et al. 2019)—notably the mangrove forest, which had been the subject of a failed initiative to stimulate restoration (UNEP 2007), but people returned to living in devastated areas within a year of the tsunami (Fig. 5.2; Radio New Zealand 2019), albeit not necessarily entirely of their own volition.

The knock-on effect of changes to the landscape and ecology upon humans (and their post-event efforts at clearance and recovery or return) is an important consideration for social scientists. Various studies have highlighted how inflexibility or the unanticipated consequences of post-disaster recovery strategies may prolong, exacerbate or create new challenges for a community (e.g. Maschner and Jordan 2008; Inglin 2012). The extent to which these kinds of problems would have affected past societies—and particularly prehistoric hunter-gatherers—is worthy of consideration (e.g. Losey 2005; McFadgen 2007; Riede 2019). Such enquiry is only possible, however, with a good characterisation of the hazard phenomenon, its impact upon the environment and how people lived within that environment.

Fig. 5.2 Aceh, Sumatra, Indonesia (taken 4 Jan 2005). Photograph by Photographer's Mate 2nd Class J.J. Kirk. Available on Wikicommons, US Navy 050,104-N-9293 K-499

5.4.2 The Effects of Hazards upon Archaeological Formation Processes

An understanding of the environmental processes involved in hazardous phenomena may also allow for consideration of their role as taphonomic processes. Michael Schiffer (1987) mentions earthquakes and floods as potential non-cultural transformations in his treatise on archaeological formation processes, to which we may add volcanic eruptions, landslides, tsunamis and other extreme environmental phenomena. They may affect the extant archaeological record, as well as contemporary people, ecosystems and landscapes. Consequently, in Diane Gifford's (1981) schema for element transformation in taphonomy, a hazard may have the potential to affect nearly every stage and require consideration in each area of accompanying relevant theory (Fig. 5.3), ironically illustrating that the notion of a 'Pompeii premise' in archaeology is indeed a misconception (Schiffer 1985). The nature of these transforms may be generalised according to the type of hazard and landscape, but the specifics vary from case to case. As seen in Fig. 5.3, a natural hazard such as a tsunami may simultaneously (and varyingly) affect different contexts and transform stages from C1 to C4 and, by extension, may influence stages T4 to C6. Similarly, this is highlighted in Fig. 5.4, where the hazard 'event' is capable of affecting all the other domains, both directly and indirectly. The nature and extent of the impact upon

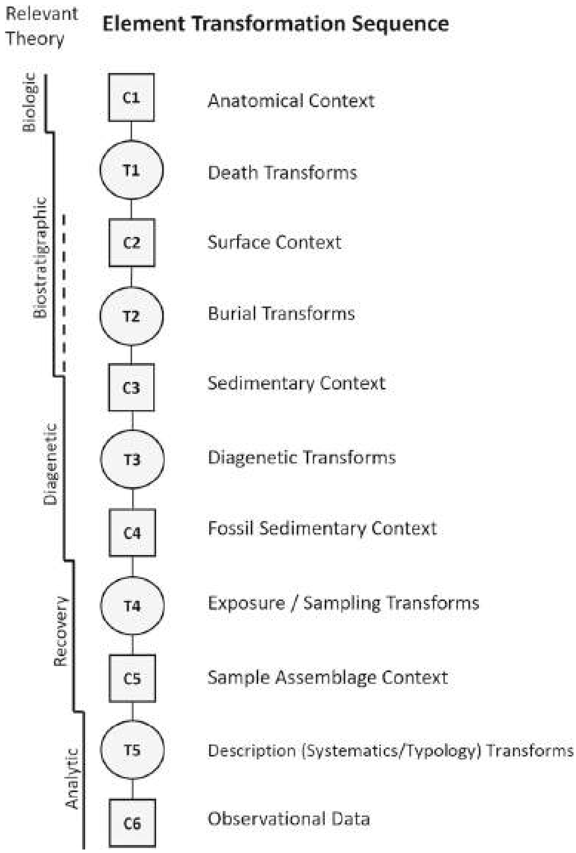

Fig. 5.3 Schematic representation of the states through which a fossil element passes and the processes that transfer it, after Gifford 1981. Although designed with anatomical elements in mind, the same taphonomic sequence is largely applicable to the formation and transformation of the archaeological record more broadly

human groups are what influences whether or not we perceive the event to have been disastrous.

In the case of tsunamis, damage may be widespread across affected stretches of coastline, but run-up deposits are only liable to form in sediment traps (Dawson et al. 2020). As erosive phenomena, they are more likely to disrupt, remove or destroy exposed archaeological deposits or aspects of hunter-gatherer cultural material yet to form within the archaeological record. While a particularly large tsunami may leave a wide-reaching geological signature, direct evidence of the moment at which the tsunami intersected with human populations is likely to be less commonly encountered within archaeological sequences. Even if an archaeological sequence was found to be interrupted by a tsunami deposit of a contemporary date, it may remain difficult to reliably infer if there were people there at the time of the tsunami or 2 hours, 2 weeks, 2 months or 10 years earlier, short of a scenario akin to the rare example at the Bweni Escarpment, Pangani Bay, in Tanzania, where fatalities appear to be represented by the presence of human remains found along with debris within a tsunami deposit (Maselli et al. 2020).

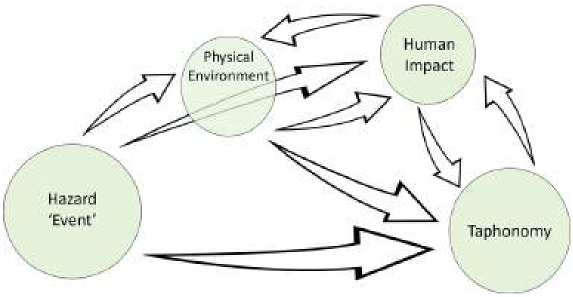

Fig. 5.4 Schematic showing the dynamic interplay between a natural hazard event, the physical environment, human impact and taphonomy. Note the taphonomic feedback into human impact refers primarily to what may be perceived archaeologically, rather than the actual impact of the event upon a human population

While archaeological sites may be useful for evidencing a hazard (e.g. Goff et al. 2012), they are perhaps less useful, particularly in isolation or low numbers, for providing insight into more widespread cultural or population impacts. The exception to this would be rare sites or regions where occupation appears to have spanned the event, and from which changes in cultural practices or local ecologies (e.g. where adjustments in site organisation, location, or subsistence practices) may be assessed (Goff et al. 2012). The potentially destructive nature of tsunamis and other extreme waves, however, combined with the already low resolution of (particularly more ancient) prehistoric datasets may mean that even for a phenomenon that tracks widely across a landscape, finding archaeological sites that highlight the moment at which the hazard and a human use system intersect is a challenging prospect, and one that, while informative, is perhaps not always able to answer questions of broader or long-term impact (Torrence and Grattan 2002). To add to this, with the question of what a disaster might look like archaeologically, few would argue with either the 2004 Indian Ocean tsunami or Hurricane Katrina in 2005 being regarded as disasters, but we may ponder to what extent these would be archaeologically visible in the distant future.

The ecological and taphonomic consequences of natural hazards influence what we might see archaeologically. Equally, both the nature of the hazard and the organisation of the society experiencing it are important considerations for attempting to understand impact (Kohler 2011, 223). With this in mind, it is pertinent to review what we know regarding the Storegga tsunami, long assumed to have been a disaster for Mesolithic hunter-gatherers living along the early Holocene coasts of the Norwegian and North Seas (see Nyland et al. 2021).

5.5 The Storegga Tsunami

Around 8150 years ago, during the Mesolithic period, the coastlines of western Norway, northeast Britain, Doggerland and further afield (Nyland et al. 2021; Wagner et al. 2007) were struck by a large tsunami triggered by a huge submarine landslide (the Storegga Slide) off the western Norwegian continental shelf. The widespread reach and high run-up (25 m or higher in places) attained by these waves have made it one of the most widely attested palaeotsunamis (Costa et al. 2021), yet to date there is little in the way of archaeological evidence to indicate the impact it had upon Mesolithic people. Consequently, our data paint a verisimilar impression of a disaster, without actually providing more robust evidence of how people were actually affected (Fig. 5.5).

Recognition of the Storegga Slide and realisation of its tsunamigenic potential precipitated the discovery of sedimentary facies relating to the tsunami. It also prompted re-evaluation of existing transgression deposits, which had previously been interpreted as relating to storm surges (Long et al. 1989) or in Norway, the early-mid Holocene 'Tapes' marine transgression (Bondevik et al. 1998), including some known from Mesolithic archaeological sites (Dawson et al. 1990; Bondevik 2003). As recognition of the tsunami and its scale grew, awareness of it permeated into the broader recognition of the archaeological community (Warren 1995; Smith and Wickham Jones 2002). The scale of the tsunami led many to assume that it must have resulted in a disaster (e.g. Edwards 2004; Bjerck 2008), yet whereas geologists had successfully re-evaluated deposits in the light of this phenomena, archaeologists have struggled to evince a disaster from a period that does not, at least in north-eastern Britain and western Norway, appear to coincide with any marked departures in traditions of material culture (Waddington and Wicks 2017; Nyland et al. 2021; see also Conneller 2022). However, it should be noted that recent research has begun to nuance a more regionally focussed resolution in western Norway (Nyland and Damlien 2024; Damlien et al. 2024; Walker et al. 2024).

The Mesolithic hunter-fisher-gatherers of western Norway are known to have been a maritime-oriented culture that would have spent much of (if not nearly all) their time in close proximity to the coast (Bergsvik 2001). Consequently, the Storegga tsunami almost certainly posed a significant hazard to habitation areas, coastally bound infrastructure and equipment (e.g. boats and tools), as well as coastal ecosystems and associated resource bases, if not also Mesolithic people. Similarly, coastal inhabitants in northern Britain and from around the coastlines of the southern North Sea may also have been left in a vulnerable position (Sharrocks and Hill 2024). We may reasonably posit then, that the Storegga tsunami would have constituted a major hazard to various Mesolithic peoples around the North and Norwegian seas. The potential for disaster posed to at least some people, in some places, would seemingly have been high, which makes the relative lack of evidence relating to human impact all the more curious. More recently, alternative approaches to data and new ways of thinking about the issues at hand have helped provide new insights and nuance to our understanding (Kilhavn, Chap. 12; Nyland, Chap. 7; Riede et al. Chap. 13; Damlien

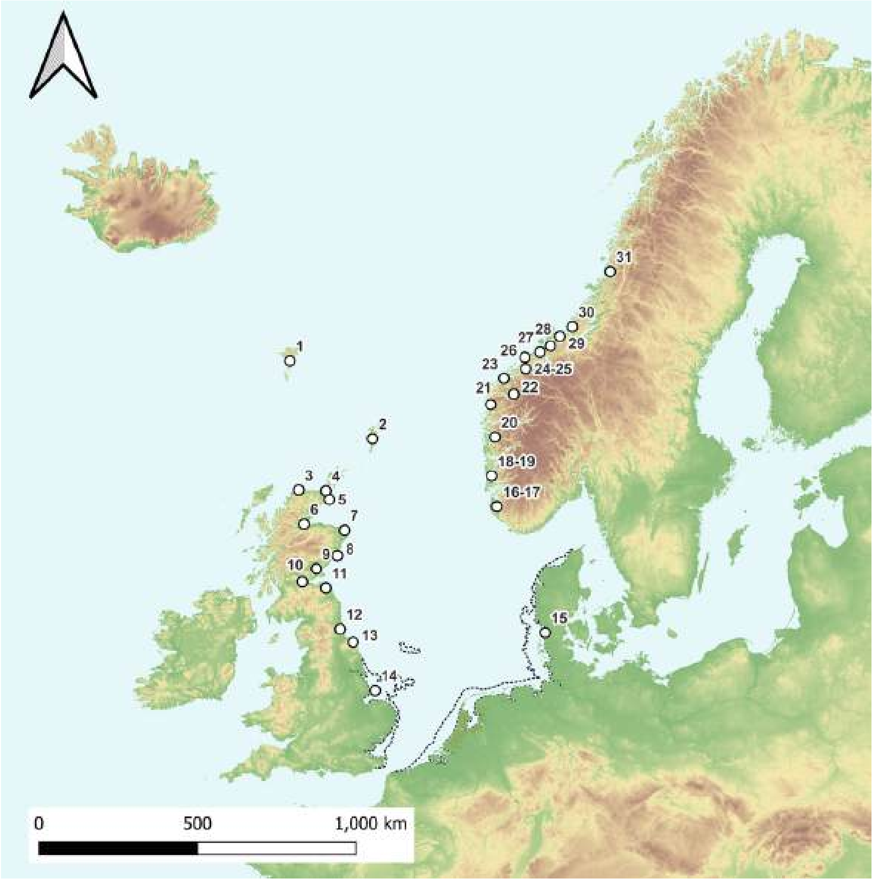

Fig. 5.5 Map showing a selection of geologically recorded instances of the Storegga tsunami from the northeast of the British Isles and western Norway. The dotted line denotes the approximate southern North Sea coastline at the time of the tsunami. Numbered Locations: 1. Suderøy, 2. Unst, 3. Loch Eriboll/Lochan Harvurn, 4. Sutherland/Caithness, 5. Dornoch Firth, 6. Inner Moray Firth, 7. North East Scotland, 8. Tayside, 9. Near St. Andrews (Silver Cross, Craigie), 10. Firth of Forth, 11. Near Dunbar (East Lothian), 12. Broomhouse Farm, 13. Howick, 14. ELF001A, 15. Rømø, 16–17. Hålandsvannet and Sola, 18–19. Løvegapet & Bømlo, 20. Austrheim, 21. Florø, 22. Nordfjord, 23. Bergsøy/Leinøy, 24–2.5. Longva &and Dysvikja, 26. Harøy, 27. Lok.30 Nyhamna, 28. Leira, 29. Litjvatnet, 30. Bjugn, 31. Hommelstø. Adapted from Nyland et al 2021, and redrawn by Micheál Butler

et al. 2024; Nyland and Damlien 2024; Walker et al. 2024; 2020; Sharrocks and Hill 2024; Mithen and Wicks 2021; Nyland et al. 2021; Blankholm 2020; Waddington and Wicks 2017).

Although evidence of the Storegga tsunami has been found at a small handful of Mesolithic sites (e.g. Bondevik 2003; Dawson et al. 1990), the erosive effect of tsunamis upon the landscape coupled with the specific geomorphological requirements needed for run-up deposit formation means that tsunamis are more likely to be agents of taphonomic disruption than conducive to archaeological site formation (e.g. Waddington and Wicks 2017). In some cases, there may be low potential for long-term preservation of tsunami deposits on land (Tyuleneva et al. 2018). For example, while Storegga deposits are well documented from terrestrial sequences in northern Britain, they are mostly known from subaquatic contexts in Norway due to the differing geomorphology of the affected coastlines (Bondevik 2022).

Run-up heights need not be excessively high before constituting a hazard, and yet heights lower than 5 m may often be insufficient to leave a lasting geological record (Lowe and de Lange 2000, 403). As in the case of the Storegga tsunami, for areas where palaeotsunami run-up fails to exceed the heights attained by subsequent transgression maxima, such deposits may have been buried (and potentially denuded) by subsequent palaeoshore formation (Fig. 5.6). This does not negate the possibility of locating palaeotsunami deposits beneath transgression horizons (e.g. Bondevik et al. 2019), but it highlights the complex sequence of taphonomically destructive phenomena facing archaeological deposits forming immediately prior to these events. In some cases, the wave may have disrupted stratigraphic integrity in an equivocal manner, without necessarily leaving a structured deposit (Nyland et al. 2021). Additionally, establishing evidence of the tsunami at an archaeological site is, itself, of potentially limited value for inferring broader social or cultural impact. To date, very few Mesolithic sites (currently just Castle Street in Scotland and Dysvikja in Norway, though this may of course change) have yielded cultural sequences confirmed as underlying a Storegga deposit, although it has recently been suggested that the tsunami may have transported and redeposited lithic materials at Guardbridge in Fife, Scotland (Ballin 2023).

Another big challenge in understanding the impact of the Storegga tsunami is the extent to which we might causally link any of these changes with the tsunami rather

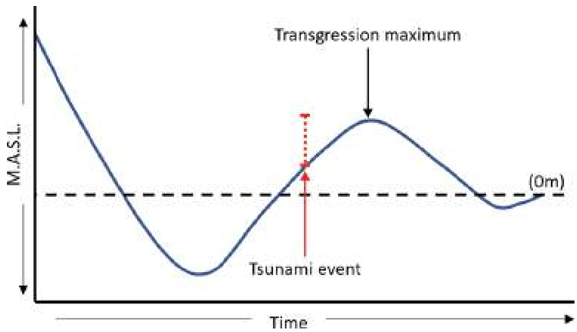

Fig. 5.6 Hypothetical sea-level curve showing that tsunami run-up that fails to exceed the sea-level attained during subsequent transgression maxima (indicated here by the red dotted line) will be temporarily submerged if not buried by subsequent beach formation, and potentially eroded by wave action. The same is also true for coastal (i.e. at risk of inundation) archaeological deposits located at elevations below the transgression maximum

than other environmental pressures or indeed with endogenic change. The Storegga tsunami struck during the chilliest years of the most pronounced climatic downturn of the Holocene, the 8.2 kiloyear event (Bondevik et al. 2012). In addition to colder temperatures overall, weather patterns across north Atlantic coastlines may have deteriorated, with an increased frequency of storminess (Wicks and Mithen 2014). This cooling episode was prompted by the release of glacially dammed waters from Lakes Agassiz and Ojibway into the North Atlantic, and this appears to have caused an accelerated period of sea-level rise in some areas just prior to 8200 BP (Hijma and Cohen 2019). In addition to contributing to broader environmental pressures, these factors may also have contributed to taphonomic loss and, in places, a rapidly changing coastline that left less time for extended periods of occupation (Bicket et al. 2017; Walker et al. 2020). In some cases, it has proven difficult to separate the environmental signatures (Bondevik et al. 2024; Earland et al. 2024), much less cultural impacts, of these phenomena.

Although there is little indication of broader cultural change associated with this time period in either Norway or the UK (Waddington and Wicks 2017; Nyland et al. 2021), it is possible that any impact (and even disaster) was experienced without archaeologically visible cultural change as a result, or perhaps at least through more subtle, derived, regionally varied changes (Nyland and Damlien 2024; Damlien et al. 2024). It has been suggested that the successive impacts of the 8.2 event and Storegga tsunami, among other pressures, resulted in a demographic dip in northern Britain (Wicks and Mithen 2014; Waddington and Wicks 2017; Mithen and Wicks 2021) in a scenario akin to punctuated entropy (see Dyer 2002; Wicks and Mithen 2014). Issues regarding chronological precision in these models (the drops begin slightly prior to the tsunami) may speak to the different tempos and pacing of other contributing causes (Waddington and Wicks 2017; Mithen and Wicks 2021), as well as the potential of associated taphonomic loss. Although it is difficult to infer the extent to which the tsunami contributed to such a scenario, it does stand out as an event with potential for associated mortality along some coastlines (Mithen and Wicks 2021). A similar approach is currently being developed for addressing the question in western Norway (see also Lundström et al. 2024; Lundström 2023), but the later and (notably) smaller Garth Voe tsunami, at least, appears not have severely affected Neolithic demography in this region (Nielsen 2020).

Regarding the lack of change seen in the material culture record in some areas, it has been argued that this represents a failure to adapt (Waddington and Wicks 2017), but it could also reflect continued ways of living, particularly if specialist subsets of cultural and technological knowledge survived (McFadgen 2007, 231). Temporary (and sometimes permanent) abandonment of settlement locations in the wake of tsunami events is well documented among tribal and some non-tribal societies (Davies 2002; Kumar and Haider 2007; Goff and McFadgen 2003; Fitzhugh 2012; Goff and Nunn 2016; Barnes 2017), which suggests that changes in settlement patterns and ecosystem destabilisation could be avenues of future investigation worth exploring to understand the impact of the tsunami.

Such a scenario has been suggested as reflected by a change in the settlement system in northern Britain between 8200 and 7000 BP indicative of increased mobility and linked to a putative population drop (Mithen and Wicks 2021). The invocation of substantial Mesolithic structures (or rather the lack thereof) during the period in question perhaps complicates more than it elucidates, as the number of archaeological sites with evidence of these in northern Britain remains small, and such sites were nearly unheard of until 20 years ago. However, if they do speak to a change in settlement patterns, then this may reflect a change in living, possibly in response to destabilised ecosystems (Mithen and Wicks 2021). Alternatively, a recent study of the Mesolithic in western Norway has suggested that mobility may have been facilitated by abundant and predictable resources, at least for Mesolithic hunter-fisher-gatherers in this particular area (Åstveit and Tøssebro 2023).

5.6 Concluding Remarks

Archaeology is nothing if not fraught with the possibility of what we might not be able to see. The Storegga tsunami appears to have been a major hazard to coastal Mesolithic communities, yet reliably parsing its impact from the archaeological record has proven difficult. As with archaeological attempts to assess prehistoric disasters elsewhere, it behoves us to be mindful of what a disaster might look like archaeologically, if not also what it might have looked like for Mesolithic people. This is particularly important in cases such as the Storegga tsunami, where much of our understanding relates to the natural hazard and its physical impact as understood through palaeoenvironmental data, rather than its social or cultural impact as understood through archaeological data. Environmentally attested hazards present inviting lures upon which to frame socially or culturally tumultuous narratives, but plenty of hazards pass by without resulting in these scenarios. If the scale of an event such as the Storegga tsunami makes the likelihood of its impact seem all that much greater, then it should push us further to understand why the archaeological record has been so unforthcoming as to what actually happened. We are, perhaps, pulled to such ways of thinking because, as James Goff notes on the first page of his book about palaeotsunami research, 'the only reason we really care about tsunamis is because they catch us by surprise, destroy our coastal communities, and kill us' (Goff 2023, 1). However, because environmental data are also a key asset to reconstructing hazardous phenomena such as palaeotsunamis, we are provided a means with which to discuss a point of departure, through being able to characterise the hazard and how it unfolded. In the case of the Storegga tsunami, two thoughts, based on what we know already, may go some way towards helping explain why we have struggled to find direct or compelling evidence of the tsunami's impact so far.

First, taphonomic loss, caused by the wave itself (but also by other factors such as erosion or submergence as a result of subsequent marine transgression), might have reduced the archaeological visibility of the moment of impact, if not also the years immediately prior to the tsunami, or even afterwards in the event of subsequent freak storms or marine transgressions. This may have had the effect of archaeologically erasing the moment when the hazard intersected with Mesolithic groups—when people may have lost their lives, loved ones, homes, tools or equipment—in many areas.

Second, although extended impacts might include destabilised ecosystems, changes in settlement or lasting impacts upon populations or constraints upon demographic growth (see Tallavaara and Jørgensen 2020) the nature and extent of ecosystem damage in the wake of a tsunami would have been variable. It is possible that key aspects of environmental damage may have recovered in a relatively short time (e.g. Losey 2005) or required only modest relocation (Fitzhugh 2012), particularly in areas with a rich abundance and/or variety of resources (e.g. Åstveit and Tøssebro 2023). This may have made a return to pre-tsunami ways of living possible or even attractive in a relatively short time, maybe within decades or less (Walker et al. 2024), as well as being potentially difficult to track in the temporal resolution afforded by archaeological data. Improved tsunami modelling may allow for more regionally attenuated information regarding variability in wave-arrival time, draw-down, run-up, intensity and sequencing, among other aspects, which may in turn allow for more nuanced consideration of regionally specific ecological and taphonomic effects.

Many of the theoretical premises in this chapter were discussed by Torrence and Grattan some 20 years ago when they noted that archaeological writing had tended to focus on environmental forcing mechanisms rather than hazards or vulnerability, thus contributing to the widely assumed (but less frequently evidenced) idea that catastrophes, disasters and extreme environmental events are powerful agents of cultural change (Torrence and Grattan 2002, 2; 7). This has arguably improved somewhat in recent years, as hazards and disasters have come increasingly under archaeological focus, and interest in the relevance of deep environmental histories for present and future challenges of climate and natural hazards has grown (Hussain and Riede 2020; Rick and Sandweiss 2020; Sandweiss and Kelley 2012).

It remains important, however, to be critically aware of normative assumptions and environmental determinism when accounting for a lack of archaeological data. This is particularly true of deeper prehistory, where datasets may offer sparse spatiotemporal resolution, and cultural impacts and responses may differ from available frames of reference. Disasters offer alluring narrative devices for explaining cultural change, but evidence of a severe hazard cannot de facto be read as evidence of a disaster. It is equally possible that severe impacts, if not disasters, may transpire without leaving clearly visible or unambiguous archaeological traces. The Storegga tsunami may well have had a severe impact upon coastal Mesolithic communities, but the erosive nature of the run-up, combined with a potentially rapid opportunity to return to pre-tsunami lifeways for the surviving populace, might partly explain why we struggle to discern this impact archaeologically.

Acknowledgements The research undertaken for this paper was supported by the 'The Storegga tsunami c. 6150 BC—a wave of destruction or transformative disruption for a prehistoric society' project, funded by the Norwegian Research Council (project no. 302858). I am grateful to the Life After the Storegga Tsunami (LAST) team, my colleagues at the Universititet i Stavanger, and especially Astrid Nyland and Håvard Kilhavn for their friendship and many thought-provoking discussions. I also thank the participants of the Under Pressure conference and CHAGS13 Living Well with Hazards session, both of which opened my mind to many new and influential perspectives.

Finally, my thanks to the editors of this volume for their invitation, patience and work in bringing everything together, to Micheál Butler for creating Fig. 5.6, and to the two peer reviewers whose comments helped me greatly improve this text. Any mistakes are my own.

References

Affan M, Fadli N, Jufriadi J et al (2019) Assessment of mangrove forest damage and its recovery in Banda Aceh city post-tsunami disaster. IOP Conf Ser: Earth Environ Sci 248:012108

Alagona PS (2006) What makes a disaster "natural"? Space Cult 9(1):77–79. https://doi.org/10.1177/1206331205283727

Allison PM (2002) Recurring tremors: the continuing impact of the Ad 79 eruption of Mt Vesuvius. In: Torrence R, Grattan J (eds) Natural Disasters and cultural change. Routledge, London, pp 107–125

Ambrose SH (1998) Late Pleistocene human population bottlenecks, volcanic winter, and differentiation of modern humans. J Hum Evol 34(6):623–651

Aronsson-Storrier M, Dahlberg R (eds) (2022) Defining disaster: Disciplines and domains. Edward Elgar, Cheltenham

Arponen VPJ, Dörfler W, Feeser I et al (2019) Environmental determinism and archaeology: understanding and evaluating determinism in research design. Archaeol Dialogues 26(1):1–9

Åstveit LI, Tøssebro C (2023) Sedentary people or short time events? High resolution radiocarbon chronology from a Late Mesolithic dwelling site in Western Norway. J Archaeol Sci Rep 51:104178

Ballin T (2023) Lithic evidence of the Storegga tsunami at Guardbridge in Fife. CIfA Scottish Group Summer Newsletter:12–15

Barnes GL (2017) The search for tsunami evidence in the geological and archaeological records, with a focus on Japan. Asian Perspect 56(2):132–165

Bergsvik KA (2001) Sedentary and mobile hunter-fishers in stone age western Norway. Arct Anthropol 38(1):2–26

Bettinger RL, Garvey R, Tushingam S (2015) Hunter-Gatherers. Archaeological and evolutionary theory. Springer, New York. https://doi.org/10.1007/978-1-4899-7581-2

Bicket AR, Mellett CL, Tizzard L et al (2017) Exploring Holocene palaeogeography in the 'White Ribbon': a Mesolithic case study from the Northumberland Coast. J Quat Sci 32(2):311–328

Bjerck HB (2008) Norwegian mesolithic trends. In: Bailey G, Spikins P (eds) Mesolithic Europe. Cambridge University, Cambridge, UK, pp 60–106

Blackburn J (2019) Time song: Searching for Doggerland. Jonathan Cape, London

Blankholm HP (2020) In the wake of the wake. An investigation of the impact of the Storegga tsunami on the human settlement of inner Varangerfjord, Northern Norway. Quat Int 549(30):65–73. https://doi.org/10.1016/j.quaint.2018.05.050

Bondevik S (2003) Storegga tsunami sand in peat below the Tapes beach ridge at Haroy, western Norway, and its possible relation to an early Stone Age settlement. Boreas 32(3):476–483

Bondevik S, Svendsen JI, Mangerud J (1998) Distinction between the Storegga tsunami and the Holocene marine transgression in coastal basin deposits of western Norway. J Quat Sci 13(6):529–537

Bondevik S, Stormo SL, Skjerdal G (2012) Green mosses date the Storegga tsunami to the chilliest decades of the 8.2 ka cold event. Quatern Sci Rev 45:1–6

Bondevik S, Lødøen T, Tøssebro C et al (2019) Between winter storm surges-human occupation on a growing Mid-Holocene transgression maximum (Tapes) beach ridge at Longva, western Norway. Quatern Sci Rev 215:116–131

Bondevik S, Risebrobakken B, Gibbons SJ et al (2024) Contamination of 8.2ka cold climate records by the Storegga tsunami in the Nordic Seas. Nat Commun 15:2904. https://doi.org/10.1038/s41467-024-47347-9

Bondevik S (2022) Tsunami from the Storegga Landslide. In: Tilling RI (ed) Complexity in tsunamis, volcanoes, and their hazards. Encyclopedia of Complexity and Systems Science Series. Springer, New York

Burroughs WJ (2005) Climate change in prehistory. Cambridge University, Cambridge, UK, The End of the Reign of Chaos

Chmutina K, von Meding J (2019) A dilemma of language: "natural disasters" in academic literature. Int J Disaster Risk Sci 10:283–292. https://doi.org/10.1007/s13753-019-00232-2

Clarkson C, Harris C, Li B et al (2020) Human occupation of northern India spans the Toba super-eruption ~74,000 years ago. Nat Commun 11:961. https://doi.org/10.1038/s41467-020-14668-4

Coffman JL, von Hake CA, Stover CW (ed) (1982) Earthquake history of the United States (reprint). Publication 41–1. US. Dept. of Commerce, National Oceanic and Atmospheric Administration; US. Dept of the Interior, Geological Survey, Boulder, Colorado

Coles BJ (1998) Doggerland: a speculative survey. Proc Prehist Soc 64:45–81

Conneller C (2004) Becoming deer: Corporeal transformations at Star Carr. Archaeological Dialogues 11:37–56

Conneller C (2022) The Mesolithic in Britain. Landscape and Society in Times of Change, Routledge, London

Conneller C, Bates M, Bates R et al (2016) Rethinking human responses to sea-level rise: The Mesolithic occupation of the channel Islands. Proc Prehist Soc 82:27–71

Conneller C (2003) Star Carr recontextualised. In: Bevan L, Moore J (eds) Peopling the Mesolithic in a Northern Environment. BAR International Series, vol 1157. BAR Publishing, Oxford, pp 81–85

Costa PJM, Dawson S, Ramalho RS et al (2021) A review of onshore tsunami deposits along the Atlantic coasts. Earth Sci Rev 212:103441

Damlien H, Nyland AJ, Redmond JJ (2024) Lithic technology before and after the Storegga tsunami (8200 cal BP): Dissolving large-scale regional trends to identify social impact of crisis in western Norway. The Holocene. https://doi.org/10.1177/09596836241274987

Davies H (2002) Tsunamis and the coastal communities of Papua New Guinea. In: Torrence R, Grattan J (eds) Natural disasters and cultural change. Routledge, London, pp 28–42

Dawson AG, Smith DE, Long D (1990) Evidence for a tsunami from a Mesolithic site in Inverness. Scotland J Archaeol Sci 17(5):509–512

Dawson S, Costa PJM, Dawson A et al (2020) Onshore archives of tsunami deposits. In: Engel M, Pilarczyk J, May SM et al (eds) Geological records of tsunamis and other extreme waves. Elsevier, Amsterdam, pp 95–111

Doocy S, Rofi A, Moodie C et al (2007) Tsunami mortality in Aceh Province, Indonesia. Bull World Health Organ 85(4):273–278

Dyer CL (2002) Punctuated entropy as a culture-induced change: the case of the Exxon Valdez oil spill. In: Hoffman SM, Oliver-Smith A (eds) Catastrophe & culture: The anthropology of disaster. School of American Research Advanced Seminar Series. School of American Research, Santa Fe, pp 159–185

Earland JL, Scourse JD, Ehmen T et al (2024) Identification of the Storegga event offshore Shetland. Mar Geol 474:107334

Edwards KJ (2004) Palaeoenvironments of the Late Upper Palaeolithic and Mesolithic periods in Scotland and the North Sea area: new work, new thoughts. In: Saville A (ed) Mesolithic Scotland and its neighbours. The Early Holocene Prehistory of Scotland, its British and Irish Context and Some Northern European Perspectives. Society of Antiquaries of Scotland, Edinburgh, pp 55–72

Elliott JR, Pais J (2006) Race, class, and Hurricane Katrina: social differences in human responses to disaster. Soc Sci Res 35(2):295–321

Engel M, Pilarczyk J, May SM et al (2020) Geological records of tsunamis and other extreme waves: concepts, applications and a short history of research. In: Engel M, Pilarczyk J, May SM et al (eds) Geological Records of Tsunamis and Other Extreme Waves. Elsevier, Amsterdam, pp 3–20. https://doi.org/10.1016/B978-0-12-815686-5.00001-8

Gaffney V, Fitch S (eds) (2022) Europe's lost frontiers. Volume 1: Context and methodology. Archaeopress, Oxford

Fitch S, Gaffney V, Thomson K (2007) In sight of Doggerland: from speculative survey to landscape exploration. Internet Archaeol 22. https://doi.org/10.11141/ia.22.3

Fitzhugh B (2012) Hazards, impacts, and resilience among hunter-gatherers of the Kuril Islands. In: Cooper J, Sheets P (eds) Surviving sudden environmental change. University Press of Colorado, Denver, Colorado, Answers from Archaeology, pp 19–41

Furedi F (2007) The changing meaning of disaster. Area 39(4):482–489

Gaffney V, Fitch S, Smith D (2009) Europe's lost world. The Rediscovery of Doggerland. CBA Research Report, vol 160. Council for British Archaeology, York

Gifford DP (1981) Taphonomy and paleoecology: A critical review of archaeology's sister disciplines. Adv Archeol Method Theory 4:365–438

Goff J (2023) In search of ancient tsunamis: A researcher's travels. Oxford University, Oxford, Tools and Techniques

Goff J, Nunn PD (2016) Rapid societal change as a proxy for regional environmental forcing: evidence and explanations for Pacific Island societies in the 14–15th centuries. Island Arc 25(5):305–315

Goff J, McFadgen BG, Chagué-Goff C et al (2012) Palaeotsunamis and their influence on Polynesian settlement. Holocene 22(9):1067–1069

Goff JR, McFadgen BG (2003) Large earthquakes and the abandonment of prehistoric coastal settlements in 15th century New Zealand. Geoarchaeology: Int J 18(6):609–623

Goff J (2020) Tsunami databases. In: Engel M, Pilarczyk J, May SM et al (eds) Geological records of tsunamis and other extreme waves. Elsevier, Amsterdam, pp 75–93. https://doi.org/10.1016/C2017-0-03458-4

Grattan J (2006) Aspects of Armageddon: an exploration of the role of volcanic eruptions in human history and civilization. Quatern Int 151:10–18

Guidoboni E, Ebel JE (2009) Earthquakes and tsunamis in the past. A guide to techniques in historical seismology. Cambridge University, Cambridge, UK

Hartman C, Squires GD (eds) (2006) There is no such thing as a natural disaster: Race, class, and Hurricane Katrina. Routledge, New York

Haslam M, Clarkson C, Petraglia M et al (2010) The 74 ka Toba super-eruption and southern Indian hominins: archaeology, lithic technology and environments at Jwalapuram Locality 3. J Archaeol Sci 37(12):3370–3384

Hijma MP, Cohen KM (2019) Holocene sea-level database for the Rhine-Meuse Delta, the Netherlands: implications for the pre-8.2 ka sea-level jump. Quatern Sci Rev 214:68–86

Hussain ST, Riede F (2020) Paleoenvironmental humanities: Challenges and prospects of writing deep environmental histories. Wires Clim Change 11(5):e667

Inglin S (2012) Links between post-tsunami relocation and changes in fishing practices in Tamil Nadu: a microlevel case study. In: Duyne Barenstein JE, Leeman E (eds) Post-disaster reconstruction and change. CRC, Boca Raton, pp 241–257

Jones L (2018) The big ones: How natural disasters have shaped us (and what we can do about them). Doubleday, New York

Jørgensen EK, Riede F (2019) Convergent catastrophes and the termination of the Arctic Norwegian Stone Age: a multi-proxy assessment of the demographic and adaptive responses of mid-Holocene collectors to biophysical forcing. The Holocene 29(11):1782–1800. https://doi.org/10.1177/0959683619862036

Kaplan D (2000) The darker side of the "original affluent society." J Anthropol Res 56(3):301–324

Kappelman J, Todd LC, Davis CA et al (2024) Adaptive foraging behaviours in the Horn of Africa during Toba supereruption. Nature 628:365–372

Kohler TA (2011) Social evolution, hazards, and resilience: some concluding thoughts. In: Cooper J, Sheets P (eds) Surviving sudden environmental change. University Press of Colorado, Denver, Colorado, Answers from Archaeology, pp 223–236
Kumar U, Haider R (2007) Impact of tsunami at the Onge settlements at Dugong Creek, Little Andaman. In: The Anthropological Survey of India (ed) Tsunami in South Asia. Studies of impact on communities of Andaman and Nicobar Islands. Allied Publishers Private, New Delhi, pp 103–119
Kuper A (2005) The reinvention of primitive society: Transformations of a myth, 2nd edn. Routledge, London
Amkreutz L, van der Vaart-Verschoof S (eds) (2022) Doggerland. Lost World under the North Sea. Sidestone, Leiden
Leary J (2009) Perceptions of and responses to the Holocene flooding of the North Sea lowlands. Oxf J Archaeol 28:227–237
Leary J (2011) Experiencing change on the prehistoric shores of Northsealand: an anthropological perspective on early Holocene sea-level rise. In: Benjamin J, Bonsall C, Pickard C et al (eds) Submerged prehistory. Oxbow Books, Oxford, pp 75–84
Leary J (2015) The remembered land. Surviving sea-level rise after the last ice age. Bloomsbury, London
Long D, Dawson AG, Smith DE (1989) Tsunami risk in northwestern Europe: A Holocene example. Terra Nova 1(6):532–537
Losey RJ (2005) Earthquakes and tsunami as elements of environmental disturbance on the Northwest Coast of North America. J Anthropol Archaeol 24(2):101–116
Lowe DJ, de Lange WP (2000) Volcano-meteorological tsunamis, thec. AD 200 Taupo eruption (New Zealand) and the possibility of a global tsunami. The Holocene 10(3):401–407
Lundström V (2023) Living through changing climates: Temperature and seasonality correlate with population fluctuations among Holocene hunter-fisher-gatherers on the west coast of Norway. The Holocene 33(11):1376–1388
Lundström V, Simpson D, Yaworsky P (2024) 'Here by the sea and sand': Uninterrupted hunter-fisher-gatherer coastal habitation despite considerable population growth. Open Quaternary 10(3):1–16
Maschner HDG, Jordan JW (2008) Catastrophic events and punctuated culture change: the Southern Bering Sea and North Pacific in a dynamic global system. In: Papagianni D, Layton R, Maschner H (eds) Time and change: Archaeological and anthropological perspectives on the long-term in hunter-gatherer societies. Oxbow Books, Oxford, pp 95–114
Maselli V, Oppo D, Moore AL et al (2020) A 1000-yr-old tsunami in the Indian Ocean points to greater risk for East Africa. Geology 48(8):808–813
McFadgen B (2007) Hostile shores: Catastrophic events in prehistoric New Zealand and their impact on Mãori Coastal communities. Auckland University, Auckland
Milner N, Woodman P (2005) Looking into the Canon's mouth: Mesolithic studies in the 21st century. In: Milner N, Woodman P (eds) Mesolithic Studies at the beginning of the 21st Century. Oxbow Books, Oxford, pp 1–13
Mithen S, Wicks K (2021) Population level models for testing hunter-gatherer resilience and settlement response to the combined impact of abrupt climatic events and sea level change: a case study from the Holocene of northern Britain. Quatern Sci Rev 265:107027
Moore J (2003). Beyond hazelnuts and into the forest. In: Bevan L, Moore J (eds) Peopling the Mesolithic in a northern environment. BAR International Series, vol 1157. BAR Publishing, Oxford, pp 53–58
Murayama M, Burton L (2015) Cassandra, Prometheus and hubris: the epic tragedy of Fukushima. Studies in Law. Polit, Soc 68 (Special Issue: Cassandra's Curse: The Law and Foreseeable Future Disasters):125–153
Nielsen SV (2020) Wave? What wave? Testing for impact of the Garth tsunami (3500 BCE) on Neolithic coastal settlements in Western Norway. J Archaeol Sci Rep 33:102464

Nyland AJ, Walker J, Warren G (2021) Evidence of the Storegga tsunami 8200 bp? An archaeological review of impact after a large-scale marine event in Mesolithic Northern Europe. Front Earth Sci 9:767460. https://doi.org/10.3389/feart.2021.767460

Nyland AJ, Damlien H (2024) Lithic stories of broken relations after the Storegga tsunami in Mesolithic western Norway? World Archaeol (special issue: Lithic Ontology). https://doi.org/10.1080/00438243.2024.2357384

Papadopoulos GA, Imamura F, Nosov M et al (2020) Tsunami magnitude scales. In: Engel M, Pilarczyk J, May SM et al (eds) Geological records of tsunamis and other extreme waves. Elsevier, Amsterdam, pp 33–46

Papadopoulos GA, Imamura F (2001) Proposal for a new tsunami intensity scale. In: ITS 2001 Proceedings, Session 5, no 5–1, pp 569–577

Perry R (2007) What is a disaster? In: Rodríguez H, Quarantelli EL, Dynes RR (eds) Handbook of disaster research. Springer, New York, pp 1–15

Perry RW (2018) Defining disaster: an evolving concept. In: Rodríguez H, Donner W, Trainor JE (eds) Handbook of disaster research. Springer, Cham, pp 3–32. https://doi.org/10.1007/978-3-319-63254-4

Puttick S, Bosher L, Chmutina K (2018) Disasters are not natural. Teach Geogr 43(3):118–120

Quarantelli EL, Lagadec P, Boin A (2007) A heuristic approach to future disasters and crises: new, old, and in-between types. In: Rodríguez H, Quarantelli EL, Dynes RR (eds) Handbook of disaster research. Springer, New York, pp 16–41

Quarantelli EL (2005) A social science research agenda for the disasters of the 21st century: theoretical, methodological and empirical issues and their professional implementation. In: Perry RW, Quarantelli EL (eds) What is a disaster? New answers to old questions. International Research Committee on Disasters. Xlibris, Philadelphia, pp 325–396

Radio New Zealand (2019) The Indian Ocean tsunami remembered by those who survived it. https://www.rnz.co.nz/news/world/406241/the-indian-ocean-tsunami-remembered-by-those-who-survived-it Accessed 3 May 2024

Rick TC, Sandweiss DH (2020) Archaeology, climate, and global change in the age of humans. PNAS 117(15):32284423

Riede F (2019) Doing palaeo-social volcanology: developing a framework for systematically investigating the impacts of past volcanic eruptions on human societies using archaeological datasets. Quatern Int 499:266–277

de Roest K (2013) How to cope with a drowning land- scape? A research history into changing representations of Doggerland in relation to climate change. In: Raemaekers D (ed) A Kaleidoscope of maritime perspectives: Essays on the archaeology, art history and landscape history of the maritime World View. Institute of Archaeology, Groningen, pp 7–15

Rueben K (2014) Late Middle Palaeolithic bifacial technologies across northwest Europe: typo-technological variability and trends. Quatern Int 350:130–146

Perry RW, Quarantelli EL (eds) (2005) What is a disaster? New answers to old questions. International Research Committee on Disasters. Xlibris, Philadelphia

Sahlins M (1972) Stone age economics. Aldine Atherton, Chicago

Sandweiss DH, Kelley AR (2012) Archaeological contributions to climate change research: the archaeological record as a paleoclimatic and paleoenvironmental archive. Annu Rev Anthropol 41:371–391

Satake K (2014) Advances in earthquake and tsunami sciences and disaster risk reduction since the 2004 Indian ocean tsunami. Geoscience Letters 1:15. https://doi.org/10.1186/s40562-014-0015-7

Schiffer MB (1985) Is there a “Pompeii premise” in archaeology? J Anthropol Res 41:18–41

Schiffer MB (1987) Formation processes of the archaeological record. University of New Mexico, Albuquerque, NM

Sharrocks PD, Hill J (2024) Evaluating the impact of the Storegga tsunami on Mesolithic communities in Northumberland. J Quat Sci 39(3):473–487

Smith D, Wickham-Jones C (2002) The Storegga disaster: in search of squashed Mesolithic people. Curr Archaeol 179:472–473

Smith E, Jacobs Z, Johnsen R et al (2018) Humans thrived in South Africa through the Toba eruption about 74,000 years ago. Nature 555:511–515. https://doi.org/10.1038/nature25967

Spikins P (2000) Ethno-fact or ethno-fiction? Searching for the 'Structure' of settlement patterns. In: Young R (ed) Current Research on the British and Irish Mesolithic. Leicester University, Leicester, pp 105–118

Tallavaara M, Jørgensen EK (2020) Why are population growth rate estimates of past and present hunter-gatherers so different? Philos Trans R Soc B 376:20190708

Taylor B (2018) Subsistence, environment and Mesolithic landscape archaeology. Camb Archaeol J 28(3):493–510

Tobin GA, Montz BE (1997) Natural hazards. Guilford Press, New York, Explanation and Integration

Torrence R, Grattan J (2002) The archaeology of disasters: past and future trends. In: Torrence R, Grattan J (eds) Natural disasters and cultural change. Routledge, London, pp 1–19

Truedinger AJ, Jamshed A, Sauter H et al (2023) Adaptation after extreme flooding events: moving or staying? The case of the Ahr Valley in Germany. Sustainability 15(2):1407

Tyuleneva N, Braun Y, Katz T et al (2018) A new chalcolithic-era tsunami event identified in the offshore sedimentary record of Jisr al-Zarka (Israel). Mar Geol 396:67–78

UNEP (2007) Environment and reconstruction in Aceh: Two years after the tsunami. United Nations Environment Programme. https://www.unep.org/resources/report/environment-and-reconstruction-aceh-two-years-after-tsunami. Accessed 2 Dec 2024

Urabe J, Nakashizuka T (eds) (2016) Ecological Impacts of Tsunamis on Coastal Ecosystems Lessons from the Great East Japan Earthquake. Springer, Tokyo. https://doi.org/10.1007/978-4-431-56448-5

Waddington C, Wicks K (2017) Resilience or wipe out? Evaluating the convergent impacts of the 8.2 ka event and Storegga tsunami on the Mesolithic of northeast Britain. J Archaeol Sci Rep 14:692–714

Wagner B, Bennike O, Klug M et al (2007) First indication of Storegga tsunami deposits from East Greenland. J Quat Sci 14:692–714

Walker J, Gaffney V, Fitch S et al (2020) A great wave: the Storegga tsunami and the end of Doggerland. Antiquity 94:1409–1425

Walker J, Nyland AJ, Bergsvik KA et al (2024) A multiproxy approach to understanding the impact of the Storegga tsunami upon Mesolithic hunter-fisher-gatherers across different regions of western Norway. Quatern Sci Rev 324:108433

Warren EJ (1995) Coastal sedentism during the Atlantic period in Nordhordland, western Norway? The middle and late Mesolithic components at Kotedalen. Unpublished master thesis, Memorial University of Newfoundland

Wickham-Jones C (2021) Surviving Doggerland. In: Borić D, Antonović D, Mihailović B (eds) Foraging Assemblages, vol 1. Serbian Archaeological Society and The Italian Academy for Advanced Studies in America, Belgrade and New York, pp 135–141

Wicks K, Mithen S (2014) The impact of the abrupt 8.2 ka cold event on the Mesolithic population of Western Scotland: a Bayesian chronological analysis using 'activity events' as a population proxy. J Archaeol Sci 45:240–269

Williams M (2012) The ≈73 ka Toba super-eruption and its impact: History of a debate. Quatern Int 258(1):19–29. https://doi.org/10.1016/j.quaint.2011.08.025

Yeh H, Barbosa A, Mason BH (2015) Tsunami effects in man-made environment. In: Tilling RI (ed) Complexity in tsunamis, volcanoes, and their hazards. Encyclopedia of Complexity and Systems Science Series. Springer, New York, NY, pp 187–211. https://doi.org/10.1007/978-1-0716-1705-2_623

Young R (ed) (2000) Mesolithic lifeways: Current research from Britain and Ireland. Leicester archaeology monographs, vol 7. University of Leicester Archaeological Services, Leicester

Chapter 6
Telling Transformative Climate Narratives from Prehistoric Pasts for Future Positive Existence

Stephanie F. Piper, Sonja B. Grimm, and Marcel Bradtmöller

Abstract Alarmist narratives of the present climate crisis, coupled with poorly framed histories of past societal collapse, are generating an increasing sense of climate doomism. The deep time perspectives archaeology brings to understanding human–environment relations has potential to influence actionable solutions, yet archaeologists need to take more proactive measures to communicate this, in curricula and public engagement. Hunter-gatherer histories present challenges for educators to positively communicate the survival, resilience, and adaptive successes of humans, owing to perceived differences in lifeways. To understand these perceptions, archaeology students and trainee history teachers in Germany were surveyed. The results show that whilst few knew about specific climate-related events and human responses beforehand, many retained this knowledge two years later. Additionally, analysis of climate change and archaeology topics on social media indicates a lack of serious archaeological content on platforms where climate change is debated. We consider how storytelling, specifically through transformative narratives, has the power to capture the imagination, make the past relatable, and provide positive frames for change. In education and wider science communication, such frames could inspire hope and activism necessary for a future positive and equitable existence. We conclude by recommending mechanisms for the implementation of transformative narratives by the archaeological community.

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_6

Keywords Climate change · Climate doomism · Public engagement · Teaching · Hunter-gatherer archaeology · Social media

6.1 Introduction

Education, in its various forms, has been recognised as having a "critical" role in the creation of a "climate positive future" with commitments to urgently embed "climate considerations into all levels of education" (UN Climate Change Conference 2021). Archaeology is a discipline rich in research on the reconstruction of past environments, landscapes, and their change over time, as well as people's social and cultural relationships with these changes. However, the recognition of archaeology's relevance in environmental education has been slow-paced, and the lack of acknowledgement about its potential to be situated within global responses criticised for over a decade (Burke et al. 2021; Degroot et al. 2021; Frost 2000; Hudson et al. 2012; Jackson et al. 2018, 2022b; Rockman and Hritz 2020; Smith 2021). Integrating the deep time perspectives of small-scale hunter-gatherer societies and their social and cultural responses to climate change into education and outreach is vital in enabling students and the public to better situate themselves within the present crisis. By understanding processes and actions from the past and their applicability to the present, it may inspire hope, highlight inequalities, and lead students and the public to take greater responsibility and action.

In this chapter, we share our experiences of teaching early European prehistory at German (MB) and UK (SP) universities, and in engaging with the wider public through social media outreach (SG). Drawing on this, we address three themes:

1. Perceptions: what are students' and the public's understanding of the climate crisis in the present, and their views about the future? How does this relate to what they know, believe, or assume about people and climate change in the past?
2. Pedagogy: how do our teaching methods address this? What tools do we have at our disposal, and are they effective? What other approaches can we take?
3. Climate communication: how can we enable more effective communication of the relevance of human responses to climate change in the past? Can this activate learners to address contemporary concerns?

In reflecting on this anecdotal evidence, we suggest approaches that may be useful for colleagues in relating to experiences in science communication. Moreover, we believe that educating multipliers, via teacher training, and the broader public via social media, can help reach politicians and policymakers as more reliably informed social discussions and subsequent decision-making occur.

6.1.1 Young People and the Climate Crisis: Anthem for a Doomed Youth?

The effects of the anthropogenically induced climate crisis are regular headline news, with media outlets holding significant influence over the political, social, and cultural consumption of climate communication globally (e.g. Boykoff 2011; Burgess 1990; Hase et al. 2021; Newman et al. 2018; Schmidt et al. 2013). Increasingly, social media has become a "soft power" through which the public engage with climate change (Mavrodieva et al. 2019). Young people are prolific consumers of social media among Internet users. In 2022, Instagram (UK: 90%; DE: 74%), Snapchat (UK: 83%; DE: 47%), and TikTok (UK: 74%; DE: 44%) were the platforms most frequently accessed by UK and German Internet users aged 14–29 (Koch 2022; Ofcom 2022, 24). In Germany, YouTube as an online video platform also reached 95% of this age group monthly (Rhody 2022).

There are two opposing extremes of linguistic repertoires that dominate climate change narratives—"alarmist" and "small actions" (Ereaut and Segnit 2006). The former has sparked debate over its efficacy in motivating action (Chapman et al. 2017; Hinkel et al. 2020; Nerlich et al. 2010). Whilst it has pushed the climate crisis onto political agendas and presents a stark reality, it has also been criticised as a paralysing rhetoric of "doom and gloom" that is beyond action (Hinkel et al. 2020; Mann et al. 2017). Among young people, alarmist media headlines have been blamed for causing a viral spread of "doomism", climate and eco-anxiety, and helplessness among Generation Z students around the world (Goodykoontz 2022; Hautea et al. 2021; Hickman et al. 2021; Silva 2022; Touma and Davey 2023).

Psychological and social research suggests that a lower risk perception, and climate scepticism or denial, act as coping strategies and defence mechanisms against eco-anxiety, or as identity-protecting cognitions, particularly for people with specific world views and political affiliations (Feinberg and Willer 2011; Hornsey 2021; Hornsey et al. 2016; Leka and Furnham 2024). Climate change has become increasingly politically charged in industrialised nations, with lobbying by companies to hinder mitigation efforts and capitalisation of divisive stances on the issue harnessed by right-wing parties to attract people across the political spectrum (Beder 2014; Dickson and Hobolt 2024). Increasing support for these parties in the Global North will lead to less equitable climate actions being taken and aggravate already existing climate injustices. Counteracting perceptions of climate scepticism, denial, or delay (Lamb et al. 2021) with additional scientific evidence, or clearer formulation of this information, is no longer effective (Bain et al. 2016). On the contrary, this could even result in negative impacts (Feinberg and Willer 2011; Leka and Furnham 2024). Instead, aligning arguments with different world views and less dire messaging may avoid negative reactions, and encourage changes in attitude and steps towards "small actions" (Ereaut and Segnit 2006; Feinberg and Willer 2011; Hornsey 2021; cf. Hornsey and Fielding 2017). It has been suggested that positive emotions, such as hope, are linked in multiple and complex ways with intentions to take climate actions (Geiger et al. 2021, 2023; Schneider et al. 2021). Pro-environmental behaviour may increase subjective well-being (Capstick et al. 2022); in turn, addressing well-being as a co-benefit of climate actions could motivate further engagement (Bain et al. 2016). In sum: narratives that centre on doomism can be considered at best unproductive, and at worst dangerous (Denisova 2023; Mackenthun 2021).

Children and adolescents are some of the most vulnerable individuals among the highest-risk groups that suffer from the climate crisis. The manifold "stressors" of climate change are already having an appreciably detrimental effect on young people's access to, and achievement within, education—particularly in low-income countries where education attainment is already low (Peter and van Bronswijk 2021; Prentice et al. 2024). The psychological stress induced by "climate fear" or "solastalgia" impacts mental well-being. Siperstein and colleagues recognise that, like students' "frank admissions of fear or hopelessness", it is these "same aspects [that] make climate change at first glance difficult to teach" (Siperstein et al. 2017, 6). Dunlop and Rushton (2022) report dissatisfaction among young people, teachers, and teacher educators with curriculum approaches to climate change and sustainability that centre on symptoms rather than causes, theory rather than action, and a depoliticisation of the subject that negates responsibility and values in the UK. Whilst strategy makers have acknowledged the need for support around climate anxiety, "the [UK] strategy does not consider in detail the ways in which education should incorporate emotions, nor how this could be achieved" (Dunlop and Rushton 2022, 1097). Such attitudes, as a consequence, negatively impact prospects for engagement in pro-environmental behaviour, thereby further increasing vulnerability and inequity (Prentice et al. 2024, 219–220).

It has been suggested that there are positive opportunities for teaching and learning regarding curriculum development (Sandri 2022; Siperstein et al. 2017). Research on climate change in education and public engagement is growing, with calls to reframe the way in which it is taught—utilising radical, integrative approaches that forefront human and social approaches to these issues (e.g. Leichenko and O'Brien 2020; Ojala 2016; Sutoris 2022). Notwithstanding the need to ensure that socio-economic and learning environments provide the most optimised conditions to improve educational attainment (Prentice et al. 2024), the emotional dimensions of how young people respond to learning about climate change also require recognition. Ojala (2012, 2016, 2017) suggests that emotional awareness of students' anxieties can be harnessed positively in educational settings through focussing on hope (for adults, see Geiger et al. 2021, 2023). As such, emotion inspires action, which is what is needed to disrupt pervading narratives of collapse and decline (Jackson et al. 2022a; Wynn 2020).

6.1.2 Archaeology and the Climate Crisis

The reconstruction of past landscapes, environments, and their diachronic dynamics is fundamental in archaeology, and with the post-processual turn, so too are their entanglements with human interactions (e.g. Davis 2020; Reitz and Shackley 2012).

These relationships are ever more prescient with the effects of the current climate crisis, and a key challenge that has been raised by climate change educators across disciplines and within the university sector (Hudson et al. 2012; Leichenko and O'Brien 2020; Rockman and Hritz 2020). Archaeology provides us with the power to observe long-term dynamics between humans and their environment and project them forward into the present and future. There is a growing corpus of literature—this volume included—that argues for the position of archaeology as a key discipline with a significant contribution to make in terms of addressing contemporary climate challenges (e.g. Burke et al. 2021; Chirikure 2021; Davis 2020; Degroot et al. 2021; Edgeworth et al. 2014; Kaufman et al. 2018; Lane 2015; Rockman and Hritz 2020).

From the perspective of higher education pedagogy, it has been suggested that more can be done to engage archaeology students in reflecting on how they can make a difference as graduates or understand how to convert their skills (Chirikure 2021; Handley 2015). Environmental education facilitates a feeling of both subjective well-being and responsibility, and the skills required to enact change (Capstick et al. 2022; Carman 2016; Handley 2015). However, disciplinary reform is required to ensure a truly transdisciplinary curriculum that facilitates an "ability to solve problems through such hard and soft skills [providing] the middle range that is required to ensure that archaeology achieves relevance" (Chirikure 2021, 1075). It is clear from our own teaching in the UK and Germany that students care about heritage and understand its significance beyond the discipline. By taking a similar pedagogic approach to environmental education in archaeology and expanding students' communities of practice, graduates can "communicate these positive messages about archaeology to influence local and national decision-making" (Handley 2015,162). As archaeology is a discipline with graduates not only within the heritage sector but in a range of public roles, there is a strong rationale for encouraging students to be critically socio-politically engaged (Cobb and Croucher 2020, 19–20; Schofield 2024).

6.2 Communicating Deep History

Science communication describes the exchange of scientific expertise between people, which can change depending on the people, places, and formats involved. Examples for us as scientists include chatting with friends and neighbours, advising policymakers, guiding a tour of an archaeological site, preparing a museum exhibition, participating in TV or radio programmes or podcasts, writing web articles, giving public talks, and managing social media blogs and accounts. The range of intentions behind science communication can be classified in three categories: for the sake of oneself, science, or the community. However, these are not exclusive, and it is often combinations of these that drive scientists to communicate their results (cf. Kappel & Holmen 2019). The latter two categories reflect a wish to activate the receivers of the information, for which scientists should "… help our [their] audience to establish personal, moral, and/or emotional connections with the topics we [they] are communicating…" (Berhe 2020, 377).

Scientific results are also communicated by a range of actors, and non-experts, with varied agendas. Significantly, the degree of background knowledge of receivers of this information is as variable as the outlets from which it is consumed (Kozicka and Wielocha 2020). Consequently, differentiating between scientific fact, unsubstantiated claims, misinformation, and disinformation can be difficult. As formal peer review is usually not used in social discourse, mistakes in understanding occur and mis- and disinformation are rarely identified and addressed directly. Academic online engagement in public discourse is therefore highly valuable and necessary to correct speculative information, and to counteract non-scientific or pseudo-scientific, and often damaging, narratives—whether they be about climate change (e.g. León et al. 2022) or archaeology (e.g. Caspari 2022; Dietrich and Notroff 2019). Based on their experiences at public events, Kozicka and Wielocha concluded that "interaction, i.e. talking *with, not at* people is the key to successful science communication" (Kozicka and Wielocha 2020, *emphasis added*; Dietrich and Notroff 2019, 19). Despite this general advice, the "rules" and examples of best practice around science communication are as varied as the forms and should be more tailored and individualised to suit the preferred tastes of the individual "consumers" of this information (cf. Kappel and Holmen 2019; Kozicka and Wielocha 2020).

In the following, we outline common problems and perceptions that are encountered in the communication of Pleistocene and Early Holocene archaeology before focussing on two specific areas of science communication: firstly, teaching a university class with future history teachers about archaeology in these periods, and secondly, the use of social media and online platforms to communicate archaeology and climate change.

6.2.1 Problems of Perceptions

Archaeologists involved in communicating topics relating to deep-historic small-scale societies are often faced with the challenge of engaging their audiences to overcome perceived differences and distances between the deep past and the present. These perceptions render the past, and its people, as "other" (Lucas 2005, 125–126) and are affected by multiple interconnected parameters, three of which are considered here: time, environment, and lifeways.

The first parameter to be considered is the long temporal distances. For example, the intervening 11,000 years between the Pleistocene–Holocene transition and the present day induce problems associated with perspectives of time depth, and with it the reliability of both climatic and human-scale events (Bailey 2007, 200–202; Irvine 2014). Because of this, educators and young people without formal training routinely struggle to place geological events such as the "Ice Age" or more distant cultural periods such as the "Stone Age" accurately in time, marking them as "a critical barrier to further learning" (Trend 2000, 317; also see Delgado 2013; Trend 1998, 2001). Similarly, it has been suggested that reporting the mid- and long-term impacts of climate change as happening at some point in "the future" leads to a comparably time-distant perspective that is perceived to be great enough that it confounds action (Giddens 2009 in Hudson et al. 2012).

Time is also a practical consideration for educators and science communicators. The realities of the European higher education systems mean that teaching staff are constrained by short time frames: how do we best use the 60 minutes of a lecture or a seminar to effectively communicate the issues faced by people during 60,000 or 6,000 years of changing climate and environment? Likewise, in science communication, is it possible to fully engage non-specialists with the specific nuances of our discipline inside a 60-second soundbite or 240 characters?

The second parameter is the environment. When teaching and communicating about deep-historic small-scale societies, climate change and significant climatic events are often presented first as "a key framing device" (cf. Henson 2016, 64 for the Late Pleistocene and Early Holocene)—a backdrop from which we build an understanding of subsistence practices, technology, and culture. For example, the "Ice Age" is, by its very name, entirely determined by its environmental characteristics—cold and, by implication, hard to live in (at least for temperate-dwelling societies). By contrast, the warming conditions of the Holocene may lead to the imagining of this time as a utopian "Garden of Eden", in which the abundance of temperate flora and fauna meant "no one is likely to have gone hungry" (Tilley 1996, 68, also see Pluciennik 1999, 665, cf. Sahlins 1972). However, as Wickham-Jones reminds us, small-scale societies from the European Mesolithic "were not happy hippies living in harmony with their environment" (Wickham-Jones 2010, 19–20; Henson 2021b)—environmental disasters did occur (Nyland, Chap. 7). This utopian imagery is a twentieth-century construct, ignoring several millennia of traditions established in cold-climate northern hemisphere regions north. In framing the environment first, the agency of past societies is negated. There is still a strong legacy of environmentally deterministic attitudes born of processual archaeology from the 1980s that drew on anthropological models such as optimal foraging theories and applied these to archaeological research design (cf. Arponen et al. 2019). Human adaptation in this regard is far from being seen as one of innovation and ingenuity, but rather one of survival, "driven by evolutionary imperatives" in which people existed as automatons (Davies et al. 2005, 282; Mithen 1991). We term these assumptions the "Arcadia paradigm" after Henson (2016, 2021a).

The third parameter is disconnections and incorrect assumptions about different lifeways. Perceptions of hunter-gatherers—both past and present—are often based on damaging, colonial images (Lavi et al. 2024), with the lives of past small-scale societies either being caricatured by the Hobbesian hypothesis of the state of nature as "nasty, brutish, and short" or depicted through an idealised lens of egalitarianism and romantic simplicity – the "noble savage" of Rousseau (e.g. Dettwyler 1991, 383)—another symptom of the "Arcadia paradigm" (Henson 2021b, 792–794). Although recent developments have increased general interest in, and awareness of, the different lifeways of past and present hunter-gatherers on the part of the public (Lavi et al. 2024), these attitudes underscore a disconnect between the natural and the social environment in contemporary industrialised societies (Chakrabarty 2009). Often these perspectives do not take account of the marginalised environments and concomitant challenges experienced by Indigenous communities placed under the same, narrow umbrella of "hunter-gatherer-fishers" (Lane 2014; Lavi and Friesem 2019). Additionally, these perspectives fail to recognise that Indigenous worldviews, cultures, and lifeways are intrinsically bound to their environment and landscape, social relations, and movement (Mangalasseri et al., Chap. 8; Temple et al., Chap. 10). The loss of, or displacement from, traditional lands as climate refugees through extreme weather events or inequitably considered mitigation efforts is argued to be an act of genocide. Instead, radical reconsideration of what constitutes Indigenous environmental rights and sovereignty is required (Tsosie 2007, 1674–1677).

6.2.2 Communication Example 1: School and University Teaching

> The inevitable question to university-based teachers of archaeology is: how will you incorporate ideas about sustainability in your programmes? A question for our students is: how will you respond to the challenge of sustainability as it applies to archaeology? The answers will determine the future of our field across the globe…
>
> (Carman 2016, 148)

When teaching content on deep history, educators need to consider the background of the audiences, the levels of their requisite knowledge, and their perceptions and beliefs. This is exemplified by the results of a survey of archaeology students and history teacher trainees at Rostock University, Germany, who took the course 'Introduction into Early Prehistory'. The content of the course spans from the earliest stone tool development in East Africa to the end of the Neolithic in northern Europe, with 70% of the lectures dealing with Pleistocene and Holocene hunter-gatherers in Africa and Eurasia.

A survey was conducted during the summer of 2021 for the classes of 2019 and 2020 to gain insight into students' background knowledge regarding past societies' lifeways and ancient climate dynamics. This also provided a better understanding of the opportunities to put the present climate crisis into perspective with past societies' ways of adapting, their survival, and failures. A total of 25 out of 85 students replied, and whilst this represents a small and biased data set, the answers are indicative in understanding communication outcomes.

Two questions were posed regarding the background knowledge of the course participants:

- How do you rank your knowledge about climatic changes during the last million years before visiting the class?
- How do you rank your knowledge about hunter-gatherer societies before visiting the class?

Almost half of the group replied that they completely lacked knowledge regarding the dynamics of climate variability (47%), and of hunter-gatherer communities

(53%), which was unexpected. The highest declared level of previous knowledge on the topics in this poll was "not good, not bad" for only 12% (climate), and 6% (hunter-gatherers), respectively. Consequently, only a few students were able to answer more precisely the additional qualitative question about which specific environmental/climatic dynamics they were aware of, before visiting the class. The students mostly answered in the direction of "A long time ago there was an ice age" (N = 11), whilst knowledge about distinct conditions like the Eemian or the Green Sahara was only claimed by one person. Furthermore, time length and distances were also mentioned as problematic: for example, one respondent stated, "I had no idea about the time depth of the 'ice age'".

The second part of the poll was about students' long-term recall of climatic impacts and human coping strategies discussed in the seminar, as well as personal evaluation, and whether the content of the course encompassed information enabling a deeper understanding of the current climate crisis.

The seminar covered a wide range of climate and environmental changes/stressors. These ranged from global (e.g. sea level changes) to regional (e.g. tsunamis), as well as long-term (e.g. glacial to interglacial transitions) to short-term (e.g. Heinrich Stadials/Bond events) climate and environmental impacts. Moreover, many of these include successful transition stories, as some examples from this volume demonstrate (Bradtmöller and Lübke, Chap. 11; Nyland, Chap. 7, Riede et al., Chap. 13). After one or two years, over 90% of the students still remembered at least one impact type. Glacier development was at the top of the list, followed by temperature fluctuations, sea level changes, and volcanism. Furthermore, 86% of the students still remembered at least one human coping strategy. These included, in decreasing order: (a) migration (to better habitats); (b) innovation (fire making, clothing, etc.); and (c) the adaptation of subsistence strategies.

The poll also asked the students if the content of the lectures encompassed information enabling a deeper understanding of the current climate crisis, to which 75% answered "yes". Those who supported the relevance of this topic were asked "Which content is of special importance?" The qualitative answers can be divided into two sets: the first is enhanced background knowledge, for example:

- Climate change is a constant issue on this planet (N = 15).
- Past climatic dynamics can be compared with current environmental processes to better understand what we can expect in the future (N = 5).
- I now know that we are currently living in an interglacial phase (N = 2).

The second is implications for an emotional dealing with the climate crisis, as stated by a smaller number of students (N = 7). This is captured best in the following two quotes: "We are still alive, what a surprise" and "To know that humans have successfully cope [sic] [with] many kinds of climate changes, makes me a little bit more relaxed concerning the current climate crisis".

Although the poll received a low response rate and therefore the responses are likely to be biased, there are three takeaways from the results. First, the students remembered very basic pieces of information, which strongly implies that our background knowledge is their bottom line of understanding. We need to bear this in mind when talking and teaching about ancient communities and climate dynamics in various contexts. Second, we see that differences in lifeways can hamper understanding and engagement, but this does not fully preclude acknowledging that information about past hunter-gatherers or climate change is useful for the broader public to situate present-day changes. Taking this further, certain perceptions—such as the quote above—suggest that an uncritical or uninformed view of the causes and impacts of climate change in both the past and present risks a degree of complacency about the adaptive capacity for change. As a species, climate, environment, and subsistence have shaped our body and brain size (Will et al. 2021), the complexity of cognition (Liebenberg 1990), and the nature of our social interactions (Spikins et al. 2021). This has taken millennia, and so the relevance of utilising deep or recent historical case studies in proposing solutions for the historically unanalogous event of the so-called Anthropocene is questionable (Jackson et al. 2022a; cf. Edgeworth et al. 2024; Steffen et al. 2002, 207–208). Balance is therefore required between narratives of past survival and resilience, and failure.

6.2.3 Communication Example 2: Online Social Media Interaction

Our second example comes from social media. The opportunity for an instant connection and direct exchange of information between scientists and the public that consume and/or participate in social media could increase accessibility, multivocality, and inclusivity of research (Fitzpatrick and Boyle 2024; Foell 2021).

Currently, approximately 5.44 billion people, i.e. 67.1% of the world's population (Kemp 2024, 26), use the Internet. Between 57 and 66% of 25- to 64-year-olds state that the main reason they use the Internet is to find information (Kemp 2024, 38 f.). Regardless of the different ranking schemes, the top three visited websites are usually Google, YouTube, and Facebook, with X (formerly Twitter), Instagram, and Wikipedia in the top ten most visited globally (Kemp 2024, 72).

The rapid advancement of the Internet towards Web 4.0, and its mobile accessibility through smartphones and smartwatches, allows billions of people to use the Internet and social media, all of whom can contribute to the information held on various platforms (Kemp 2024; cf. Pavelle and Wilkinson 2020). These different, though unfiltered, engagements have resulted in what has been described as a "data deluge" (Bonacchi and Moshenska 2015)—big data that can, for instance, be used to analyse how archaeological messages are publicly understood and used (Bonacchi 2017; Bonacchi and Krzyzanska 2019). One means of identifying relevant content for analysis in the constantly growing volume of data is metadata tags, or "hashtags" (#). These non-regulated, descriptive keywords relate to digital content on a specific topic and can be searched for and "followed" on specific platforms.

To investigate doomist vs activist narratives about climate change and the human past, hashtags relating to these topics on social media were analysed—assuming their use reflects communication about these topics. As exemplified below, increased communication does not necessarily reflect agreement with, or awareness of, the nuances and complexity of the terms used.

Several relevant hashtags were searched for using a free trial version of a web monitoring service (Brand24) between mid-August and mid-September 2021, with a manual search also being performed across platforms in 2021 and 2024. The platforms and a selection of productive hashtags searched are presented in Fig. 6.1 and Table1. Analysing hashtags requires methodical data mining approaches (Rueger et al. 2023), and there are a range of factors that impact the standardisation and comparability of data and results. The first is that hashtags are used differently across different social networks, from very frequently (Instagram) to rarely (Facebook). Despite the different patterns of use, hashtags should still show broadly similar trends, albeit on different levels. Secondly, analysis is compounded by different platforms publishing data on hashtags differently: for example, some provide the numbers of posts or videos containing the hashtag, whereas for others it is the people or channels posting about this hashtag; others report the number of views that posts with this hashtag receive. Some networks do not publish their data (anymore), and for others, data retention is limited to a time-limited window, e.g. seven days for X/Twitter. Furthermore, none of the platforms allow their users to search for combinations of hashtags, which is possible with other databases. Whilst searching for posts that combine hashtags about archaeology and climate change would be the most fruitful way to gauge public engagement with these topics, this is not straightforward. Hence, data mining approaches using AI need to collect significant amounts of data over longer periods of time to search for combinations and compare them.

The results of the monitoring analysis (Fig. 6.1) showed that the most active platforms where the selected hashtags were most frequently mentioned were X/Twitter, followed by TikTok and YouTube. It should be noted that the web monitoring service only monitored Instagram for business accounts and only analysed connected Facebook pages, which limited the results for these platforms.

Despite the heterogeneity of the data, a general trend in the types of hashtags used across platforms is visible. The monitoring survey (Fig. 6.1) showed that X/Twitter was the most frequently used platform for discussions about #ClimateChange and #ClimateCrisis, whereas TikTok and YouTube were comparably low. Conversely, the latter platforms represent a significantly larger number of users and are where users spend more of their time on average (Fig. 6.2). This may be due to the dynamic video nature of these platforms, which facilitates greater engagement than static photograph or text-based content (e.g. Habibi and Salim 2021).

The number of recorded uses of #ClimateCrisis (negatively connotated) was almost equal to #ClimateAction (positively connotated) and the neutrally connotated #ClimateChange, as well as discussions using #Archaeology on X/Twitter. The relatively equal use of #ClimateCrisis and #ClimateAction was also found on the other platforms. Looking at a selection of the posts, it became clear that posts containing #ClimateAction were usually an appeal to do something, rather than a strategy on how to face the anticipated #ClimateCrisis. Comparing the manually collected data with a ranking website (https://all-hashtag.com/hashtag-analytics.php) for 2021 and 2024

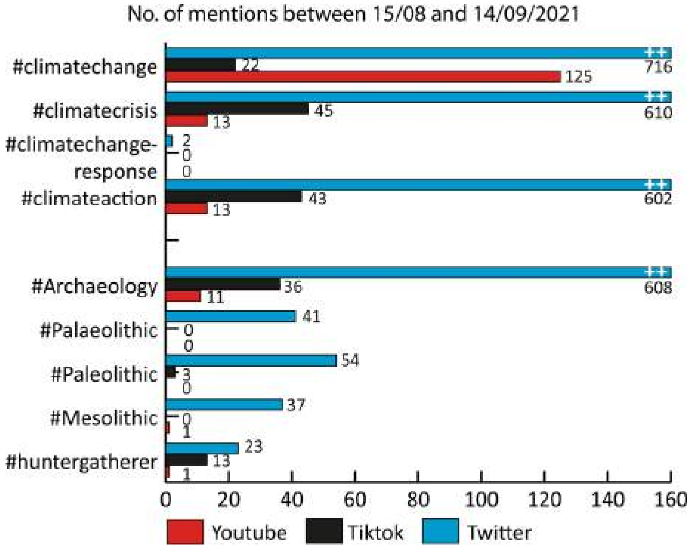

Fig. 6.1 Number of mentions on the searched platforms between 15 August and 14 September 2021 as analysed by a free trial of the monitoring service Brand24. Further platforms, on which the hashtags appeared occasionally, are left out for clarity reasons. For simpler visualisation, the X axis stops at n = 160

(Table 6.1), #ClimateCrisis has become supplemented by its plural, #ClimateCrises. It is not clear whether this shift to using the plural suggests a growing understanding that climate change is not a single event in human history, or refers to multiple catastrophic events. The plural #ClimateActions appears so rarely that it is excluded from the data set.

With regard to archaeological associated content, specifically relating to #Palaeolithic/#Paleolithic and #Mesolithic, the most frequently used platforms are X/Twitter and TikTok; again, YouTube rarely features. However, the manually collected data show that the numbers for the archaeological hashtags on YouTube have risen over time, with a substantial increase in the use of #Paleolithic between 2021 and 2024. However, caution is needed in interpreting this as representing a rise in the visibility of this archaeological period, as the American spelling of the word is often connected with "paleodiet"—a trending diet that promotes eating foods that hypothetically could be obtained by hunting and gathering, avoiding processed foods and many, but not all, domesticated crops (cf. Lavi et al. 2024). Nevertheless, the use of all other archaeologically associated hashtags searched for has also grown at exceptional rates.

Based on user profiles, the discussions involving #ClimateCrisis and #ClimateAction almost exclusively remained in academic circles on X/Twitter (Mohammadi et al. 2018; cf. Walter et al. 2019). Therefore, to generate more impactful outreach and a wider, engaged public audience of these discussions, other social media platforms appear to be better suited (e.g. Caspari 2022; Pavelle and Wilkinson 2021). From

Table 6.1 Trending of hashtags on different platforms at different times. Data checked on 7 September 2021 and 18 April 2024. Facebook has counted different numbers between 2021 (people posting about a hashtag) and 2024 (posts including a hashtag). x: number not given. *: no change between 2021 and 2024

	Ranking*	Facebook	Facebook	TikTok (accesses)	TikTok (accesses)	Instagram (posts)	Instagram (posts)
Hashtag (#) / Year		2021 (people)	2024 (posts)	2021	2024 (change to 2021)	2021	2024 (change to 2021)
#ClimateChange	6,126	4,18,172	~5.8 mill	~982.3 mill	~5.5 bill. (~560%)	~5.8 mill	~7.8 mill. (~135%)
#ClimateCrisis	5,48,453	77,658	8,06,412	~138.7 mill	~912.6 mill. (~658%)	~748,000	~1.1 mill. (~147%)
#ClimateCrises	×	×	15,738	×	1 mill. (+1 mill.)	1,000 >	5,000 > (~500%)
#ClimateAction	68,780	94.64	~1.1 mill	~39 mill	~2.3 bill. (~5.897%)	~982,000	~1.6 mill. (~163%)
#Archaeology	21,774	31,465	5,44,874	~164.4 mill	~1.2 bill. (~730%)	~1.4 mill	~1.8 mill. (~129%)
#Palaeolithic	×	×	1,000 >	×	~113,500 (+113,500)	1,000 >	5,221 (~522%)
#Paleolithic	2,58,448	1,198	10.908	~32,900	~18 mill. (~54,711%)	~47,300	~56,461 (~119%)
#Mesolithic	5,48,453	×	1,000 >	~782,900	~2.7 mill. (~345%)	5,000 >	~13,700 (~274%)
#HunterGatherer	2,00,318	4,169	28,661	~8.9 mill	~45.5 mill. (~511%)	~124,000	~129,000 (~104%)
#HunterGatherers	×	×	1,000 >	×	~730,400 (+730,400)	1,000 >	5,000 > (~500%)

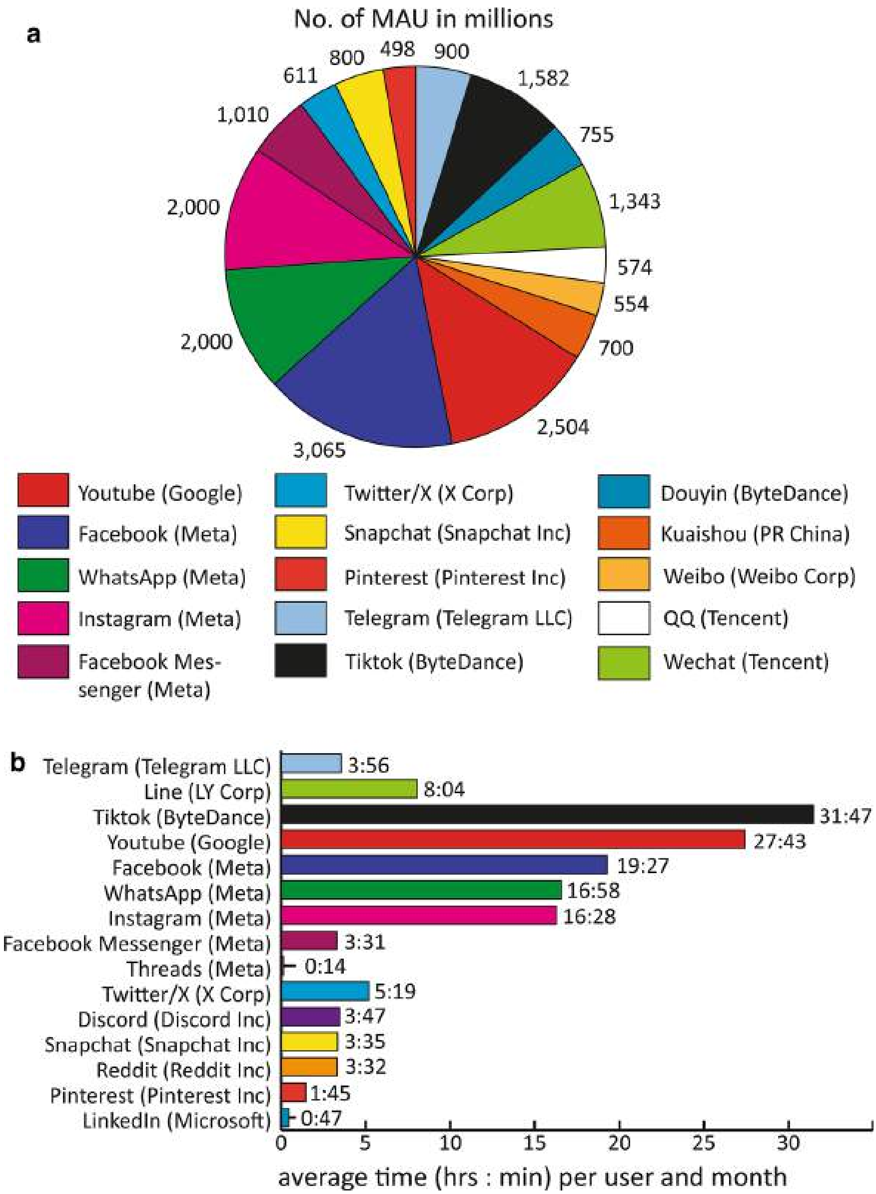

Fig. 6.2 (**a**) Proportions of social media platforms by global active users (GAU) and (**b**) average time per user and month based on data collected from 1 October until 31 December 2023 (Kemp 2024, 201, 210)

the data, the growing use of TikTok between 2021 and 2024 suggests this platform could be the most impactful.

Overall, the data show that the climate crisis and the call for climate action have arrived in public discourse on social media platforms. However, there is still a void in terms of awareness, knowledge, and integration regarding archaeology's deep time archives in this context. Creating greater awareness around the intersection between archaeology and the diverse examples of climate actions can thrive from an already good visibility of archaeology on social media, and this engagement can help present positive frames from (deep) history against doomist narratives.

The influence of social media on most people's everyday lives makes it a powerful tool for science communication, even if its effects as such are still difficult to assess (cf. Kappel and Holmen 2019; Mavrodieva et al. 2019). This is of particular importance in academia as funding bodies require dissemination of research results to both academic and lay audiences. However, effective science communication and public media—particularly social media—require a level of engagement and training that few academics can commit to. A substantial gap exists between research publications and corresponding public outreach, which necessitates greater consideration in project planning and legacy to effectively make this knowledge transfer (Dietrich and Notroff 2019). In doing so, there is greater opportunity to engage with the public in ways that are relatable and emotive, and which can have the greatest impact to inspire action (Perry 2019).

Nevertheless, effecting small changes is possible by offering time and expertise, without requiring media savviness and viral video content. Wikipedia is a platform that is rarely included in the statistics but is known by almost everyone with Internet access (Nevel and Moore 2024). This Wiki-based online encyclopaedia is maintained by volunteers and is not a platform of social exchange but one of research discourse through its editorial system. Although this system is open to numerous biases and is often maligned in academic contexts, it is an important information source, with a total of 24,687,776,934 page views in the month of May 2024 (Wikimedia Statistics 2024), for example. Academics are increasingly engaging in writing, correcting, and/or supplementing information from their field of expertise to make articles accurate and informative starting points for further in-depth research. In short, here a peer-review system exists for a significant amount of knowledge that is open for engagement.

6.3 Being Homo Narrans

6.3.1 The Power of Storytelling—Narrative Pedagogies and the Archaeological Imagination

> The archaeological imagination frames our engagement with remains of the past, frames our perception of the past, frames the possibility of making sense of the past.

(Shanks 2012, 48)

Storytelling is a universally human cultural concept (Boyd 2009; Ranke 1967). It is powerful and can be deeply emotive (Dubourg and Baumard 2021; Dillon and Craig 2022; Gottschall 2012; Kristensen et al. 2020). Storytelling as a means of knowledge transmission and informal teaching is utilised by Indigenous societies to codify learning from experience (personal, ancestral), situating histories (recent, origin), geographies, subsistence, and sociality (Cajete 2017; Lew-Levy et al. 2017; Mithen 2006; Sugiyama 2021, 2022). In Western pedagogy, storytelling is an effective, and sometimes disruptive (sensu Freire 1974), teaching method in a range of disciplines (e.g. Barber 2016; Coulter et al. 2007; Deniston-Trochta 2003; Garcia and Rossiter 2010; Landrum et al. 2019; Phillips 2012). It is organisational, allowing us to order chronologies and events to frame an understanding of how these were experienced (Cronon 1992; Nyland, Chap. 7).

Storytelling by archaeologists—both fictive and in research—has a long history (van Helden & Witcher 2020). When used responsibly in history and archaeology, it is a powerful and effective pedagogic tool; although not without flaws, it can be used to challenge dominant binaries of "collapse" and "resilience" narratives (e.g. Fitzsimons 2022; Jackson et al. 2022a, 2022b; Kristensen et al. 2020; Perry 2019; Peuramaki-Brown 2020; Praetzellis 2014; Rockman and Maase 2017). Recognising its value is also an important step in decolonial practice to equally situate different perspectives and world views by creating opportunities for empathy and multivocality, where we can mesh voices with interdisciplinary approaches, and alter perceptions of others and otherness (e.g. Archibald 2008; Atalay 2008; Cajete 2017; Hatcher et al. 2009; Hearne 2019; Porr 2021; Steeves 2021).

However, there is a risk that narratives can lead to ideas of romantic escapism (cf. Lavi et al. 2024). Students have reported to one of the authors (SP) that they enjoy studying the Mesolithic because it transports them back to a time when things are perceived to have been "better" or different (also experienced by the public in engaging with archaeological landscapes, e.g. Nolan 2019, 167). This has been thrown into sharp relief by the COVID-19 pandemic, as well as wider anxieties about the future. It is here that caution and critical consideration are necessary regarding human–environment relations in the past and present, to prevent projections of our own assumptions onto the past, appropriation of the interpretative prerogative ("Deutungshoheit"), unhelpful generalisations, or legitimisation of passiveness in view of current events (Henson 2021b; Rowland 2004). This can be countered by embedding literary sources that critically navigate the complex interactions between anthropology and archaeology, the deep past, the recent past, and the current world, and embed Indigenous perspectives about the effects of climate change across these time frames (Halfon and Barkai 2020; Nunn 2016; Nunn and Cook 2022; also see Elliott and Warren 2023 and comments and replies). This enables the construction of transformative narratives.

6.3.2 Telling Transformative Narratives as an Alternative Approach

> An overabundance of catastrophic near future scenarios largely prevents imagining the necessary transition toward a socially responsible and ecologically mindful future as a non-violent and non-disastrous process.
>
> (Mackenthun 2021, 1)

To engage wider audiences in responding to sustainability challenges, whilst addressing legitimate existential and emotional anxieties, Bergdahl and Lagmann propose the creation of "educational environments in the public sphere", termed "pedagogical publics" (Bergdahl and Lagmann 2022). They suggest three qualities that this environment must consider to hold people together: "(a) making room for new rituals for sustainable living to be developed in order to offer a sense of permanence; (b) inviting *narratives that can frame sustainability challenges in more supportive and positive registers*; and (c) reinstating a certain kind of intergenerational difference that serves to give back hopes and dreams to both adults and children in time of climate change" (Bergdahl and Lagmann 2022, 412, *emphasis added*). Within the theme of this paper, archaeology can make a significant contribution to the second of these aspects. The longue durée perspective that archaeology can provide within conversations about present-day climate change, coupled with the telling of "untold stories" of the past, can harness an understanding of the delicacy of the environment, the resilience of people, and alternative lifeways. It provides a "narrative anchor" to mark change over time that can challenge existing issues whilst avoiding a sense of passiveness and doomism, thus engendering "supportive frames" and a willingness to act and adapt (Bergdahl and Lagmann 2022, 413–414; Burke et al. 2021; Stoknes 2014, 167–168).

These supportive frames may be introduced by way of transformative or transition narratives. Transformative narratives are described as "bottom-up narratives that tell a positive and engaging story, articulate a vision of 'where we want to go' and provide solutions for attaining this vision, rather than articulating problems to avoid" (Hinkel et al. 2020, 503). "Social-ecological transition stories are part of mankind's cultural heritage" (Mackenthun 2021, 19). They generate hope, which "form[s] an alternative archive for imagining the near future" (Mackenthun 2021, 8) through positive gestures and actions amid crisis that ultimately "may help overcome the present paralysis in generating in readers a positive disposition towards behavioural change" (Mackenthun 2021, 18, cf. Bain et al. 2016; Geiger et al. 2021).

Within archaeology, telling transformative narratives by creatively harnessing our research data and translating them using narrative approaches enables us to present the deep past in an accessible way for people to engage with it. This has a twofold effect. First, it begins to dismantle long-held binary stereotypes concerning small-scale hunter-gatherer lives in combating the "otherness" implied by the Arcadia paradigm, by focussing precisely on the humanness of the past (Hamilakis 2004). Second, it can counteract feelings of helplessness or despair. Nolan (2019, 176) suggests how the types of narratives associated with British prehistoric remains "have the capacity to prompt existential thought", via therapeutic impacts of the historic environment. Although in Nolan's example this pertains to interactions in a physical landscape, the similarly transformative and immersive nature of stories may have similar benefits (Perry 2019).

By its nature, there is little within the deep-historic archaeological record that informs on the psychological or emotional effects of significant climatic or environmental events, and their impact on animal decline, or the disappearance of known cultural landscapes (Halfon and Barkai 2020, 26–27; Leary 2009; 2015, 94). Nevertheless, when told through engaging narratives of characters, actions, and happenings (Henson 2021a), hunter-gatherer pasts become alive with people that are relatable and can be recognised through a spectrum of experiences, in which we may "enjoy and suffer the full range of human emotion" (Mithen 1991, 14). They are active agents within their environment, and not simply at the mercy of it. Equipping oneself with emotional awareness of the anxieties people are experiencing about climate change in the present may facilitate a recognition that people did, in all probability, experience similar emotions towards rapid climatic and environmental change, for example, at the end of the Pleistocene (Halfon and Barkai 2020; Wickham-Jones 2002). Introducing positively framed experience through narrative-based science communication has the potential to improve mental health and engender empathy and compassion that may activate pro-future environmental behaviours (Kondrat and Teater 2009; Mackenthun 2021; Oliver et al. 2012). In this way, positive narratives could open new perspectives towards creating an equitable future.

Many of these sentiments resonate with the practical action-based origins of resilience theory (Bradtmöller et al. 2017, 11). However, rather than utilising ill-defined and generalising ("resilience", "adaptation") or rigid ("collapse") narratives, transition narratives provide a greater capacity to capture nuances that place human action at the fore. To use Bradtmöller et al.'s example, an environmentally related "collapse event" described as such implies that it was imposed on the society to which it is attributed, and this is the end of the story. By contrast, situating environmental change within a transitional narrative enables such an event to be "better interpreted…as well [-] engaged periods of reorganisation" (Bradtmöller et al. 2017, 12). Such narratives may be easier to construct from a historical perspective (see Larsson, Chap. 9), but it is also possible from the deep past (see Kilhavn, Chap. 12, and Nyland, Chap. 7).

6.4 Our Conclusion: Harnessing Hope—Supportive Frames for a Positive Future

> Natural climate archives… and the paleontological and archaeological records offer unique opportunities for observing, measuring, and understanding how humans have responded to a wide range of climate events in the past, forming a sound basis for predicting how climate change could transform our lives in the future and offering a range of possible solutions…

(Burke et al. 2021, 1)

Following Burke et al. (2021), we conclude by offering several suggestions that can be implemented by the archaeological community through their various mechanisms of science communication, to create supportive frames that may inspire hope and activism for a positive future. These solutions involve the use of transformative narratives, whereby the "hidden" treasure from the past can be harnessed to demonstrate its increasing importance for our future positive existence. We can divide this into three spheres of implication:

1. Processual implications for modern dynamics: These encompass examples of pure analogies via narratives, such as using humans' multiple migration histories to explain current migration dynamics, or using examples of "too late/too little" adaptation scenarios for understanding but also challenging the current Zeitgeist. Additionally, several narratives can be combined using real past knowledge implementation, like socio-economic reorganisation by present-day urban farming, or subsistence adaptation strategies such as "less meat" campaigns.
2. Emotional narratives that encompass more general narratives regarding our perception of the current climate crisis: examples of adaptation and reorganisation are not abnormal or unusual patterns but are implemented in basic human characteristics like social learning (Morgan et al. 2022). As previously mentioned by the students, yes, we are still alive and this is because we have the capacity for change, but only to a certain extent. Incorporating narratives leaves space for multivocal perspectives, ontologies, and knowledge, which is of special importance for Indigenous understanding of climates (e.g. Kuptana 1996).
3. Dismantling barriers between the experts and the public, to build and maintain archaeological consciousness in contemporary society (Kozicka and Wielocha 2020). This means including public or communal archaeology in the widest sense (cf. Bonacchi and Moshenska 2015; Rivera-Collazo et al. 2020) to re-evaluate the way archaeological narratives and approaches are presented.

There are opportunities for almost everybody to create pathways to societal impact in a positive way. To do this as archaeologists and anthropologists, a shift in the status quo is needed, as captured by Dietrich and Notroff (2019) and expanded upon here:

- Embed science communication into project planning in all areas, with public outreach fully work loaded into staff time. This can take any form and use any platform. For instance, instead of telling students not to use Wikipedia, tell them to improve it! This may require taking a deep breath, and we may need, as a first step, more reliable analyses regarding which platforms attract the relevant audience, and how engagement is initiated, maintained, and evaluated. Bonacchi (2018) reminds us: "Regardless of the route we choose, it is vital to remember that the public will interpret what we say based on their own experience, knowledge and inclinations" (Bonacchi 2018, 1660). As we have experienced with our students, our background knowledge is their baseline.
- School engagement is a particularly important expansion of the previous point. By signing up for initiatives such as Inspiring the Future (UK), Skype a Scientist

(US), or Rent a Scientist (DE), archaeologists can get directly into the classroom to engage with children and young people. Developing narrative-based school resources is also vital to equip teachers with archaeologically accurate material. Successful examples include those produced by Don Henson for the Star Carr project (Star Carr Project 2023), and the Forestry Commission Scotland Outdoor Archaeological Learning and period-specific learning resources, co-produced by archaeologists and science communicators (Forestry and Land Scotland 2023).
- Finally, storytelling creates empathy and mutual understanding, with invested emotional bonds and memories that can be used to reinforce a sense of identity and place (Cajete 2017; Landrum et al. 2019; Phillips 2012). Co-production of narrative-based outputs (beyond classroom materials) between scientists and creatives has the potential for greater reach and impact using a holistic approach—one that considers the scale of the deep human past and people's long-standing connection to place. Truly multivocal narratives are needed to drive future strategy that is just and equitable.

Every scientist can contribute to changing the public perception, improving our pedagogic impact, and increasing climate communication by addressing contemporary concerns using evidence from the past. Transforming science communication through supportive frames enables young people to become active in equipping themselves with the critical skills to question the singularity of Western viewpoints, train their empathy for people perceived as others, and recognise that by effectively uniting the human and natural environmental spheres, this opens new pathways to addressing contemporary environmental issues relevant to whatever roles in society they have now, or may take, to help create a future positive existence (Cobb and Croucher 2016, 962; Handley 2015, 162; Hector 2003).

> Everything works out in the end. If it does not, it is because it has not yet come to an end.
>
> Fernando Sabino

References

Archibald J-A (2008) Indigenous storywork: educating the heart, mind, body, and spirit. University of British Columbia Press, Vancouver Canada

Arponen VPJ, Dörfler W, Feeser I et al (2019) Environmental determinism and archaeology. Understanding and evaluating determinism in research design. Archaeol Dialogues 26:1–9

Atalay S (2008) Multivocality and Indigenous archaeologies. In: Habu J, Fawcett C, Matsunaga JM (eds) Evaluating multiple narratives: beyond nationalist, colonialist, imperialist archaeologies. Springer, New York, pp 29–44

Bailey G (2007) Time perspectives, palimpsests and the archaeology of time. J Anthropol Archaeol 26:198–223

Bain PG, Milfont Taciano L et al (2016) Co-benefits of addressing climate change can motivate action around the world. Nat Clim Chang 6:154–157

Barber JF (2016) Digital storytelling: new opportunities for humanities scholarship and pedagogy. Cogent Arts & HumIties 3(1):1181037

Basch CH, Yalamanchili B, Fera J (2021) #Climate change on TikTok: a content analysis of videos. J Community Health 47:163–167
Beder S (2014) Lobbying, greenwash and deliberate confusion: how vested interests undermine climate change. In: Huang MC-T, Huang RR-C (eds) Green thoughts and environmental politics: green trends and environmental politics. Asia-seok Digital Technology, Taipei, pp 297–328
Bergdahl L, Langmann E (2022) Pedagogical publics: creating sustainable educational environments in times of climate change. Eur Educ Res J 21(3):405–418
Berhe AA (2020) Communicating climate change science to diverse audiences. In: Henry C, Rockström J, Stern N (eds) Standing up for a sustainable world: voices of change. Edward Elgar Publishing, Cheltenham, UK and Northampton, MA, pp 376–383
Bierski K (2016) Recovering mental health across outdoor places in Richmond, London: tuning, skill and narrative. Health Place 40:137–144
Bonacchi C (2017) Digital media in public archaeology. In: Moshenska G (ed) Key concepts in public archaeology. UCL Press, London, pp 60–72
Bonacchi C, Krzyzanska M (2019) Digital heritage research re-theorised: ontologies and epistemologies in a world of big data. Int J Herit Stud 25:1235–1247
Bonacchi C, Moshenska G (2015) Critical reflections on digital public archaeology. Internet Archaeol 40(7):1
Boyd B (2009) On the origin of stories: evolution, cognition, and fiction. Harvard University Press, Cambridge MA
Boykoff MT (2011) Who speaks for the climate? Making sense of media reporting on climate change. Cambridge University Press, Cambridge
Bradtmöller M, Grimm S, Riel-Salvatore J (2017) Resilience theory in archaeological practice – an annotated review. Quatern Int 446:3–16
Burgess J (1990) The production and consumption of environmental meanings in the mass media: a research agenda for the 1990s. Trans Inst Br Geogr 15(2):139–161
Burke A, Peros MC, Wren CD et al (2021) The archaeology of climate change: the case for cultural diversity. Proc Natl Acad Sci 118(30):e2108537118
Cajete GA (2017) Children, myth and storytelling: an Indigenous perspective. Glob Stud Child 7(2):113–130
Capstick S, Nash N, Whitmarsh L et al (2022) The connection between subjective wellbeing and pro-environmental behaviour: individual and cross-national characteristics in a seven-country study. Environ Sci Policy 133:63–73
Carman J (2016) Educating for sustainability in archaeology. Archaeol: J World Archaeol Congr 12:133–152
Caspari G (2022) Instagram as a tool for archaeological science communication. Digit Appl Archaeol Cult Herit 24:e00219
Chakrabarty D (2009) The climate of history: four theses. Crit Inq 35(2):197–222
Chapman DA, Lickel B, Markowitz EM (2017) Reassessing emotion in climate change communication. Nat Clim Chang 7:850–852
Chirikure S (2021) Making archaeology relevant to global challenges: a global south perspective. Antiquity 95(382):1073–1077
Cobb H, Croucher K (2016) Personal, political, pedagogic: challenging the binary bind in archaeological teaching, learning and fieldwork. J Archaeol Method Theory 23:949–969
Cobb H, Croucher K (2020) Assembling archaeology: teaching, practice, and research. Oxford University Press, Oxford
Coulter C, Michael C, Poynor L (2007) Storytelling as pedagogy: an unexpected outcome of narrative inquiry. Curric Inq 37(2):103–122
Cronon W (1992) A place for stories: nature, history, and narrative. J Am Hist 78(4):1347–1376
Davies P, Robb J, Ladbrook D (2005) Woodland clearance in the Mesolithic: the social aspects. Antiquity 79(304):280–288
Davis DS (2020) Studying human responses to environmental change: trends and trajectories of archaeological research. Environ Archaeol 25(4):367–380

Degroot D, Anchukaitis K, Bauch M et al (2021) Towards a rigorous understanding of societal responses to climate change. Nature 591:539–550

Delgado C (2013) Navigating deep time: landmarks for time from the Big Bang to the present. J Geosci Educ 61(1):103–112

Denisova A (2023) Climate doomism is bad storytelling – hope is much more effective at triggering action, The Conversation. 28 March 2023. https://theconversation.com/climate-doomism-is-bad-storytelling-hope-is-much-more-effective-at-triggering-action-202401 Accessed 06 July 2023

Deniston-Trochta GM (2003) The meaning of storytelling as pedagogy. Vis Arts Res 29(57):103–108

Dettwyler KA (1991) Can paleopathology provide evidence for "compassion"? Am J Phys Anthropol 84(4):375–384

Dickson ZP, Hobolt S B (2024) Going against the grain: climate change as a wedge issue for the radical right. Comparative Political Studies in press: 00104140241271297

Dietrich O, Notroff J (2019) Hashtag SciComm: communicating archaeology in a post-factual age. Report on Session 371 at the 24th EAA Annual Meeting in Barcelona Spain. Eur Archaeol 59:17–19

Dillon S, Craig C (2023) Storylistening: how narrative evidence can improve public reasoning about climate change. Wires Clim Change 14:e812

Dubourg E, Baumard N (2022) Why imaginary worlds? The psychological foundations and cultural evolution of fictions with imaginary worlds. Behav Brain Sci 45:e276

Dunlop L, Rushton EAC (2022) Putting climate change at the heart of education: is England's strategy a placebo for policy? Br Edu Res J 48:1083–1101

Edgeworth M, Benjamin J, Clarke B et al (2014) Archaeology of the Anthropocene. J Contemp Archaeol 1(1):73–132

Edgeworth M, Bauer AM, Ellis EC et al (2024) The Anthropocene is more than a time interval. Earth's Future 12:e2024EF004831

Elliott B, Warren GM (2023) Colonialism and the European Mesolithic. Nor Archaeol Rev 56:71–89

Ereaut G, Segnit N (2006) Warm words. How are we telling the climate story and can we tell it better? Institute for Public Policy Research, London

Feinberg M, Willer R (2011) Apocalypse soon? Dire messages reduce belief in global warming by contradicting just-world beliefs. Psychol Sci 22:34–38

Fitzpatrick A, Boyle T (2024) How to provide outreach that is in reach. An examination of trends towards multivocality and accessibility in digital public archaeology. In: Richardson L-J, Reinhard A, Smith N (eds) The Routledge handbook of archaeology and the media in the 21st century, 1st edn. Routledge, New York, pp 273–284

Fitzsimons W (2022) Social responses to climate change in a politically decentralized context: a case study from East African history. In: Izdebski A, Haldon J, Filipkowski P (eds) Perspectives on public policy in societal-environmental crises: what the future needs from history. Springer, Cham, Switzerland, pp 145–159

Foell J (2021) Social media science communication is a nonstop academic conference for all. Nat Hum Behav 5:812–812

Forestry and Land Scotland (2023) Outdoor archaeological learning. https://forestryandland.gov.scot/what-we-do/biodiversity-and-conservation/historic-environment-conservation/learning Accessed 07 July 2023

Freire P (1974) Education for critical consciousness. Sheed & Ward, London

Frost NR (2000) Environmental education: perspectives for archaeology. In: Smardz KE, Smith SJ (eds) The archaeology education handbook: sharing the past with kids. AltaMira Press, Walnut Creek, CA, pp 377–393

Garcia P, Rossiter M (2010) Digital storytelling as narrative pedagogy. Society for Information Technology & Teacher Education International Conference. Association for the Advancement of Computing in Education (AACE), San Diego, CA, pp 1091–1097

Geiger N, Swim JK, Gasper K et al (2021) How do I feel when I think about taking action? Hope and boredom, not anxiety and helplessness, predict intentions to take climate action. J Environ Psychol 76:101649

Geiger N, Dwyer T, Swim JK (2023) Hopium or empowering hope? A meta-analysis of hope and climate engagement. Front Psychol 14:1139427

Giddens A (2009) The politics of climate change. Polity Press, Cambridge

Goodykoontz A (2022) The spread of 'climate doom' on TikTok is hurting the climate justice movement – and Gen Z, USA Today, 22 September 2022. https://eu.usatoday.com/story/opinion/voices/2022/09/22/climate-doom-tiktok-gen-z-eco-anxiety/8004862001/ Accessed 17 February 2023

Gottschall J (2012) The storytelling animal: how stories make us human. Houghton Mifflin Harcourt, Boston MA

Habibi SA, Salim L (2021) Static vs. dynamic methods of delivery for science communication: a critical analysis of user engagement with science on social media. PLoS ONE 16(3):e0248507

Halfon E, Barkai R (2020) The material and mental effects of animal disappearance on Indigenous hunter-gatherers, past and present. Time and Mind 13(1):5–33

Hamilakis Y (2004) Archaeology and the politics of pedagogy. World Archaeol 36(2):287–309

Handley F (2015) Developing archaeological pedagogies in Higher Education: addressing changes in the Community of Practice of archaeology. Hist Environ: Policy & Pract 6(2):156–166

Hase V, Mahl D, Schäfer MS et al (2021) Climate change in news media across the globe: an automated analysis of issue attention and themes in climate change coverage in 10 countries (2006–2018). Glob Environ Chang 70:102353

Hatcher A, Bartlett C, Marshall A et al (2009) Two-eyed seeing in the classroom environment: concepts, approaches, and challenges. Can J Sci Math Technol Educ 9:141–153

Hautea S, Parks P, Takahadhi B et al (2021) Showing they care (or don't): affective publics and ambivalent climate activism on TikTok. Social Media + Society, April-June, pp 1–14

Hearne R (2019) 'The archaeological imagination': new ways of seeing for mental health recovery. In: Darvill T, Barrass K, Drysdale L, Heaslip V, Staelens Y (eds) Historic landscapes and mental wellbeing. Archaeopress, Oxford, pp 153–162

Hector S (2003) Archaeology and young students: making the environmental education connection. Proc Soc Calif Archaeol 16:9–12

van Helden D, Witcher R (2020) Historical fiction and archaeological interpretation. Introduction. In: van Helden D, Witcher R (eds) Researching the archaeological past through imagined narratives: a necessary fiction. Routledge, Abingdon, Oxon, pp 1–37

Henson D (2021a) Elusive, perplexing, and peculiar? Presenting the Mesolithic to twenty-first century audiences. In: Borić D, Antonović D, Mihailović B (eds) Foraging assemblages, vol 2. Serbian Archaeological Society, Belgrade, pp 785–788

Henson D (2021b) Public perceptions and engagement with the Jomon and the Mesolithic. In: Borić D, Antonović D, Mihailović B (eds) Foraging assemblages, vol 2. Serbian Archaeological Society, Belgrade, pp 789–795

Henson D (2016) The Meso-what? the public perceptions of the Mesolithic, Unpublished PhD thesis, Department of Archaeology, University of York

Hickman C, Marks E, Pihkala P et al (2021) Climate anxiety in children and young people and their beliefs about government responses to climate change: a global survey. Lancet Planet Health 5:e863–e783

Hinkel J, Mangalagiu D, Bisaro A et al (2020) Transformative narratives for climate action. Clim Change 160:495–506

Hoika J (1998) Archäologie, Vorgeschichte, Urgeschichte, Frühgeschichte, Geschichte. Ein Beitrag zu Begriffsgeschichte und Zeitgeist. Archäologische Informationen 21:51–86

Hornsey MJ (2021) The role of worldviews in shaping how people appraise climate change. Curr Opin Behav Sci 42:36–41

Hornsey MJ, Fielding KS (2017) Attitude roots and Jiu Jitsu persuasion: understanding and overcoming the motivated rejection of science. Am Psychol 72:459–473

Hornsey MJ, Harris EA, Bain PG et al (2016) Meta-analyses of the determinants and outcomes of belief in climate change. Nat Clim Chang 6:622–626
Hudson MJ, Aoyama M, Hoover KC et al (2012) Prospects and challenges for an archaeology of global climate change. Wires Clim Change 3:313–328
Irvine RDG (2014) Deep time: an anthropological problem. Soc Anthropol/Anthropol Soc 22(2):157–172
Jackson RC, Dugmore AJ, Riede F (2018) Rediscovering lessons of adaptation from the past. Glob Environ Chang 52:58–65
Jackson R, Arneborg J, Dugmore A et al (2022a) Success and failure in the Norse North Atlantic: origins, pathway divergence, extinction and survival. In: Izdebski A, Haldon J, Filipkowski P (eds) Perspectives on public policy in societal-environmental crises: what the future needs from history. Springer, Cham, Switzerland, pp 247–272
Jackson R, Hartman S, Trump B, Crumley C, McGovern T, Linkov I, Ogilvie AEJ (2022b) Disjunctures of practice and the problems of collapse. In: Izdebski A, Haldon J, Filipkowski P (eds) Perspectives on public policy in societal-environmental crises: what the future needs from history. Springer, Cham, Switzerland, pp 75–108
Kappel K, Holmen SJ (2019) Why science communication, and does it work? A taxonomy of science communication aims and a survey of the empirical evidence. Front Commun 4:55
Kaufman B, Kelly CS, Vachula RS (2018) Palaeoenvironment and archaeology provide cautionary tales for climate policymakers. Geogr Bull 59(1):5–24
Kemp S (ed) (2024) Digital 2024 April global statshot report. https://datareportal.com/reports/digital-2024-april-global-statshot Accessed 01 July 2024
Koch W (2022) Reichweiten von Social-Media_Plattformen und Messengern. Ergebnisse der ARD/ZDF-Onlinestudie 2022. Media Perpektiven 10:471–478
Kondrat DC, Teater B (2009) An anti-stigma approach to working with persons with severe mental disability: seeking real change through narrative change. J Soc Work Pract 23(1):35–47
Kozicka M, Wielocha E (2020) Sharing stories: students' experiences in archaeological education. 21st Century Pedagogy 4:23–28
Kristensen TJ, Henry M, Brownlee K et al (2020) Grand challenge no. 5: communicating archaeology outreach and narratives in professional practice. J Archaeol Educ 4(3). https://digitalcommons.library.umaine.edu/jae/vol4/iss3/6 (accessed 20/03/2023)
Kuptana R (1996) Inuit perspectives on climate change. Statement by Kuptana, Rosemarie, president of the Inuit Circumpolar Conference to the second conference of the parties to the United Nations framework convention on climate change, Geneva, 16–19 July 1996. The Center for World Indigenous Studies. https://www.cwis.org/document/inuit-perspectives-on-climate-change/ Accessed 04 July 2024
Lamb WF, Mattioli G, Levi S et al (2020) Discourses of climate delay. Glob Sustain 3:e17
Landrum RE, Brakke K, McCarthy MA (2019) The pedagogical power of storytelling. Scholarsh Teach Learn Psychol 5(3):247–253
Lane PJ (2014) Hunter-gatherer-fishers, ethnoarchaeology, and analogical reasoning. In: Cummings V, Jordan P, Zvelebil M (eds) The Oxford handbook of the archaeology and anthropology of hunter-gatherers. Oxford University Press, Oxford, pp 104–150
Lane PJ (2015) Archaeology in the age of the Anthropocene: a critical assessment of its scope and societal contributions. J Field Archaeol 40(5):485–498
Larkin J, Clark K, Baxter I et al (2013) Public archaeology response to 'The future care of our nation's heritage' debate. Public Archaeol 12(3):200–210
Lavi N, Friesem DE (eds) (2019) Towards a broader view of hunter-gatherer sharing. McDonald Institute for Archaeological Research, Cambridge
Lavi N, Rudge A, Warren G (2024) Rewild your inner hunter-gatherer: how an idea about our ancestral condition is recruited into popular debate in Britain and Ireland. Curr Anthropol 65(1):72–99
Leary J (2009) Perceptions of and responses to the Holocene flooding of the North Sea lowlands. Oxf J Archaeol 28(3):227–237

Leary J (2015) The remembered land. Bloomsbury, London & New York
Leichenko R, O'Brien K (2020) Teaching climate change in the Anthropocene: an integrative approach. Anthropocene 30:100241
Leka J, Furnham A (2024) Correlates of climate change skepticism. Front Psychol 15:1328307
León B, Negredo S, Erviti MC (2022) Social engagement with climate change: principles for effective visual representation on social media. Climate Policy 22:976–992
Lew-Levy S, Reckin R, Lavi N et al (2017) How do hunter-gatherer children learn subsistence skills? A meta-ethnographic review. Hum Nat 28(4):367–394
Liebenberg L (1990) The art of tracking: the origin of science. David Philip Publishers, Claremont, South Africa
Lucas G (2005) The archaeology of time. Routledge, London
Mackenthun G (2021) Sustainable stories: managing climate change with literature. Sustainability 13:4049
Mann ME, Hassol SJ, Toles T (2017) Doomsday scenarios are as harmful as climate change denial. The Washington Post, 12 July 2017. https://www.washingtonpost.com/opinions/doomsday-scenarios-are-as-harmful-as-climate-change-denial/2017/07/12/880ed002-6714-11e7-a1d7-9a32c91c6f40_story.html Accessed 03 March 2023
Mavrodieva A, Rachman OK, Harahap VB, Shaw R (2019) Role of social media as a soft power tool in raising public awareness and engagement in addressing climate change. Climate 7(10):122
Mithen S (1991) 'A cybernetic wasteland'? Rationality, emotion and Mesolithic foraging. Proc Prehist Soc 57(2):9–14
Mithen S (2006) Ethnobiology and the evolution of the human mind. J Roy Anthropol Inst 12:45–61
Mohammadi E, Thelwall M, Kwasny M et al (2018) Academic information on Twitter: a user survey. PLoS ONE 13:e0197265
Morgan TJH, Suchow JW, Griffiths TL (2022) The experimental evolution of human culture: flexibility, fidelity and environmental instability. Proc R Soc B: Biol Sci 289(1986):28920221614
Nerlich B, Koteyko N, Brown B (2010) Theory and language of climate change communication. Wires Clim Chang 1(1):97–110
Nevel R, Moore L (2024) Wikipedia and archaeology. In: Richardson L-J, Reinhard A, Smith N (eds) The Routledge handbook of archaeology and the media in the 21st century. Routledge, New York, pp 195–213
Newman TP, Nisbet EC, Nisbet MC (2018) Climate change, cultural cognition, and media effects: worldviews drive news selectivity, biased processing, and polarized attitudes. Public Underst Sci 27(8):985–1002
Nolan C (2019) Prehistoric landscapes as transitional space. In: Darvill T, Barrass K, Drysdale L, Heaslip V, Staelens Y (eds) Historic landscapes and mental wellbeing. Archaeopress, Oxford, pp 163–178
Nunn PD (2016) Australian Aboriginal traditions about coastal change reconciled with Postglacial sea-level history: a first synthesis. Environ Hist 22(3):393–420
Nunn PD, Cook M (2022) Island tales: culturally-filtered narratives about island creation through land submergence incorporate millennia old memories of postglacial sea-level rise. World Archaeol 54(1):29–51
Ofcom (2022) Adults' media use and attitudes report, London: office of communications. https://www.ofcom.org.uk/__data/assets/pdf_file/0020/234362/adults-media-use-and-attitudes-report-2022.pdf Accessed 26 June 2023
Ojala M (2012) Regulating worry, promoting hope: how do children, adolescents, and young adults cope with climate change? Int J Environ Sci Educ 7:537–561
Ojala M (2016) Facing anxiety in climate change education: from therapeutic practice to hopeful transgressive learning. Can J Environ Educ 21:41–56
Ojala M (2017) Hope and anticipation in education for a sustainable future. Futures 94:76–84
Oliver MB, Dillard JP, Bae K et al (2012) The effect of narrative news format on empathy for stigmatized groups. JIsm & Mass Commun Q 89(2):205–224

Pavelle S, Wilkinson C (2020) Into the digital wild: utilizing Twitter, Instagram, YouTube, and Facebook for effective science and environmental communication. Front Commun 5
Perry S (2019) The enchantment of the archaeological record. Eur J Archaeol 22(3):354–371
Peter F, van Bronswijk K (2021) Die Klimakrise als Krise der psychischen Gesundheit für Kinder und Jugendliche. Pädiatrische Allergologie in Klink und Praxis 3:59–64
Peuramaki-Brown MM (2020) Introduction: the 'other grand challenge': learning and sharing in archaeological education and pedagogy. J Archaeol Educ 4(3). https://digitalcommons.library.umaine.edu/jae/vol4/iss3/1 Accessed 20 March 2023
Phillips L (2012) Emergent motifs of social justice storytelling as pedagogy. Storytelling, Self, Society 8(2):108–125
Pluciennik M (1999) Archaeological narratives and other ways of telling. Curr Anthropol 40(5):653–668
Porr M (2021) Indigenous global histories and modern human origins. In: Russell L, McGrath A (eds) The Routledge companion to Indigenous global history. Routledge, London, pp 139–164
Praetzellis A (2014) Narrative and storytelling for archaeological education. In: Smith C (ed) Encyclopaedia of global archaeology. Springer, New York, pp 5135–5138
Prentice CM, Vergunst F, Minor K et al (2024) Education outcomes in the era of global climate change. Nat Clim Chang 14:214–224
Ranke K (1967) Kategorienprobleme der Volksprosa. Fabula 9(1):4–12
Reitz E, Shackley M (2012) Environmental archaeology. Springer, New York
Rhody A (2022) Bewegtbild im Internet erreicht immer mehr Menschen. Ergebnisse der ARD/ZDF-Onlinestudie 2022. Media Perpektiven 10:487–492
Rivera-Collazo IC, Rodríguez-Franco C, Garay-Vázquez JJ et al (2020) Towards a definition and practice of communal archaeology: ethics, informal learning, and citizen science in the practice of Indigenous archaeology. J Community Archaeol & Herit 7:120–134
Rockman M, Hritz C (2020) Expanding use of archaeology in climate change response by changing its social environment. Proc Nat Acad Sci 117(15):8295–8302
Rockman M, Maase J (2017) Every place has a climate story: finding and sharing climate change stories with cultural heritage. In: Dawson T, Nimura C, López-Romero E, Daire M-Y (eds) Public archaeology & climate change. Oxbow Books, Oxford, pp 107–114
Rowland MJ (2004) Return of the 'noble savage': misrepresenting the past, present and future. Aust Aborig Stud 2:2–14
Rueger J, Dolfsma W, Aalbers R (2023) Mining and analysing online social networks: studying the dynamics of digital peer support. MethodsX 10:102005
Sahlins M (1972) Stone age economics. Aldine Atherton, Chicago
Sandri O (2022) What do we mean by 'pedagogy' in sustainability education? Teach High Educ 27(1):114–129
Schmidt A, Ivanova A, Schäfer MS (2013) Media attention for climate change around the world: a comparative analysis of newspaper coverage in 27 countries. Glob Environ Chang 23:1233–1248
Schneider CR, Zaval L, Markowitz EM (2021) Positive emotions and climate change. Curr Opin Behav Sci 42:114–120
Schofield J (2024) Wicked problems for archaeologists: heritage as transformative practice. Oxford University Press, Oxford
Shanks M (2012) The archaeological imagination. In: Abraham A (ed) The Cambridge handbook of the imagination. Cambridge University Press, Cambridge, pp 47–63
Silva M (2022) Why is climate 'doomism' going viral – and who's fighting it? BBC [Online] 23 May 2022. https://www.bbc.co.uk/news/blogs-trending-61495035 Accessed 17 February 2023
Siperstein S, Hall S, LeMenager S (2017) Introduction. In: Siperstein S, Hall S, LeMenager S (eds) Teaching climate change in the humanities. Routledge, London and New York, pp 1–13
Smith ME (2021) Why archaeology's relevance to global challenges has not been recognised. Antiquity 95:1061–1069
Smith C, Jackson G (2006) Decolonizing Indigenous archaeology: developments from down under. Am Indian Q 30:311–349

Spikins P, French JC, John-Wood S et al (2021) Theoretical and methodological approaches to ecological changes, social behaviour and human intergroup tolerance 300,000 to 30,000 BP. J Archaeol Method Theory 28:53–75
Star Carr Project (2023) Information for schools. http://www.starcarr.com/schools.html Accessed 07 July 2023
Steeves PFC (2021) The Indigenous Paleolithic of the western hemisphere. University of Nebraska Press, Lincoln, NE
Steffen W, Jäger J, Carson DJ, et al (2002) Challenges of a changing earth: proceedings of the global change open science conference, Amsterdam, The Netherlands, 10–13 July 2001. Springer Science & Business Media, Berlin, Heidelberg, New York
Stoknes PE (2014) Rethinking climate communications and the 'psychological climate paradox.' Energy Res Soc Sci 1:161–170
Sugiyama M (2021) Co-occurrence of ostensive communication and generalizable knowledge in forager storytelling: cross-cultural evidence of teaching in forager societies. Hum Nat 32(1):279–300
Sugiyama M (2022) Imaginary worlds pervade forager oral tradition. Behavioral and Brain Sciences 45(e276):45–46
Sutoris P (2022) Educating for the Anthropocene: schooling and activism in the face of slow violence. The MIT Press, Cambridge, MA
Tilley C (1996) An ethnography of the Neolithic: early prehistoric societies in southern Scandinavia. Cambridge University Press, Cambridge
Touma R, Davey M (2023) 'They are despairing': climate crisis weighs heavy on mental health of young Australians, The Guardian 19 April 2023. https://www.theguardian.com/society/2023/apr/20/they-are-despairing-climate-crisis-weighs-heavy-on-mental-health-of-young-australians Accessed 25 April 2023
Trend RD (1998) An investigation into understanding of geological time among 10- and 11-year-old children. Int J Sci Educ 20(8):973–988
Trend RD (2000) Conceptions of geological time among primary teacher trainees, with reference to their engagement with geoscience, history, and science. Int J Sci Educ 22:539–555
Trend RD (2001) Deep time framework: a preliminary study of UK primary teachers' conceptions of geological time and perceptions of geoscience. J Res Sci Teach 38(2):191–221
Tsosie R (2007) Indigenous people and environmental justice: the impact of climate change. Univ Color Law Rev 78(4):1625–1678
UN Climate Change Conference (2021) Co-chairs conclusions of education and environment ministers summit at COP26. https://ukcop26.org/co-chairs-conclusions-of-education-and-environment-ministers-summit-at-cop26/ Accessed 26 March 2023
Walter S, Lörcher I, Brüggemann M (2019) Scientific networks on Twitter: analyzing scientists' interactions in the climate change debate. Public Underst Sci 28:696–712
Wickham-Jones C (2002) In search of squashed Mesolithic people. Curr Archaeol 179:472–473
Wickham-Jones C (2010) Fear of farming. Windgather Press, Oxford
Wikimedia Statistics (2024) Total page views. https://stats.wikimedia.org/#/all-projects/reading/total-page-views/normal|bar|2022-05-01~2024-07-01|~total|monthly. Accessed 28 June 2024
Will M, Krapp M, Stock TJ et al (2021) Different environmental variables predict body and brain size evolution in Homo. Nat Commun 12(1):4116
Wynn G (2020) Framing an ecology of hope. Environ Hist 25:2–34

Chapter 7
Storying Experiences with Trauma/Danger/Hazards/Disasters—The Storegga Tsunami 8.200BP as Monster

Astrid J. Nyland

Abstract Research into the Storegga tsunami that hit the coasts of Western Norway, Scotland, and beyond 8200 years ago has, until now, primarily identified its direct physical impact. However, the story of the Storegga tsunami is also about human–environment relations, capacities, and social strategies for risk reduction in Mesolithic coastal societies. This chapter is an attempt to broaden its epistemology, investigating the tsunami's social impact through exploring the ontology of tsunamis and tsunami encounters via monsters. A monster/tsunami is an entity one may see and encounter; it can have agency and influence, representing risks and dangers that people or societies respond to or develop strategies for handling. This opens the range of what can be considered the materiality of the Storegga tsunami. Furthermore, building also on geomythology and anthropological disaster research, I recognize the power of storytelling and knowledge transmission that also enable explorations of other categories in the archaeological record rarely highlighted when the stories of the Storegga tsunami are written.

Keyword Storegga tsunami · Mesolithic · Storytelling · Hazards · Geomythology · Monster

7.1 Introduction

One autumn about 8200 years ago, the world's largest known submarine landslide triggered the massive Storegga tsunami off the coast of Møre in Western Norway. The tsunami has been called a "destroyer" and a "disaster", and in many places, it probably was. Tsunami waves up to 25 m high inundated the Norwegian west coast, as well as the eastern coast of Northern England, Scotland, the Orkneys, the Shetland Isles, and even as far away as Greenland. The range and force of the tsunami have been investigated and determined in detail by natural scientists (e.g. Bondevik

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_7

et al. 2003; 2012; Blankholm 2018; Dawson and Smith 2000; Dawson et al. 1990; Prøsch-Danielsen 2006; Vasskog et al. 2013). A recent numeric simulation model demonstrates the magnitude of the tsunami, but also how the tsunami's physical impact varied regionally (Walker et al. 2023; Løvholt et al. 2017). In the present paper, the physical impact of the tsunami is taken as a given. The focus here is on ways of identifying its potential *social* impact.

Acknowledging that a disaster is a result of "socially produced vulnerability, combined with a natural hazard" (Barrios 2017, 161), my case study invites discussions on capacities and social strategies for risk reduction in Mesolithic coastal societies of societies with a hunting-gathering-fishing subsistence. I am emphasizing how the story of the Storegga tsunami is about human–environment relations. The event is not only a reflector of fundamental features of Late Mesolithic societies, but also human worlds in general. Combining archaeology with disaster anthropology, indigenous knowledge, and theories developed in science fiction studies, this paper offers new knowledge of how prehistoric societies may have coped with a hazardous world caused by large-scale geohazards. The United Nations define a hazard as a "process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation" (Dufty 2020, 3). It is also widely acknowledged that disastrous encounters with natural hazards can raise questions about social structures and organization and potentially bring about important shifts in key institutions or systemic adaptation to sustain stability and viable lifestyles (Oliver-Smith 1996). Yet to anchor interpretations of this kind of social impact of disasters archaeologically and investigate aspects of societal strategies for risk reduction in a Late Mesolithic society is a considerable challenge. The fundamental question is what we should be looking for in the material record to identify potential change caused by a prehistoric tsunami, here: the Storegga tsunami. I intentionally write potential change because what characterizes a resilient society can have more than one answer and social resilience can have more than one cause.

The geologically identified layers of mixed-up sediments, gravel, and turf left ashore by the Storegga tsunami attest to its force. Based on that, it seems the tsunami left much of the coasts in ruins. However, the discovery of the tsunami-deposited layers has led to a perhaps one-sided focus on identifying its physical impact on the landscape and the identification of tsunami-deposited layers on sites. Identifying any social consequences of this potentially life-altering event for the affected generation of coastal dwellers in the Mesolithic archaeologically—that is, beyond demographic fluctuations—is more challenging. A similar challenge is found in disaster studies of physical and technological sciences' one-sided emphasis on environmental studies; there is a lack of concern with the social impact of disasters and an often unquestioned polarity expressed between nature and culture (e.g. Killen and Lebovic 2014; Shaw 2014). Because people do not just passively respond or adapt to natural conditions: a disaster is a social phenomenon that can open socio-economic systems up to change or transform social order (Buren 2001; Killen and Lebovic 2014; Vollmer 2013).

In archaeology, knowledge production can depend on the obtainable resolution of data. However, before attempting to search for evidence of social impact, we first need to clarify what the materiality of a tsunami is or can be. There are no unambiguous archaeological traces in the material culture of this period that indicate a sudden change in practices, technology, or settlement patterns in general that is accredited to the Storegga tsunami. As Caroline Wickham-Jones (2002, 472) wrote, "it would be nice to find squashed Mesolithic people", but alas, no one has been found. Previous research on the social impact of the Storegga tsunami has primarily investigated population busts or booms around this time (Waddington and Wicks 2017; Walker et al. 2020), yet the social impact of a potential disaster is about more than identifying potential demographic fluctuations. It is also about investigating social capacities and strategies for handling feelings of fear and grief, to the degree that practices change.

When stressing that the materiality of the Storegga tsunami reaches beyond the physically deposited "tsunami layers", it opens the field of research and may produce new knowledge about Middle-Late Mesolithic societies. Although previous research has noted that a disaster may bring social change in general (e.g. Goff 2017; Riede and Sheets 2020), there has been little specificity as to why and what we should identify as such. Obviously, archaeologists will probably never find evidence of grandmothers singing songs of warning in the Late Mesolithic lithic material or sediments, nor specific "geomythologies" (Vitaliano 1976, 3) related to the Storegga tsunami. Yet a detailed deconstruction of the tsunami phenomenon and engagement through the notion of monstrosity and memories of such is attempted here to inspire exploration of new archaeological study areas or aspects beyond searching for a physical "tsunami layer".

7.2 Deconstructing the Storegga Tsunami Event as Monster

In this chapter, then, I unpack and inquire into the experience of a tsunami encounter in the Mesolithic, through thinking with monsters (Gonzalez and Perkone 2021; Haraway 1992). Not only have tsunamis or waves been anthropomorphized as monsters, in the form of stories, but as "The Monster Network" (2021, 143) argues, applying the idea of monsters when analysing different phenomena can also be a method where the "monster lends itself as a thinking tool […] we can use it as a method to help us rethink and reimagine how the tools we use to know and communicate the world also actively shape it". One may thus think with and use monsters as a method to interrupt "supposedly coherent and tidy/tidied narratives" (The Monster Network 2021, 149). Monsters and the notion of a monstrosity can also be used as a tool to enable deconstruction of any phenomenon (cf. Rajan-Rankin 2021, 114). Here, for epistemological purposes, I am deconstructing the tsunami encounter. This is to bring the materiality of the social impact of a tsunami encounter, as well as its possible potential to change ontology, to the fore. This "exercise" is to open the study of prehistoric crisis, to consider aspects of how societies may remember and communicate—story—experiences with trauma/danger/hazards/disasters, even beyond the immediate experience.

Alongside monsters and the idea of the monstrous being an analytical tool for deconstructing the narrative of the Storegga tsunami, I also draw attention to the perhaps more conventional anthropomorphizing of natural events, in the form of stories. Natural hazards have also in indigenous societies been good to think with (Cruikshank 2012). I thus describe the phenomenon of a tsunami/monster encounter as threefold (although the three aspects inevitably feed into one another). A monster/tsunami can be perceived as: (1) something someone can see and encounter—that is, something that ontologically is, or comes into being and is encountered, that is, an entity in its own right; (2) something tsunamis/monsters do, recognizing its agency; and to inquire into (3) how people or societies may respond to the risks and dangers that tsunamis/monsters represent.

7.2.1 The Monster/Tsunami that Someone Sees and Encounters

Both tsunamis and storm waves are in themselves physical entities that can be large and brutal (Fig. 7.1). Storms, waves, and the sea are considered by some to be sentient beings with their own agency and ontology. They can colloquially be described to embed human-like qualities, being anthropomorphized as "deceitful" or "evil", "rogue", or "monstrous". Tsunamis and storm waves thus lend themselves easily to explanations of being monsters or supernatural creatures and have done so in cultures across the globe and throughout history. For example, in Norwegian folklore, the sea troll "Draugen" is the personification of monstrous waves, storms, and other hazards at sea attacking boats and seamen (Fig. 7.2). In addition to being illustrated as a composition of elements of the sea (like seaweed and monkfish), Draugen is also often portrayed as an ominous corpse in fishermen's gear, rowing half a boat. "Seeing Draugen" was a warning to steer boats to the safe shore. In British Columbia, Western Canada, natural hazards like earthquakes and tsunamis were described similarly by First Nation groups as being supernatural mountain dwarfs, the Giant Thunderbird, and the Whale (Ludwin et al. 2005). In contrast, among the Moken, the sea nomads living on the islands and shores of the Mergui archipelago spanning Myanmar and Thailand, some large waves were understood as malicious spirits that formed to punish humans (Arunotai 2006).[1] For an example of Mayan beliefs, see Barrios (Chap. 3). In the examples, stories warn communities, and people were saved because they acted on the storied knowledge (e.g. if the sea recedes, seek higher ground).

Storying natural hazards as something extraordinary and supernatural makes them perhaps easier to explain or comprehend (Vansina 1985). Personification transforms the sea into something multi-specied, something that is not bound by one category. It also dismisses species distinctions and any distinction between organic and non-organic matter. Indeed, the aforementioned imaginary figures are monstrous in that they are supernatural, abnormal, extraordinary, and not confined to one category. In

[1] See also https://www.survivalinternational.org/galleries/moken-sea-gypsies.

Fig. 7.1 Stormy waves hitting land in western Norway. Photo: Astrid J. Nyland

Fig. 7.2 How the sea monster Draugen/Vasstrollet was imagined according to Norwegian folklore, painted by Theodor Kittelsen in 1881. Note the combination of sea related elements, seaweed and the mouth of a monkfish. Creative commons-attribution CC-BY

ancient Rome, a "monster" was seen as something unusual and hence understood as an alerting sign, a deviation from the norm that operated as a warning by showing itself as an exception (Baldissone 2021, 200). Things, events, or even places can be monsters or "monstrous" (Gonzalez and Perkone 2021, 63). Such metaphorical monsters can be:

> an embodiment of a certain cultural moment–of a time, a feeling, and a place. The monster's body quite literally incorporates fear, desire, anxiety, and fantasy (ataractic or incendiary), giving them life and an uncanny independence. The monstrous body is pure culture. A construct and a projection, the monster exists only to be read: the monstrum is etymologically "that which reveals", "that which warns" (Cohen 1996, 4).

The Storegga tsunami may similarly have been contemporarily defined by the abnormal behaviour of the sea that day, the memory and later story of the desolate landscape it left behind, as well as the many personal and communal tragedies it potentially caused. As I will return to, over time, the tsunami may even have been commemorated as a monstrous encounter or reinvented as a monster, and its story may have been transmitted across generations. However, its frightening impact goes beyond the monster/tsunami itself.

7.2.2 *What Monsters/Tsunamis Do*

Monsters and tsunamis alike can cause death, destruction, and chaos. As recently demonstrated by the tsunamis in 2004 in the Indian Ocean and in 2010 in Japan, tsunamis wreck shores and coastal landscapes. They temporarily suffocate ecological systems, change conditions for resource exploitation, and destroy human infrastructure and installations. They may also kill large numbers of people. Hence, although a monster can be a place and environment of danger and desolation, a monster can also be the creator of monstrous landscapes (Gonzalez and Perkone 2021).

Seeing or encountering a monster or something monstrous and experiencing what a monster, like a tsunami or another natural hazard, does can cause psychological distress (Sattler et al. 2000, 1414). While the severity of the psychological impact may vary and depend on the demographic characteristics of who immediately experiences it (age, gender, social position), or available communal and personal resources (Sattler et al. 2000, 1406), the deep effects of a catastrophe—the impact of a trauma—can also fester in people's minds and continue to reverberate over generations (Hoffman 2004, 185). Some view the brutal forces of nature as just that—forces that put one at risk. A concrete result of a tsunami's social impact may thus be the emergence of strategies that will reduce the risk of something like this ever happening again. Such can be established immediately after a tsunami or crisis but may also have already been established as a precaution and as a risk reduction strategy prior to the event.

While a tsunami may be truly terrible, due to societies' or humans' ability to adapt and adjust, even a disastrous encounter can bring with it something productive (e.g. Sattler et al. 2000; Sutton et al. 2020). If a dramatic encounter becomes an incentive to change practices and traditions related to building, infrastructure, or social organization, this may lead to the strengthening of practices that will keep the society safer. Ideas of what keeps people safe though, can vary, making risk reduction strategies hard to identify in an archaeological record. For example, in the coastal hinterland in Chidambaram, India, to mitigate danger they increased offerings to what they saw protected them from the sea and tsunamis: the mangrove forest that protected them from the 2004 Indian Ocean tsunami. Hence, sculptures of mangrove trees were worshipped like gods (Baumwoll and Krishnamurthy 2009, 31). From this, though, one may infer that one effect of a tsunami's impact is an upsurge in religious feelings or ritual practices.

In literature, particularly science fiction, monsters represent a "cosmic horror"—that is, a horror that places "fundamental emphasis on the unimportance of humanity" (Nirta and Pavoni 2021, 17). An alternative thought is that monsters—here, large-scale geohazards—underline the importance of humanity. First responders after the 2010 Japan tsunami noticed how encountering and surviving something as monstrous as a tsunami had encouraged societies to come together, sometimes erasing boundaries between social and political groups. This resonates with the idea that if monsters are lurking outside a group's safe boundaries, it reinforces notions of sameness and belonging within a bounded group. To cultural create a monster may even help "police" such boundaries (Cohen 1996, 15). Indeed, naming and thereby defining that which causes trauma or social anxiety as being monstrous has even been called a human and social "boundary-producing mechanism" (Nirta and Pavoni 2021, 16). While the social bridging between societal subgroups, like in Japan, may be temporary, the idea to keep is that there is strength in numbers and there are benefits of belonging to a particular social group. This notion is then reinforced through creating an idea of, or actually encountering, a monster/geohazard. Not standing alone is a well-known strategy for keeping safe, learned as a child when your mum says: stick with your friends and do not walk home alone. Thus, material expressions of group affinity can perhaps be perceived as a societal risk-reducing strategy in prehistoric societies, but also in our modern one's.

Social anxiety and stress can naturally be caused by different things, but a common denominator is that it is something unfamiliar and unexpected, like a tsunami, unknown people, landscapes, or regions. These elements may be warned against, as was done in world maps from the fifteenth century where ideas of danger were illustrated through drawings of monsters in the peripheries of the known world, especially occupying the sea and unknown territories (Fig. 7.3). Ideas of monsters/otherness/divergence then become necessary elements of any society to keep people safe and to prevent hazardous activity. In this way, the idea of the monstrous can expose the limits of what is considered normal (Nirta and Pavoni 2021, 20). Normal is contrasted by things considered abnormal, hybrid, marginal, even the familiar when transformed into something unrecognizable. Did the wrecked shores after the tsunami similarly become something monstrous?

Monsters, then, have the power of transformation and initiating new practices. By creating chaotic situations, sometimes by marginalizing and/or replacing parts of a

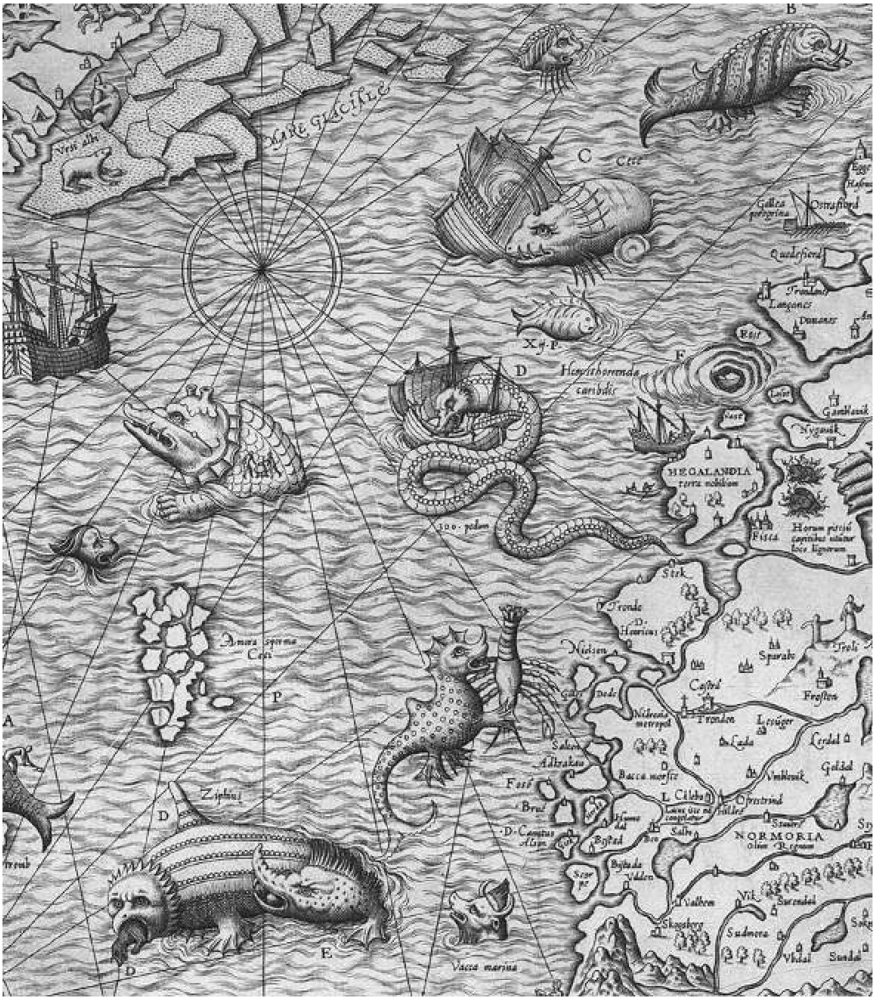

Fig. 7.3 Details from Olaus Magnus Carta Marina from 1572, monsters illustrating the dangers of the sea. OA at nb.bibsys.no (999919968100502202)

population, tsunamis and monsters are both transformative forces that can disrupt power relations, social positions, or hierarchies and in other ways politicize the situation by creating openings for power struggles (e.g. Barrios 2016; 2017; Oliver-Smith 2010). It follows that, although transitory, a catastrophe such as a tsunami or a monstrous encounter can act as a catalyst for institutional change, initiated as part of a transformative change in behaviour or social reorientation by the surviving societies. Furthermore, as mentioned under 7.2.2), a crisis may cause an upsurge of religious feelings. When the world turns upside down, underlying cultural norms, structures, and values come into focus and can challenge one's world view (Kverndokk 2015).

After a period of immense stress and loss, and as societies search for ontological security, the result could be spiritual reorientation, the introduction or intensification of specific practices aiming to control the unpredictable, or a reinstatement of status quo (Berger and Luckmann 1967 [2011]; Giddens 1984). In turn, such notions may be channelled into new visual expressions, rites, or ritual practices.

Ethnographers, anthropologists, and archaeologists have also noticed how some historical and prehistorical societies have responded with increased innovation and changing behaviour when under pressure (e.g. related to climate change, in Knecht and Davis 2008; or repeated tsunami encounters, in Fitzhugh 2012). One might say that encountering something unfamiliar or monstrous may be what forces people to think, or act, outside the box. A monstrous encounter with a tsunami can then, potentially, have social, ritual, and ontological repercussions, involving alterations to socially or culturally guided variables. Investigations into the social impact of a tsunami can therefore find that one is identifying new or changed practices. Practices introduced to reduce the risks of living with hazards may be practical, like infrastructure-related techniques, for example, flag-signal systems, “village runners”, or sound devices, developed to alert fellow fishermen or coastal dwellers to risk and to communicate sea conditions (Baumwoll and Krishnamurthy 2009, 31–32). Practices or knowledge may also be represented by physical objects, like the standing stones placed at the 1896 tsunami run-up height in Japan. These acted as mnemonic devices, encouraging people not to build below that point, although it was inland and considerably above the coast. They functioned as warning signs across generations.

Collecting and sharing knowledge of hazardous experiences to learn from them is recognized as key in risk reduction strategies (Dufty 2020; Rahman et al. 2016; Shaw et al. 2009). Knowledge transmission is not only true for modern and Western societies but has probably always been part of society in various forms, either expressed orally (Vansina 1985) or bodily (Mauss 1950). In societies with traditions of oral knowledge transmission, knowledge as stories conveys ideas about the nature of the world, and people’s place within it, or about “the webs of responsibilities that bind all things” (King 2008, 114). Detailed knowledge of the environment, technology, and resources, i.e. information, may in fact be seen as one of the most important resources shared among households (Knecht and Davis 2008, 77).

Recent studies have also highlighted the direct benefits of implementing storytelling practices as a strategy for risk reduction (Shaw et al. 2009, 5–6). As I will return to in more detail, in Simeulue, in Aceh province in Indonesia, grandmothers had told and sung the story of the Smong (Smong meaning the ocean coming onto the land), a tsunami that in 1907 killed thousands of people. That this story was transmitted throughout the twentieth century became central to the survival of the group when the 2004 tsunami hit (only seven deaths recorded!) (Baumwoll 2009, 209). This example demonstrates the power of local, orally transmitted knowledge: “[E]mbedded cultural understandings of the environment and hazards together with life-long learning are effective contributors to ‘resilience’” (Sutton et al. 2020, 8). Similar practices and strategies were probably in play in prehistoric societies too (see also Piper et al., Chap. 6).

7.3 The Materiality of the Storegga Tsunami

One of the challenges in identifying the potential social impact of the tsunami encounter is that the corpus of settlement sites from this time period (Middle-Late Mesolithic transition) is regarded as being of relatively poor quality, extremely fragmented, and hence difficult to gain valid insight from (see also discussion in Kilhavn, Chap. 12). On the West Norwegian coast, this is due to a period where the sea rose quicker than the land (eustatic processes) after a period of sinking sea levels due to isostatic rebound after the last Ice Age. The transgression covered sites with thick layers of beach deposits, which have reduced these sites' archaeological visibility. When found, sites tend to be heavily disturbed, their lithic distribution "messy", or the stratigraphy can be mixed up. To ease these challenges and for providing context to potential material patterns, deep time investigations of development in material culture or settlements, investigating the longue durée of traditions, may be perceived as a signal of success or failure of mitigating living with natural hazards or social strategies for building strong and robust societies. In this way, the Storegga tsunami can offer new entries for learning more about how Mesolithic societies lived with hazards brought on by the sea.

7.3.1 The "Tsunami Layer" as a Basis for Visual Simulation Models of Impact

The brutal nature of the tsunami's physical impact is demonstrated through finds of layers of redeposited gravel, sand, and turf documented in various sediment traps, i.e. lakes and wetlands close to the coast (e.g. Åstveit et al. 2016; Bondevik et al. 1997; 1998; 2003; 2012; Løvholt et al. 2017; Solem and Solem 1997; Vasskog et al. 2013). Only rarely is the "tsunami layer" found directly on top of an actual Mesolithic site (Dawson et al. 1990; Wordsworth 1985), or in very close proximity to a site from the same time period (Bjerck et al. 2008). The identified tsunami layers along the coast testify to the devastation of the shores and immediate coastal hinterland. The layers contain ripped-up turf, gravel, and rocks, speaking volumes as to the ferocity of the tsunami encounter, but they also provide data for simulation models of the behaviour of the wave itself.

Commissioned by the research project Life After the Storegga Tsunami (LAST), researchers from the Norwegian Geophysical Institute have produced an updated numeric simulation model of the tsunami for the coast of Central and Western Norway (Walker et al. 2023). Differing from earlier models, like the one in Løvholt (Løvholt et al. 2017), the new one may also be used to model local impact. It aims to give a close-up of the impact within a range of 3–10 km (Fig. 7.4). For example, the island of Aukra off the coast of Møre, Western Norway, is situated immediately east of the location of the Storegga submarine landslide. The model here suggests that for the first hour, the sea sank up to 20 m before the waves rolled in (Walker et al. 2023). The

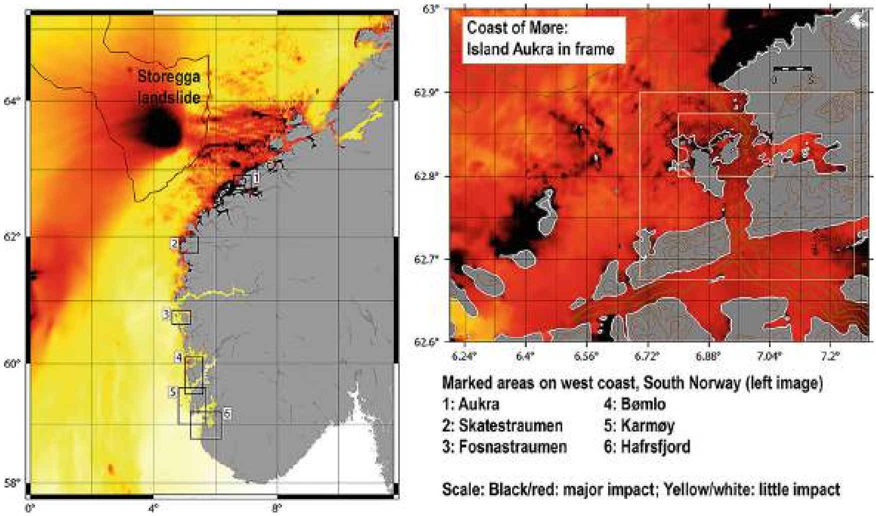

Fig. 7.4 Simulation model made by NGI demonstrating varied impact along the coast of South Norway and impact locally at Aukra, Møre (Ill: S. Gibbons, NGI, added text by AJN). (Figure is collected from a figure in paper by the present author and more (Walker et al. 2023)

first wave was not a wall of water but a fast, rising tide, reaching a height of nearly 20 m in about 15 min. The model also shows how this was not one wave, but several, with the first one not being the most severe. Furthermore, due to the island's location close to the mainland, the apparently sheltered inner coasts of the island were struck by even harsher waves since the water bounced back and forth and swirled between the mainland and the island.

The tsunami might have been both a disaster and a destroyer in more ways than one. The model allows us a glimpse of a monstrous encounter for the people living on Aukra 8200 years ago. One sees the forces in action. On Aukra, substantial archaeological excavations and surveys were undertaken between 2000 and 2005 in relation to the establishment of a gas processing plant (Bjerck et al. 2008). At least two sites (sites 29 and 62) demonstrate activity just prior to when the islands were severely hit by the tsunami. Next to site 29, a suggested "tsunami layer" was discovered in a trench dug through a wet area. However, the layer was not acknowledged as a demonstration of tsunami impact affecting the nearby site (cf. description in Hjelle and Solem 2008, 520). At site 62, a few kilometres away on a more sheltered side of the island, activity was C14-dated to just prior to the tsunami event. At both, the aforementioned sites there were discrepancies in the stratigraphic sequence of charcoal-rich cultural layers: a layer dated to the centuries before the tsunami was found deposited above layers dated to the same time of the tsunami, i.e. younger (see sites 29 and site 62, in Bjerck et al. 2008, 104, 357). Tumbled stratigraphy can cause trouble for archaeologists and influence the representativity of sites but also testify to the brutality of a tsunami and hence be a mark of sites that experienced a harsh impact. Whether there were people there at the time, we may never know, and is perhaps not necessarily essential to determine. At one place in this region, on this island or another, people would have lived at the shore and experienced the tsunami.

On Aukra, the day of the tsunami could have been experienced as a monstrous moment in time. A specific kind of green moss found repeatedly in the tsunami deposits in Western Norway tells us that the wave hit land in October–November around 8200 years ago (Bondevik et al. 2012). With an 8.2 ka climatic cold period also in progress, making winters longer and cooler (Alley and Augustdottir 2005), people were most likely back at their coastal camps preparing for the winter season. Food storage facilities were full, firewood collected, and tents and floor insulation were ready. I reckon that the tsunami could not have come at a worse time. Modern TV images have conveyed the horror of modern tsunamis, demonstrating their ability to shatter worlds. Before/after pictures demonstrate massive alterations to material culture, settlements, environment, and topography. In the year of the tsunami c.8200 years ago, coastal inhabitants would have found their coastal world suddenly devastated in a similar manner. Campsites, boats, and stored possessions were gone or broken; family or tribal members were left dead or went missing. The erosive powers of the wave would have ripped up shallow subtidal and intertidal ecosystems and left fishing grounds and harbours in ruin. However, returning to the recent simulation model made for the LAST project demonstrates how the force of the wave varied regionally. Although monstrous on the coast of Møre, further south on the Norwegian coast there are regions only slightly affected by the wave (Walker et al. 2023). This points to the importance of being attentive to what scale of investigation is adequate when researching potential social impact. How large an area must be affected in a Mesolithic society, and how severe must the damage be, for a comparison of material patterns to represent something "real"?

Knowing that the force and impact of a tsunami have regional outcomes (Blankholm 2018; Goff 2017; Walker et al. 2023), utilizing a particular geohazard or geo-event as a root cause for wide demographic change can be problematic. As previously mentioned, one dominating strand of research on the social impact of the Storegga tsunami is the modelling of 14C dates to demonstrate demographic change (Nyland et al. 2021). This type of statistical modelling normally operates with large data sets from wide geographical areas for the purpose of statistical validity (e.g. Scotland/Northern Britain, South Scandinavia, South Norway, or North Norway) (e.g. Bergsvik et al. 2021; Damm et al. 2019; Waddington and Wicks 2017; Lundström et al. 2020; see also Riede et al., Chap. 13). Some of the aforementioned studies point to a decline in 14C-dated activity, i.e. interpreted as a decline in population caused by the tsunami and climate deterioration. However, questions concerned with representativity due to severe taphonomic problems, bias from modelling data from large cross-regional studies, and knowledge of the regionality of impact are being raised (Kilhavn, Chap. 12; Walker et al. 2023). Even if groups residing in one region were wiped out, people living in other regions may only have experienced the tsunami as a transitory disruption. Despite, or perhaps because of, this, the Storegga tsunami is a potent steppingstone in gaining insight into social strategies for building robust societies that could live well with natural hazards. Although the tsunami was one freak event, expecting large and dangerous waves or storm surges comes with the reality of living by and off the sea.

7.4 Remembering a Trauma/Danger/Disaster/Hazard Though Storytelling

In archaeology, one looks for material patterns of change, but we know that the existence of long-term memories or remembrance is not necessarily linked to that which is immediate or tangible. We know that traumas and stories of tragic episodes and periods can live on beyond first-hand experience and eyewitnesses (Vansina 1985, 10). The sense of a living, personal connection to a traumatic event, despite temporal distance, has been conceptualized as post-memory, meaning a memory of proximity charged with feeling, not ideological strategy or theoretical abstraction (Hoffman 2004, 180). The concept of post-memory renders visible how events can continue to live on in the next generations' minds. The chain of events, taking someone from encounter or experience to stories and narratives, is temporal and multilevelled: from event via fable to psyche, narrative, morality, memory, to the past, and from the past to the present (cf. index in Hoffman 2004). Although the concept of post-memory was developed in relation to second-and third-generation Holocaust survivors, it is also suited to memories and stories told about past generations' traumatic events that continue to have a strong ontological impact on people's understanding of identity and place in the world, even long after the event happened (Hirsch 2008, 104). Transferring this concept, mechanism, or process on to investigations into the prehistoric past, the knowledge and story of the day the sea became a monster may have impacted the inhabitants of the coastal societies. Although the vegetation and landscapes regenerated and normalized, people moved back to islands and continued being coastal dwellers, their coastal history had changed and strong(er) relations with certain sites or places may have been established. In this way, the experiences and memories from the encounter became something to learn from. Stories were told, memories and knowledge transmitted.

The omnipresent sea seems inherently important in maritime-oriented societies. Historical ethnographical examples can demonstrate temporal longevity of memories of tsunamis or floods (McMillan and Hutchinson 2002). Such tales have led to evasive action and saved people's lives (Arunotai 2006; Budhwa 2021). Ensuring knowledge transmission is therefore an important "capacity" of a society for risk reduction. In the Middle and Late Mesolithic of the Western coast, the sea's ongoing transgression, its encroachment of land, may have influenced coastal communities' relationship with the sea explained through stories. Furthermore, even if the sea's temper were familiar, the Storegga tsunami, a marine "freak event", would have needed explanation and influenced practices in its aftermath. There are also examples where that which is considered monstrous may "take on a life in the collective imagination (sometimes) quite different from its reality" (Gonzalez and Perkone 2021, 63). Over time, events, memories, or stories can gain influential power even if the initial content or logic of a tradition is lost. A practice will endure if accepted and becoming entangled in a community's social or cultural traditions, norms, routines, or myths. Like a game of "whispers", meaning can change from its original state to what is repeated in the end. Cataclysmic events can similarly be integrated into other story traditions and their original occasion get lost. Nevertheless, if events become part of a living social memory, they can become a "conceptual and symbolic reservoir" for transmitting environmental knowledge and social traditions across generations (McIntosh et al. 2000). Activities or traditions, ways of living that persist over time, are really demonstrations of successful implementations of knowledge in a community (e.g. technologies, resource exploitation, or ritual practices) (Hodder 2012; Ingold 2003; Mauss 1950).

7.5 Storytelling—a Strategy for Risk Reduction

A telling example of the value of passing on knowledge after a traumatic tsunami event comes from the above-mentioned Simeulue of Aceh province, Indonesia. After the 2004 Indian Ocean tsunami, their astonishing survival was accredited to the way they had learned to act via knowledge of "the Smong" passed on over generations (Baumwoll 2009; Sutton et al. 2020). The 1907 survivors recorded their experience in oral stories that were told across generations. Interviewed subjects referred to their grandmothers having repeatedly told how "[i]n 1907 there was a large earthquake followed by a Smong. Nearly everyone was killed. So, if there is a big earthquake and the sea recedes—run to the mountain. Don't wait just run" (Sutton et al. 2020, 7). The young generations were made aware of the connection between a large earthquake, receding sea, and a tsunami (Baumwoll 2009, 214). The story touched the emotions of those who listened as survivors of the devastating 1907 tsunami shared their experiences, but also their sadness of experienced loss (Rahman et al. 2016, 8–9). Like the concept of post-memory, the personal connection infused the story with power and respect, ensuring its survival, i.e. transmission.

While sudden dramatic geo-events, although transitory and short-lived, often linger in people's memories due to shock effects or their eminent "newsworthiness" (Vitaliano 1976, 11), in Aceh province, due to the cultural role the Smong story was given, it became a legend over time (Baumwoll 2009, 220–221). Knowledge transmission was in this situation oral, made possible "through cultural patterns in which community members share[d] their knowledge. Family, older people, and local leaders played a major role in disseminating […] ensuring the sustainable development of culture patterns through which most Smong knowledge continues to exist" (Rahman et al. 2016, 9). Personal connections affirmed a successful internalization of the knowledge transmission, but a success factor was also the nature of the organization of the social system. In this case, this was the close-knit communities enabling communication, and value placed in strong social relationships, solidarity, and cooperation.

Indigenous knowledge is naturally strongly locally rooted and contextually dependent. However, in the example of indigenous knowledge used for disaster risk reduction in coastal areas, there are also overriding transferable elements applicable to other regions and time periods (Baumwoll and Krishnamurthy 2009, 33–35). Indigenous knowledge of warning signs of hazards and risk reduction practices demonstrate that coastal communities may have mechanisms to reduce vulnerabilities and adapt to hazardous environments different to those in the Western world (Baumwoll and Krishnamurthy 2009, 41). For example, the intimate knowledge of the marine environment, together with keen observation of the sea and precautions due to their ways of living as "sea gypsies", ensured the survival of the Moken people (Rahman et al. 2016, 33), mentioned above. The stories of the communities in this region saved lives, but knowledge of a specific hazard is not necessarily what reduces risk—it is the transmission of knowledge that is the key element in risk reduction and disaster preparedness and the implementation of social-environmental relationships that matters: "[F]or a transformation to be 'contagious' (collective or social transformation) it needs to create or tap into and facilitate a schema or narrative that is widely held within a group's sense of coherence" (Sutton et al. 2020). Nevertheless, knowing about risks does not necessarily mean a complete change of a society's traditions (see Nyland and Damlien 2024; Piper et al., Chap. 6). As the standing stones in Japan showed, people still settled along the seashore after the 1896 tsunami. Similarly, in regions most severely hit by the Storegga tsunami, settlement patterns did not alter after the tsunami either (Walker et al. 2023). In the case of the Storegga tsunami, then, although temporarily disturbed, neither settlement patterns nor lithic production were subject to large-scale alterations immediately after the event. This indicates that the coastal dwellers found strategies other than those represented in their settlement patterns or lithic tool traditions to make them feel safe.

7.6 Final Remarks

Having undertaken the exercise of using monsters as a thinking tool, I have not tried to reconstruct the cognitive and emotional world of 8200 BC but rather to open the phenomenon to enable a wider range of elements in the archaeological record to be acknowledged as signs of social impact of the Storegga tsunami. At the time of the tsunami, the people inhabiting the west coast of Norway were predominantly so-called shore-bound, i.e. living very close to the seashore. This did not change after the event (Walker et al. 2023). A recent study of lithic technology before and after the tsunami has also demonstrated that traditions more or less continued. However, there are modifications to traditions developing in regions concurring with those most and least affected. Although one may never prove this, changes may well have been triggered by the tsunami (Damlien et al. 2024; Nyland and Damlien 2024). Indeed, it seems that people on the west coast of Norway lived well with the sea, its risks and natural hazards in the Mesolithic. The tsunami was not their first encounter with an unruly and monstrous sea. This means that, even in the Mesolithic, living with hazards was not necessarily disastrous (cf. Barrios 2016, 35) if the society was organized in a way that reduced the risk of collapse when encountering monstrous events. Investigating the Storegga tsunami can benefit by moving *beyond* the notion of disasters and exploring how "the dynamic and emergent qualities of human–environment relationships require anthropologists [and archaeologists] to think beyond adaptation to stable environments or ecological circumstances and to document and theorize how social and material worlds come into being through human–environment engagements in a variety of loosely connected sites" (Barrios 2017, 161) (my inclusion). Acknowledging the potential long-term mental and/or cultural impacts that the Storegga tsunami might have had makes it easier to argue for subsequent social or ritual repercussions, reorientations of social networks, or even reorganization of societies in the tsunami's aftermath.

How one interprets how an encounter with natural hazards affects a society hinges on how one perceives what makes a robust and resilient society: are swift changes in material culture or settlement practices signs of a society that can change or adapt to new situations at short notice? Or are long periods of continuity in the archaeological material the sign of a robust and resilient society that had social strategies to make sure knowledge was transmitted even if the society faced hard times? Hence, both change and continuation in the material record can demonstrate resilience towards disasters and ways to live well with hazards. Moreover, if impact is shown through material change, it is by no means certain that changes happened immediately. A tsunami may be disastrous, but even then, it is transitory. Nevertheless, just by interrupting the historical contingency, such an event can accelerate social processes, driving societies in new directions (Alexander 2005; Vollmer 2013). With a disruption to what is considered "normal", a potentially dramatic event can become a post-memory for later generations and later turn into myth and gain transformational power over time like a slow-growing seed. Change may therefore not correspond with the date of an event itself. Furthermore, acknowledging that stories can persist over millennia (e.g. Mackenthun 2021, 123) but can also change over time, what remained might just have been a sense of danger connected to certain places or related elements. The places and landscapes may in themselves also have acted as mnemonic devices for associated knowledge (Vansina 1985, 46).

Perhaps it is possible to identify "the Storegga tsunami remembered" archaeologically. But if the tsunami became a powerful before/after moment for the inhabitants of the north-Western coast, especially where the tsunami hit the hardest (Fig. 7.4, see full simulation model for more areas in Walker et al. 2023), stories of such a monstrous encounter could explain a growing ritualization of the landscape in the Late Mesolithic represented by developments in rock art production, adze depositions, or a persistent and intensified use of certain coastal adze quarries. Both quarrying and making rock art were traditions established prior to the tsunami, but during the Late Mesolithic, their character appeared to change and intensify (cf. Bjerck 2008; Fuglestvedt 2017; Lødøen 2003, 1995; Nyland 2017). I think we should view rock art images illustrating elements of the sea and land in odd combinations, like the hybrids "whale-bear" and "elk-bear", both found at Hammer, in Central Norway (Bakka 1988; Nyland and Stebergløkken 2021), as storied monsters. Perhaps

Fig. 7.5 Abnormal creature in transformation—a monstrous(?) "whale-bear" carved at site Hammer V, Trøndelag in the Late Mesolithic (Bakka† 1988, 19)

monster waves, but at least tales of abnormalities, situating knowledge, creating frameworks for understanding and living (Fig. 7.5). Stories explain the inexplicable and can make sense of the initially senseless. Storytelling is a worlding practice, which anchors identity and notions of one's place in the world (Archibald 2008; Haraway 2016; King 2008).

Acknowledgements The paper has come to be due to research made possible through the FRIPRO project 302858 "The Storegga tsunami c. 6150 BC-a wave of destruction or transformative disruption for a prehistoric society?" funded by the Norwegian Research Council. Thanks goes to Gabriel Cooney and Daniela Hofmann for reading and commenting on the first draft, and to anyone giving feedback on the idea of combining monsters and archaeology in talks given on the topic 2021–2023. Finally, thanks to the reviewers, Gesa Mackenthun and Stephanie Piper, for their constructive feedback.

References

Alexander D (2005) An interpretation of disaster in terms of change in culture, society and international relations. In: Perry RW, Quantarelli EL (eds) What is a disaster? New answers to old questions. Xlibris, Philadelphia, pp 25–48

Alley RB, Augustdottir AM (2005) The 8k event: cause and consequences of a major Holocene abrupt climate change. Quatern Sci Rev 24:1123–1149

Archibald JA (2008) Indigenous storywork: educating the heart, mind, body, and spirit. University of British Columbia, Vancouver

Arunotai N (2006) Moken traditional knowledge: an unrecognised form of natural resources management and conservation. Int Soc Sci J 58(187):139–150

Åstveit LI, Carrasco L, Svendsen JI et al (2016) Arkeologiske undersøkelser ved Tjong-Løvegapet på Søre Bømlo. Gnr 44/Bnr 5, 34, Bømlo kommune, Hordaland. Rapport nr, vol 6. Universitetsmuseet i Bergen, Fornminneseksjonen

Bakka E (1988) Helleristningane på Hammer Beitstad, Steinkjer, Nord-Trøndelag. Granskingar i 1977 og 1981. Rapport arkeologisk serie 1988 (7). Vitenskapsmuseet; Universitetet i Trondheim, Trondheim

Baldissone R (2021) The unbearable monstrosity of being. On the narrative provincialization of ontologies. In: Nirta C, Pavoni A (eds) Monstrous ontologies. Politics, Ethics, Materiality. Vernon, Delaware, pp 193–218

Barrios RE (2016) Resilience: a commentary from the vantage point of anthropology. Ann Anthropol Pract 40(1):28–38. https://doi.org/10.1111/napa.12085

Barrios RE (2017) What does catastrophe reveal for whom? The anthropology of crises and disasters at the onset of the Anthropocene. Annu Rev Anthropol 46:151–166

Baumwoll J, Krishnamurthy RR (2009) Indigeneous knowledge and disaster reduction in coastal areas. In: Shaw R, Sharma A, Takeuchi Y (eds) Indigeneous knowledge and disaster risk reduction. From practice to policy. Nova, New York, pp 27–43

Baumwoll J (2009) Indigenous knowledge for tsunami early warning in Simeulue, Indonesia. In: Shaw R, Sharma A, Takeuchi Y (eds) Indigeneous knowledge and disaster risk reduction. From practice to policy. Nova, New York, pp 209–226

Berger PL, Luckmann T (1967 [2011]) Den samfunnskapte virkelighet [The Social Construction of reality. A Treatise of the Sociology of Knowledge]. Fagbokforlaget, Bergen

Bergsvik KA, Darmark K, Hjelle KL et al (2021) Demographic developments in stone age coastal western Norway by proxy of radiocarbon dates, stray finds and palynological data. Quatern Sci Rev 259:106898. https://doi.org/10.1016/j.quascirev.2021.106898

Bjerck HB (2008) Norwegian Mesolithic Trends. In: Bailey G, Spikins P (eds) Mesolithic Europe. Cambridge University Press, Cambridge, pp 60–106

Bjerck HB, Åstveit LI, Meling T et al (2008) NTNU Vitenskapsmuseets arkeologiske undersøkelser Ormen Lange Nyhamna. Tapir, Trondheim

Blankholm HP (2018) In the wake of the wake. An investigation of the impact of the Storegga tsunami on the human settlement of inner Varangerfjord, northern Norway. Quatern Int 549:65–73. https://doi.org/10.1016/j.quaint.2018.05.050

Bondevik S, Svendsen JI, Johnsen G et al (1997) The Storegga tsunami along the Norwegian coast, its age and runup. Boreas 26(1):29–53

Bondevik S, Svendsen JI, Mangerud J (1998) Distinction between the Storegga tsunami and the Holocene marine transgression in coastal basin deposits of western Norway. J Quat Sci 13(6):529–537

Bondevik S, Mangerud J, Dawson S et al (2003) Record-breaking height for 8000-year-old Tsunami in the North Atlantic. Eos 84(31):289–300

Bondevik S, Stormo SK, Skjerdal G (2012) Green mosses date the Storegga tsunami to the chilliest decades of the 8.2 ka cold event. Quatern Sci Rev 45:1–6

Buren MV (2001) The archaeology of El Niño events and other "natural" disasters. J Archaeol Method Theory 8(2):129–149

Cohen JJ (1996) Monster culture (seven theses). In: Cohen JJ (ed) Monster theory: reading culture. University of Minnesota, Minnesota, pp 3–25

Cruikshank J (2012) Are glaciers 'good to think with'? Recognising indigenous environmental knowledge. Anthropol Forum 22(3):239–250. https://doi.org/10.1080/00664677.2012.707972

Damlien H, Nyland AJ, Redmond J (2024) Lithic technology before and after the Storegga tsunami (8200 cal BP): dissolving large-scale regional trends to identify social impact of crisis in western Norway. Holocene. https://doi.org/10.1177/09596836241274987

Damm C, Skandfer M, Jørgensen EK et al (2019) Investigating long-term human ecodynamics in the European Arctic: towards an integrated multi-scalar analysis of early and mid holocene cultural, environmental and palaeodemographic sequences in Finnmark County, Northern Norway. Quatern Int 549:52–64. https://doi.org/10.1016/j.quaint.2019.02.032

Dawson S, Smith DE (2000) The sedimentology of middle holocene tsunami facies in northern Sutherland, Scotland, UK. Mar Geol 170:69–79

Dawson A, Smith DE, Long D (1990) Evidence for a Tsunami from a Mesolithic site in inverness, Scotland. J Archaelogical Sci 17:509–512

Dufty N (2020) Disaster education, communication and engagement. Wiley Blackwell, Hoboken NJ

Budhwa R (2021) Witnessing catastrophe: correlations between catastrophic palaeoenvironmental events and first Nations' oral traditions in North America's Pacific Northwest. In: MackenthunG, Mucher C (eds) Decolonizing "Prehistory": deep time and indigenous knowledges in North America. University of Arizona Press, Tucson, pp 89–111

Fitzhugh B (2012) Hazards, impacts, and resilience among hunter-gatherers of the Kuril islands. In: Cooper J, Sheets P (eds) Surviving sudden environmental change: answers from archaeology. University Press of Colorado, Boulder, pp 19–42

Fuglestvedt I (2017) Rock art and the wild mind. Visual imagery in Mesolithic Northern Europe. Routledge, London

Giddens A (1984) The constitution of society: outline of the theory of structuration. Polity, Cambridge

Goff J (2017) Palaeotsunamis. Oxf Res Encycl, Nat Hazard Science. https://doi.org/10.1093/acrefore/9780199389407.013.78

Gonzalez RC, Perkone S (2021) Monster as a tool for thinking. Learning from spatial practices in abnormal territories. In Nirta C, Pavoni A (eds) Monstrous ontologies. Politics Ethics Materiality. Vernon, Delaware, pp 61–76

Haraway DJ (2016) Staying with the trouble: making kin in the Chthulucene. Duke University, Durham

Haraway DJ (1992) The promises of monsters. A regenerative politics for inappropriated others. In: Grossberg L, Nelson C, Treichler P (eds) Cultural studies. Routledge, London, pp 295–337

Hirsch M (2008) The generation of postmemory. Poetics Today 29(1):103−128. https://doi.org/10.1215/03335372-2007-019

Hjelle KL, Solem T (2008) Kapittel 4: Botaniske undersøkelser-Ormen Lange Nyhavna. In: Bjerck HB (ed) NTNU Vitenskapsmuseets arkeologiske undersøkelser. Ormen Lange Nyhamna. Tapir, Trondheim, pp 477–545

Hodder I (2012) Entangled: an archaeology of the relationships between humans and things. Wiley-Blackwell, Chichester

Hoffman E (2004) After such knowledge. Memory, history, and the legacy of the holocaust. PublicAffairs, New York

Ingold T (2003) Three in one: How an ecological approach can obviate the distinction between body, mind and culture. In: Roepstorff A, Bubandt N, Kull K (eds) Imagining nature. Aarhus University Press, Århus, Practices of cosmology and identity, pp 40–55

Killen A, Lebovic N (2014) Catastrophes: a history and theory of an operative concept. de Gruyter, Amsterdam

King T (2008) The truth about stories: a native narrative. University of Minnesota Press, Minnesota

Knecht RA, Davis RS (2008) The Amaknak bridge site: cultural change and the Neoglacial in the eastern Aleutians. Arct Anthropol 45(1):61–78

Kverndokk K (2015) Naturkatastrofer (en kulturhistorie). Scandinavian Academic Press, Oslo

Lødøen TK (1995) Landskapet som rituell sfære i steinalder. Unpublished MA thesis, University of Bergen

Lødøen TK (2003) Late Mesolithic rock art and expressions of ideology. In: Larsson L, Knutsson K, Loeffler D et al (eds) Mesolithic on the move. Papers presented at the Sixth International Conference on the Mesolithic in Europe, Stockholm 2000. Oxbow Books, Oxford, pp 511–520

Løvholt F, Bondevik S, Laberg J et al (2017) Some giant submarine landslides do not produce large tsunamis. Geophys Res Lett 44(16). https://doi.org/10.1002/2017GL074062

Ludwin RS, Dennis R, Carver D et al (2005) Dating the 1700 Cascadia earthquake: great coastal earthquakes in native stories. Seismol Res Lett 76:140–148

Lundström V, Peters R, Riede F (2020) Demographic estimates from the palaeolithic-mesolithic boundary in Scandinavia: comparative benchmarks and novel insights. Philos Trans R Soc 376:20200037. https://doi.org/10.1098/rstb.2020.0037

Mackenthun G (2021) "A fearful hope". Extinction, termination, ruination, and the colonial politics of American antiquity. In: Mackenthun G, Mucher C (eds) Decolonizing prehistory. Deep time and indigeneous knowledges in North America. University of Arizona Press, Tucson Az, pp 112–130

Mauss M (1950) The notion of body techniques. Sociology and psychology. Essays 1979. Routledge & Keagan Paul, London, pp 97–123

McIntosh RJ, Tainter JA, McIntosch SK (2000) The way the wind blows: climate, history, and human action. Columbia University, New York

McMillan A, Hutchinson I (2002) When the mountain dwarfs danced: aboriginal traditions of paleoseismic events along the Cascadia subduction zone of Western North America. Ethnohistory 49(1):41–68

Nirta C, Pavoni A (2021) Introduction. In: Nirta C, Pavoni A (eds) Monstrous ontologies. Politics, Ethics, Materiality. Vernon, Delaware, pp 15–34

Nyland AJ (2017) Materialized taskscapes? Mesolithic lithic procurement in Southern Norway. In: Rajala U, Mills P (eds) Forms of Dwelling; 20 years of taskscapes in archaeology. Oxbow books, Oxford, pp 125–150

Nyland AJ, Walker J, Warren G (2021) Evidence of the Storegga tsunami 8200 BP? an archaeological review of impact after a large-scale marine event in Mesolithic Northern Europe. Front Earth Sci 9:767460. https://doi.org/10.3389/feart.2021.767460

Nyland AJ, Damlien H (2024) Lithic stories of broken relations after the Storegga tsunami in Mesolithic western Norway? World Archaeol (special issue: Lithic Ontology). https://doi.org/10.1080/00438243.2024.2357384

Nyland AJ, Stebergløkken H (2021) Changing perceptions of rock art: storying prehistoric worlds. World Archaeol 53(1). https://doi.org/10.1080/00438243.2021.1899042

Oliver-Smith A (1996) Anthropological research on hazards and disasters. Annu Rev Anthropol 25:303–328

Oliver-Smith A (2010) Haiti and the historical construction of disasters. NACLA Rep Am 2010:32–36

Prøsch-Danielsen L (2006) Sea-level studies along the coast of south-western Norway. With emphasis on three short-lived Holocene marine events. AmS-Skrifter 20. Arkeologisk museum, Stavanger

Rahman A, Sakurai A, Munadi K (2016) Indigenous knowledge management to enhance community resilience to tsunami risk: lessons learned from Smong traditions in Simeulue island, Indonesia. IOP Conf Ser: Earth Environ Sci 56:1–12. https://doi.org/10.1088/1755-1315/56/1/012018

Rajan-Rankin S (2021) Beyond scientific racism: monstrous ontologies and hostile environments. In Nirta C, Pavoni A (eds) Monstrous ontologies: politics, ethics, materiality. Vernon, Malaga, pp 111–128

Riede F, Sheets P (2020) Introduction. Framing disasters archaeologically. In: Riede F, Sheets P (eds) Going forward by looking back. Archaeological perspectives on socio-ecological crisis, response, and collapse. Berghahn, New York; Oxford, pp 1–14

Sattler DN, Kaiser CF, Hittner JB (2000) Disaster preparedness: relationships among prior experience, personal characteristics, and distress. J Appl Soc Psychol 30(7):1396–1420

Shaw R, Sharma A, Takeuchi Y (2009) Introduction: indigeneous knowledge and disaster risk reduction. In: Shaw R, Sharma A, Takeuchi Y (eds) Indigeneous knowledge and disaster risk reduction. Nova, New York, pp 1–14

Shaw R (2014) "Nature", "culture" and disasters. Floods and gender in Bangladesh. In: Dove MR (ed) The anthropology of climatic change. A historical reader. Wiley Blackwell, Chichester
Solem T, Solem JO (1997) Shoreline displacement on the coast of Sør-Trøndelag and Møre og Romsdal, central Norway; a botanical and zoological approach. Nor Geol Tidsskr 77:193–203
Sutton SA, Paton D, Buergelt P, Sagala S, Meilianda E (2020) Sustaining a transformative disaster risk reduction strategy: Grandmothers' telling and singing tsunami stories for over 100 years saving lives on Simeulue Island. Int J Environ Res Public Health 17(21):7764. https://doi.org/10.3390/ijerph17217764
The Monster Network (2021) Collective voices and the materialisation of ideas: the monster as methods. In: Nirta C, Pavoni A (eds) Monstrous ontologies. Politics, Ethics, Materiality. Vernon, Delaware, pp 143–167
Vansina JM (1985) Oral tradition as history. University of Wisconsin Press, Wisconsin
Vasskog K, Waldmann N, Bondevik S et al (2013) Evidence for Storegga tsunami run-up at the head of Nordfjord, western Norway. J Quat Sci 28(4):391–402
Vitaliano DB (1976) Legends of the earth. The Citadel Press, Secaucus, Indiana, Their geologic origins
Vollmer H (2013) The sociology of disruption, disaster and social change. Cambridge University Press, Cambridge, Punctuated cooperation
Waddington C, Wicks K (2017) Resilience or wipe out? Evaluating the convergent impacts of the 8.2 ka event and Storegga tsunami on the Mesolithic of northeast Britain. J Archaeological Sci Rep 14:692–714
Walker J, Gaffney V, Fitch S et al (2020) A great wave: the Storegga tsunami and the end of Doggerland? Antiquity 94:1409–1425
Walker J, Nyland AJ, Bergsvik KA et al (2023) A multiproxy approach to understanding the impact of the Storegga tsunami upon Mesolithic hunter-fisher-gatherers across different regions of western Norway. Quarternary Sci Rev 324:108433. https://doi.org/10.1016/j.quascirev.2023.108433
Wickham-Jones C (2002) The Storegga Tsunami in 6000 BC. Curr Archaeol 179(11):468–472
Wordsworth J (1985) The excavation of a Mesolithic horizon at 13–24 castle street. Inverness. Proc Soc Antiqu Scotl 115:89–103

Part II
Stories of Societies Under Pressure

Chapter 8
Living with a Changing Environment: An Ethnographic Account of Indigenous Forest Village Communities' Experience of Floods and Landslides in the Nilgiri Biosphere Reserve, India

Asish Mangalasseri, M. Ajesh, Vinod Chellan, and Noa Lavi

Abstract Extreme landslide events have become a prevalent phenomenon in India over the last decade, with flash floods and landmass slips that wash away slopes and villages in minutes, causing fatalities and severe damage. This paper explores the experience of two small communities (Kattunayakan and Cholanaickan), living in the Nilambur region of the Western Ghats, Southern India, which has become a hot spot for extreme and unpredictable landslides and floods. By amplifying the voices of community members, we aim to provide a better understanding of communities' perspectives of the challenges they face and offer a unique view of key concepts like vulnerability and resilience, which are often taken-for-granted within the discourse of natural disasters. We show that, due to the recent history of knowledge loss and the unpredictability of extreme weather events, the ability of these communities to rely on their forest knowledge and skills is limited. On the other hand, current challenges have in fact opened new paths for intergenerational communication and collaboration and for locally derived coping initiatives, including the harnessing of digital technologies. These localized strategies have so far been underrepresented in official and scientific discussions on disaster management in the region, despite their deep roots in long-standing community values and relationships and their innovative nature.

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_8

Keywords Landslides · India · Natural hazards · Local knowledge · Intergenerational relations

8.1 Introduction

Over the past decade, extreme landslides and flash floods have become a frequent occurrence in India, causing fatalities and severe infrastructure damages. The Western Ghats, a mountain range stretching across 1600 km parallel to the Western coast of India, is one of the India's "hot spots" for landslides. The area's extreme meteorological conditions, steep forested slopes, thick soil cover, and poor land management, following a history of massive deforestation and agricultural expansion, made the land particularly susceptible (Yunus et al. 2021). The current state of unpredictability of flood and landslide events, alongside poor settlement location choices, particularly in some of the government-built permanent settlements for indigenous populations who have been relocated from the forest, and a growing reliance on resources from outside the forest, have increased the vulnerability of many of the area's inhabitants. In this paper, we present an ethnographic account of two communities indigenous to the Western Ghats biodiversity hot spot, the Cholanaickan and Kattunayakan, both considered among the most vulnerable populations in India due to recent extreme hydrological events taking place in their home forest. We draw attention to the importance of taking their words, experience, and actions into account when studying their issues of vulnerability, resilience, and disaster management.

8.2 Background

8.2.1 The Study Area

Our study focuses on the Nilambur region, a part of the Nilgiri Biosphere Reserve and Western Ghats biodiversity hot spot. Nilambur is situated on the eastern side of Malappuram District in Kerala, India. It borders Tamil Nadu to the east and is situated in the foothills of the Nilgiri Hills. These tropical evergreen and monsoon forests are home to many endemic and endangered flora and fauna. The word "Nilambur" originated from the Sanskrit word nilamba, meaning "bamboo" (Keystone Foundation 2007). Deforestation, generally in India and particularly in the Nilgiri Hills, poses a major threat to the environment (Karla 2017; Kumar and Bhagavanulu 2008; Kumari et al. 2020). Quarrying, mining, industrial agriculture, and urbanization are among the major drivers of deforestation (Hosonuma et al. 2012; Karla 2017). According to Global Forest Watch, between 2002 and 2022, India lost 3.9% of its humid primary forest, making up 18% of its tree cover loss in this period (Global Forest Watch 2024). In Nilambur and the mountain slopes above it, vast parts of the forest have been likewise affected by anthropogenic activities such as the conversion of forests for monoculture plantations (e.g. teak and tea) and the expansion of built-up areas. This loss of primary forests brought about land degradation and made the hillslopes more susceptible to instability (or mass movement) (Kumar and Bhagavanulu 2008).

The Nilambur area is home to several communities, such as the Kattunayakan, Cholanaickan, Paniya, Aranadar, and Muthuvan (Das et al. 2013; Development Studies Wing 2017). These communities are known to be indigenous to the area and thus hold specialized environmental knowledge about their environment, and yet many of them struggle today to maintain access and use rights in the surrounding forests. In 2006, the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act came into force to undo the historical injustice experienced by the indigenous people in India (Ministry of Tribal Affairs, Government of India 2024). It recognizes the individual and community rights towards their forests and natural resources. But until now, almost two decades later, this has only been implemented effectively in very few places in India (Call for Justice 2024). The state of Kerala is lagging behind in implementing this act (Sirur 2024). In Nilambur, so far, no community has received the community forest rights (CFR). Consequently, while in the past, many indigenous communities in Nilambur could gather their own food and building materials and were fully dependent on their surrounding forests, many of these communities now rely on state subsidies, gather some products for sale, and buy their own food from outside sellers (Keystone Foundation 2007), thus changing not only their economy but also their social and ecological relations.

8.2.2 Cholanaickan and Kattunayakan People in Nilambur

The Cholanaickan and Kattunayakan are two of the five Particularly Vulnerable Tribal Groups (PVTG) in Kerala. Both communities were historically classified as semi-nomadic hunter-gatherers. They lived in settlements along the river tributaries, composed of temporary shelters, and changed locations on a seasonal basis (Kakkoth 2009). Since 2006, the government has provided them with some permanent housing, often in government-built “tribal colonies” closer to main roads. Yet, many Cholanaickan prefer to continue to build temporary shelters alongside the permanent structures, and the latter are mostly used to escape from elephants at night. Working with a community of Cholanaickan, Kakkoth (2009) explored how state-provided social support, especially housing, for the Cholanaickan community in Kerala has been perceived as a curse rather than care, due to its misalignment with the community’s traditional social structures, emotional needs, and cultural practices. Today, many Cholanaickan people still maintain a relatively mobile lifestyle, collecting resources from their forests and living in remote settlements inside the forest. Despite the continuous deforestation and restrictions, Cholanaickan people are still highly dependent on the forest, with almost all members of the community involved in the collection and trade of non-timber forest products (NTFP) (Haridas et al. 2022).

Kattunayakan were also historically classified as hunter-gatherers and engaged in the collection and trade of NTFP. Like Cholanaickan, most of the Kattunayakan villages were historically located inside the forest. However, while in the past, Kattunayakan were highly mobile inside the forest, today, many of the villages are built by the government and local NGOs and are found on the edge of the forest and near government and private plantations. Many Kattunayakan people now depend on wage labour in these plantations for their livelihood. Traditionally, both Cholanaickan and Kattunayakan settlements had their own area for collecting NTFP, where boundaries and use were mostly defined by social relationships between villages and the members of the communities. In both communities, while forest food still plays an important role in people's daily nutrition, there is a constantly growing reliance on market resources. Many people in these communities are also currently entitled to government subsidies, such as portions of rice, wheat, pulses, and sugar provided through ration cards.

The Cholanaickan and Kattunayakan are known for their strong connections with, and knowledge of, their forest (Bird-David 1990) and its animals (Bird-David and Naveh 2008). However, recent changes related to deforestation and urbanization have resulted in an increase in clashes between animals and humans. For example, crop raiding by elephants is considered to be one of the major challenges related to negative human-elephant interaction in Nilambur (Rohini et al. 2018). In the last few years, an increased threat from tigers (including fatal attacks on domestic animals) has resulted in significant concerns among those living in areas favoured by tigers.

8.2.3 Landslides and Floods in Nilambur

Floods are the most common natural disaster in Kerala. Nearly, 14.5% of Kerala is flood-prone. Such hydrologically driven events are not new to the region. In fact, one of the Cholanaickan's folktales describe their people's origin from two ancestors in the blue mountains who, during a flood, were swept down the forested hills into Mancheeri in the Nilambur region, and they settled there (Keystone Foundation 2007).

However, in the monsoon seasons of 2018, 2019, and 2020, Kerala experienced unexpected and unprecedented extreme rainfall, which resulted in massive floods and landslides. Masses of water, rock, earth, and debris came crashing down the mountain slopes into Nilambur, causing widespread damage. For example, one major landslide in 2019 took 59 lives and caused severe destruction to houses and property in the village of Kavalapara in Nilambur. Another landslide in the same year completely washed away many parts of the Nadukani Ghat road, an important state highway connecting Kerala and Tamil Nadu.

While these events are triggered by high-intensity and prolonged rainfall, there is a complex dynamic system with preparatory causes making slopes vulnerable to failure. Slope failures are often triggered by anthropogenic activities with large-scale land cover changes in the ecologically fragile landscapes. The past several decades have witnessed large-scale land use and intense disruption of forest cover leading to the removal of natural forests with native species (through processes of deforestation, monoculture plantations, industrial agriculture, human settlements, roads, etc.), blockage of stream networks leading to poor network drainage, and removal of the basal support with steep slopes cut for linear projects (roads, pathways, etc.) and residential buildings near the base of the slope. All of these gradually led to land degradation and made the hillslopes more susceptible to instability (Meena et al. 2021; Ramachandra et al. 2021; Vasantha and Bhagavanulu 2008). Coupled with extreme meteorological events, such as recurring instances of high-intensity precipitation in a short time due to changes in the climate, the growing instability of the hillslopes resulted in mudslides or landslides, leading to the loss of life and large-scale destruction of property witnessed by the region's populations today. Following these events, there has been a significant rise in reports of mental health issues, with anxiety about living close to rivers and landslide-prone hillsides increasing during every monsoon season (Kunnathepeedikayil 2020; Parthasarathy et al. 2021). During those major landslips and floods, access to villages of indigenous communities that were situated along the major river tributaries in Nilambur was cut off, making it difficult for rescue and relief work to reach these communities. It had also become challenging for community members who rely on resources from outside of the forest (e.g. wage labour, state subsidies, etc.) to gain access to those resources. This has led to the region being classified as a potential hazard zone during the rainy season, with the local populations—particularly marginalized communities like the Cholanaickan and the Kattunayakan—being categorized as extremely vulnerable (e.g. Vadakkuveettil and Grover 2022).

8.2.4 Perceiving Vulnerability

The question of community vulnerability is often a complex one. According to the Sendai Framework terminology on disaster risk reduction, vulnerability is defined as "[t]he conditions determined by physical, social, economic, and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards" (UNDRR 2007). Indigenous communities often find themselves uniquely positioned in Disaster Risk Reduction (DRR) (Berkes et al. 2021; Hilhorst et al. 2015). On the one hand, they are often perceived as more vulnerable than non-indigenous groups, particularly in cases in which they belong to lower socio-economic classes. But on the other hand, they are also often considered to possess invaluable local knowledge that empowers them to understand hazards and disasters and enhances their adaptive capacity and resilience (Berkes et al. 2021; Paulraj and Andharia 2015). The role of social memory and social learning within these communities is considered crucial in this regard. Berkes et al. (2021) argued that indigenous peoples retain a memory of once-in-a-generation events and use this knowledge to develop local responses to disasters. In recent decades, the notion of Indigenous Knowledge (IK) has gained significant recognition in the context of flood risk reduction, particularly as an essential participatory resource. While conventional hard infrastructure and scientific technologies used for flood management have often fallen short in preventing recurrent flood disasters, in some areas, indigenous knowledge has demonstrated its effectiveness in various ways (Danladi et al. 2018). For instance, indigenous indicators (such as the appearance of bush crickets, wind direction, the movement of migratory birds, and the calling of certain birds of prey) have been found to play vital roles in predicting rain and flood events, and in managing agricultural activities (Okonya and Kroschel 2013). Research conducted among traditional fish workers in Kerala, India (Santha 2014), affirms the presence of indigenous knowledge systems that enable coastal hazard prediction. Likewise, studies in Nepal emphasize the efficiency of community-level flood adaptation techniques and prediction practices, involving methods such as cloud patterns and ant behaviour analysis, rainfall monitoring in upper catchment areas, hotness evaluation, interpretation of natural phenomena like thunderstorms and wind patterns, and initiating communication strategies during flood outbreaks (Devkota and Cockfield 2014; Devkota et al. 2013).

Yet, whether local knowledge can enhance people's resilience and ability to anticipate natural hazards and reduce disaster risks depends on the specific historical circumstances of each community, as well as the nature of the hazard they find themselves in. Loss of land and financial capital has been shown to amplify vulnerability. For example, a study conducted by Sithole et al. (2023) in Zimbabwe highlighted how climate change has heightened the vulnerability of local communities, diminishing their capacity to adapt, and disrupting their efforts to foster resilience. Likewise, Felding (2013) observed consequences of the erosion of local knowledge among the displaced Mishing tribe on Majuli island during flood events. This case study shows the increased vulnerability of the Mishing people, who lost their traditional knowledge, their means of earning a living, and the social structures that had developed around coexisting with the river and flood events. This reveals the adverse outcomes of climate change and the difficulties of the community in dealing with it in the context of inadequate adaptation policies, food insecurity, and the erosion of community coherence (Felding 2013).

In the context of Nilambur, as most indigenous communities live along the riverbanks and depend on the rivers for water and food, they are considered particularly vulnerable to floods and landslides. Moreover, a local history of displacement, restrictions, pressure to send children to boarding schools, and social stigma and discrimination has left communities with fragmented local knowledge and fragile social ties (e.g. Kakkoth 2014; Lavi 2022b).

In the following, we explore the lived experiences of extreme and unpredictable hydrological events of Kattunayakan and Cholanaickan communities. By amplifying the voices of the community members, we aim to offer a unique perspective of key concepts like vulnerability and resilience, which are often taken-for-granted within the discourse of natural disasters. To do so, we bring into the discussion the communities' perspectives of the unpredictable climatic changes, including the economic, social, and mobility implications of these changes, the contemporary situation of cross-generational relations and local knowledge transmission, and the new opportunities and pathways of communication that people are currently forging, in light of the new situation.

8.3 Methodology

This paper focuses on the experience of landslides and floods in two villages in Nilambur: one of Cholanaickan and the other of Kattunayakan. The work within these two communities combined ethnographic and qualitative methods, particularly participant observations, group discussions, and interviews. This work has been part of an ongoing larger Citizen Science project conducted in several villages in the area, aimed at monitoring their natural resources. The Citizen Science project itself is not at the centre of this paper. However, during the group meetings, discussions emerged about people’s experience and perceptions of their environment in light of landslides and floods, which are brought forward in this paper. This group of participants, which included men and women of diverse ages, formed the initial focus group for this study as well. Further informants were recruited to this study from the same communities, to include more voices. The villages chosen for this study were villages that had been significantly affected by the recent landslide and flood events. Access to, and communication with, the communities were facilitated by a long acquaintance and having worked with them. Two of this paper’s authors, Vinod Chellan and Ajesh M., are members of Cholanaickan and Kattunayakan, respectively and thus have extensive knowledge of the community, the villages, and the challenges they face. The two other authors, Asish Mangalasseri and Noa Lavi, have been working with these communities for many years and hold close and long-term relationships with their people.

8.4 The Experience of Floods and Landslides

8.4.1 Unpredictable Changes

When asked about their experience of the recent increase in landslides and flood events, the first thing people immediately highlighted was the current unpredictability of the rainfall. Customary practices and methods practised in previous generations seem to have become ineffective nowadays in predicting rain, leading to a growing sense of insecurity.

> We used to be able to assess the chance of rain in the nearby hills and the Tamil Nadu boundary by looking at the clouds daily. The intensity and the type of rain could be identified and predicted by seeing the rain for continuous two or three days. Each type of rain has different characteristics. We learn this from childhood. So, for example, in settlement A, if an adult

was going to take water from the river, the child stayed at the top of the hill and looked [at the sky] and warned others if the rain was coming from the top of the river's flow. Now it is becoming difficult to predict this because of changes. The weather events used to have a pattern, and now it has changed. For example, the Chammala meen [a type of fish] spawning was an indicator of the [beginning of the] rainy season. However, now it has changed. The fish is spawning late. Now it is difficult to predict anything. Chammala meen used to come at the same time to all areas, but now it arrives in each place at a different time. Now it [the practice of looking at the clouds for two or three days to predict coming rains] changed to using day-to-day cloud movement. After the 2018 flood, the width of the river increased; after that, the river became wider and wider in each rainy season.

Community member, Cholanaickan

The inability to predict the next flood is often described in terms of changes in people's relations and engagement with the environment.

Now the relationship with nature [from malayalam=prakrthi] has become associated with fear. The river changed after the flood, and we could not predict it anymore. Earlier, one could predict it for the next 10 seconds at least and cross a river easily, but now the course has changed; rocks are placed in unknown locations and become unpredictable.

Community member, Cholanaickan

Primarily everyone used to go to the forest, but the relationship and connection with the forest have been reduced during the rainy season. We are afraid to go near the river, and no one is going outside their house [in the rainy season].

Community member, Kattunayakan

In recent years, landslides washed away areas inside the forest, impacting local flora and fauna just as they did humans. Wildlife paths, previously known to, and avoided by, forest-dweller people, were washed away. This, along with the ongoing process of deforestation, forced all of the forest dwellers, humans and animals, into closer contact and negative interactions with the wildlife are increasing. Abrahms (2021) asserted that climate change is compounding human-wildlife conflicts, amplifying resource scarcity, and necessitating cohabitation in increasingly congested spaces. Other studies also confirm that with the habitat loss, wildlife like elephants are increasingly compelled to interact closely with humans, leading to more frequent and severe conflicts over both space and resources, with outcomes spanning from crop damage to loss of life (Chartier et al. 2011; Shaffer et al. 2019).

Animals and people now share the same forest paths and locations, increasing tension and difficulty. Animals and humans share similar places to escape [floods and landslides], because the different corridors and other parts [of the forest] are lost, due to landslides. So… animals now come closer to settlements.

Community member, Cholanaickan

Another aspect of the growing human-animal friction mentioned by people was that following the floods, the safest locations had already been claimed by community members, and people may have inadvertently forced wildlife to move away from these areas, heightening fear among wild animals towards humans and thus resulting in negative interactions in encounters.

> The environment changed. Now the wildlife's lives might be more difficult. The community would claim the best and safest locations for settlements during the rainy season. Moreover, they keep a distance from wild animals, and these animals would be afraid [of humans] in the future too.
>
> **Community member, Cholanaickan**

> The river and forest changed a lot compared to what it was during my childhood. New plants started to be observed now.
>
> **Community member, Kattunayakan**

This last comment echoes research conducted around the world (e.g. Aleen Yoosuf and Unaisudheen 2021; Bhattarai and Cronin 2014; Čuda et al. 2017) that confirms the spread of invasive species after natural disasters such as floods and hurricanes. Such natural disasters provide channels for these species to move from one location to another and establish themselves in new areas. Indeed, in a research conducted in Nilambur after the 2018 flood, Aleen Yoosuf and Unaisudheen (2021) confirmed a comparatively higher dissemination of invasive plants in the flood-affected area.

8.4.2 Economic Implications

The new circumstances have brought changes to people's foraging patterns and economic opportunities. Today, with safe roads being washed away, people are often unable to reach the cities to claim their subsidies. The fear of landslides limits people's foraging ventures during the rainy season and resources are being washed away. As many forest products are now being collected to be sold outside the forests, such changes carry immediate economic implications.

> It's challenging to go to the forest now and collect anything from it. It also affected us economically. Everyone is afraid of the rain and landslides. Thus, most people do not go to the forest during the rainy season. Only floods and landslides are in their mind during these times.
>
> **Community member, Cholanaickan**

> Resources like wild tamarind and greens have been reduced after the flood. Each flood is washing away the resources that were regerminating.
>
> **Community member, Cholanaickan**

> Usually, April-May would be the honey collecting season. However, now we compromised this economic activity to construct our houses and prepare our settlements. We are collecting less honey than before. We are also not catching fish during the rainy season, due to fear. Now all these sorts of activities happen during September-March, when there is no rain. NTFP collecting during the rainy season also decreased significantly. People do not want to take that much risk now. Now people are avoiding NTFP collection during the rainy season. Earlier in the past, they also collected some NTFP during the rainy season. They used to collect wild tamarind, dupa, and asparagus. They set this aside now and decided to only restart collecting these when they are certain they can understand and predict the river flow and rain.

> The honey season was a primary financial resource for us. Now, it is reduced, and we use most of our gains [from the honey] to buy things to prepare for the rainy season–store food items and tarpaulin sheets for shelter.
>
> **Community member, Cholanaickan**

The heavy rains not only caused a decrease in foraging opportunities but also brought about new unexpected expenses. Increased rain is responsible for a quicker deterioration of the houses built by the government in many of the villages. There is also quicker wear to the plastic sheets people often use to repair roofs and walls (Lavi and Bird-David 2014). Bridges have likewise become an economic burden.

> Constructing bridges across rivers used to be easier; it used to take only two or three days, and people used only natural materials like chooral (common rattan) and bamboo back then. However, today, the width of rivers has increased, and people have to spend more money and time constructing bridges. They are also forced to use ropes they buy from outside for extra support. ITDP (Integrated Tribal Development Projects) supports partially, yet people have to add money from their own savings.
>
> **Community member, Cholanaickan**

8.4.3 Mobility and Social Opportunities

Extreme events such as landslides and floods have ongoing social implications of various degrees. Among the flood-displaced Mishing tribe of Assam, for example, a loss of community coherence was caused by the spread of families across the island (Felding 2013). In the Nilambur region, landslides and floods are repeatedly mentioned by the communities in relation to access and mobility. This includes people's inability to move between villages inside the forest and visit their relatives, as well as to travel outside the forest for work and to gain access to subsidies and markets, among other things. Alongside the economic implications, the challenges imposed in terms of reduced mobility have clear social implications, as it reduces the opportunities for social interactions.

> Cultural practices, except for death rituals, are avoided in monsoons. Marriage rituals and practices also moved to the non-rainy season. It is not easy, but now we have to adjust. Earlier, it was generally difficult to adjust or compromise, people needed to be more flexible about their ways.
>
> **Community member, Cholanaickan**

Mobility has always been very significant in the life of both Cholanaickan and Kattunayakan communities. Prior to the increase in flood and landslide events, community members used to move frequently between villages, visiting and spending time with various relatives (Lavi and Bird-David 2014). Creating and maintaining social relations among those communities largely depends on being together, and sharing things, actions, and time (Bird-David 1999, 2017). This has often been done spontaneously, or in response to immediate social situations (e.g. social tensions or new relationships) and events (e.g. births, festivals, etc.), in all seasons. Among other things, widespread sharing has ensured community ties and well-being and has been a central means of establishing, reaffirming, and maintaining relationships and identity (Lavi and Friesem 2019). In the current situation, people's travel is very limited during the rainy season, due to fears of the unpredictability of major flood events. Social gatherings and rituals only take place during the dry season. This gradual decline in gathering opportunities has resulted in a general reduction of sharing.

> Relationships and the opportunities to meet as a group have reduced last year due to the reduced access. People started to think that they should prioritize themselves, and their focus was reduced to their family or house rather than the larger Chemmam [clan].
>
> **Community member, Cholanaickan**
>
> Since, after flood they [Cholanaickan] feel like they have to make their family safe first. ... they also [started to] store food for their family. [Even when] their parents might be in another settlement. They make sure their close family is safe and prepared for the monsoons and even store food considering their relatives.
>
> **Community member, Cholanaickan**
>
> People are also aware of the economic change. They started to store food. They did not used to do this, since every Wednesday they could go and collect.
>
> **Community member, Cholanaickan**

Storing food for family members who live elsewhere stands in contradiction to previous practices of sharing resources with the people present at any particular moment, a practice that has been a core value and marker of personhood in those communities (Bird-David 2017; Lavi 2018; Naveh 2007). Over the last couple of decades, various development agents working with these communities have been continuously encouraging people to forgo sharing practices and strive to accumulate wealth. Yet, before the increase in landslides and floods, in many villages, people maintained this core social practice and continued to share, actively and knowingly prioritizing social networks over personal wealth (Lavi 2018). As sharing was, up until recently, the most common way to express contact and care, the current situation of reduced sharing brought about new social tensions, with various community members repeatedly mentioning to us that "their relatives no longer care" about their community and extended families. It is, however, also important to note that the above comments might be a part of the dynamics of the practice of demand-sharing, in which loudly declared lack and scarcity ("no one shares with me") are meant to encourage and facilitate new acts of sharing, thus providing new opportunities for the reaffirmation and creation of social ties (Lavi 2018; Peterson 1993, 2013).

8.4.4 Cross-Generational Relations and Local Knowledge Transmission

With the heavy rains restricting people's opportunities to travel and forage in the forest, children's learning opportunities are also significantly limited. Among

Kattunayakan and Cholanaickan communities, children learn mostly through observation, participation in adults' practices, and trial and error (Lavi 2022b; Naveh 2016). Learning about the forest, therefore, requires one to join adults or peers in the forest, observing their actions, taking part, and listening—to the people and the environment. Rather than having a clear corpus of educational narratives, stories are told as a reaction to particular meetings, findings, or events encountered in the forest. Learning is therefore very context-based and depends on children's presence and participation (Lavi 2018).

The fear of flash landslides and changed animal behaviour patterns brought about more restrictions on children's time in the forest and their autonomy. Today, children rarely accompany adults to the forest during the rainy season. In one village, people told us that children can no longer even play in the nearby forest, as a tiger recently started moving closer and closer to the village. Alarmed by its presence, parents now restrict children's play to areas where they can be watched at all times. This is a significant change from play patterns observed in the same village in 2014, when groups of children made short ventures to the forest surrounding the village on their own, providing younger children with the opportunity to learn from, and with, their slightly older relatives, to experiment and practise together. Children therefore have fewer opportunities today to gain knowledge and skills related to the forest.

> One should practise in all seasons to learn to swim or climb trees. It was the usual practice, even in the rainy season. In safe places people used to practise these activities, like swimming. However, now, with their experience of only summertime, they will find it difficult to use these skills if needed. Also, the inactivity during this period might make them weak in the future. During the rainy season, people make younger children sit at home, and only children above around 15 years old or mature children go with adults [to the forest].
>
> **Community member, Cholanaickan**
>
> [Today] kids cannot go out during the rainy season since the river is near their village. Earlier in the past, they used to go fishing during this season, so right now, this might be preventing kids from learning these [skills].
>
> **Community member, Kattunayaka**

8.4.5 New Pathways of Communication

While many observed the reduction of mobility, contact between villages, and learning opportunities for young children during the rainy season, an interesting shift in intergenerational relations within the village has also been noted. Years of working outside the forest and relying on rations and wage labour rendered the younger generation less knowledgeable about the forest environment. This has also been enhanced by immersive education institutions that encouraged young people to seek a future outside of the forest and delegitimized many local practices and lifeways (Kakkoth 2014; Lavi 2022a, 2022b; Ninkova et al. 2024). In a study conducted by one of the authors (NL) in 2014, elders expressed sincere worry that young people who attend schools are moving farther and farther away from their communities, with some of them even refusing to speak the local language and eat food from the forest, and intergenerational communication becoming significantly tense (Lavi 2018). As mentioned above, following the flood and landslide events, children had even fewer opportunities to learn about their forest and practise the skills required to thrive in it. However, this new situation has brought about new opportunities for communication. The value of elders' experience in the forest and the new skills young people bring into the village are both newly acknowledged, and new collaborations and communication pathways between elders and young adults are forged.

> One major decision people make together is the location of their settlement. The settlement's elders depend on youngsters to shop and collect rations. But, youngsters depend on elders to decide the location of their settlement – this mainly depends on the experience of living in a place. An example is Ramu, a youngster who was living under the waterfalls; after the floods, he had to move to another location and asked an elder, Sasi, for his opinion. Ramu does not know much about that hill and where the settlement should be during the rainy season. Sasi has experience living in various locations and knows the geology of the hill. Sasi suggested [to live] on top of the rocky hill with less chance of a landslide or flood. . .
>
> **Community member, Cholanaickan**

> Flood indicators include animals crying, cloud formation, smell, colour, and river flow changes. More than this, the elders in the community will have an instinct or feeling.
>
> **Community member, Kattunayakan**

> … Earlier, I did not know flood indicators and how to predict floods. However, now [after the flood], through stories, elders are passing it to youngsters.
>
> **Community member, Kattunayakan**

Despite the difficulty in predicting a flash flood or landslide due to changes in animal and weather patterns, the young community members we talked with expressed a renewed appreciation of their elders' knowledge of their surroundings, after many years of troubled intergenerational relations. Young people pay more attention to elders' words and actions, in the hope that they will be able to note at least some of the pre-flood signs before the event. People are therefore now more attentive to elders' "instincts", gained through decades of daily engagement with the forest, an experience that the younger generation mostly lacks. Additionally, if local knowledge is now less useful in predicting events, it is still effective in risk reduction, particularly in situations where formal decision-making and scientific technologies for flood management fall short (see also Danladi et al. 2018; Devkota et al. 2014, 2013; Okonya and Kroschel 2013). For example, several people mentioned that the location of some settlements built for them closer to towns and roads makes these settlements more susceptible to floods. People thus alternate between the settlement and different locations in and out of the forest, opting to find a safer place in rainy periods, and relying on the knowledge and advice of elders who spent their lives in those woods.

Not only do people find themselves relying again on local knowledge about the landscape and water movement. In some places, the floods and landslides created circumstances in which people were required to rely fully on forest food again, due to the lack of access to rations and markets. This brought new motivation to learn and practise those skills.

> Not all settlements can store food that much. In some settlements, there are less men. For they are the ones who mainly come to Mancheeri for rations. If they do not come, they do not get the rations. Two or three families got into this situation during the flood. They returned to their traditional ways and survived with wild foods like tubers. Generally, this community is confident that they can survive by digging tubers.
>
> **Community member, Cholanaickan**

> In general, the connection and contact between villages and towns were reduced during that time. Food was also limited and challenging. Nowadays, more and more youngsters are also coming forward for the NTFP and honey collection to learn more about it, and they also think there will not be anyone to teach them in the future.
>
> **Community member, Kattunayakan**

These new pathways of communication not only rekindled a new appreciation of elders' knowledge, but also the knowledge and skills of young adults.

> The village got divided into three due to the flood. We moved inside the forest and settled in less vulnerable locations.... Now the settlement is 100 metres away from the river. After the flood, we have more community meetings since we moved to a new place, and we are now claiming our land rights [following the FRA, Forest Rights Act 2006]. Earlier, youngsters did not voice their opinions during discussions. Village elders used to make the major decisions. But now, youngsters have a space, and elders also accept their opinions.
>
> **Community member, Kattunayakan**

> After the flood year, elders and youngsters have equal importance in decision-making, which is a good practice. Earlier, the Chemmam had more importance in decision-making. However, after the flood, each settlement had to cope with the changes and make decisions [for themselves], and [thus] settlements also got more powers in decision-making.
>
> **Community member, Cholanaickan**

The changing traditions in the wake of disasters resonate with Hilhorst et al.'s (2015) argument that indigenous knowledge is not solely grounded in tradition but is flexible and evolving, and can develop in response to new conditions and incorporate new elements (Hilhorst et al. 2015). In the case of this study, those newly forged collaborations have also resulted, at least in some villages, in the rise of novel preventive and coping measures based not only on local ecological knowledge but also on new technologies and means introduced into the villages by the younger generation, which are now inserted into the local social and ecological systems. New technologies such as the use of mobile phones' cameras and WhatsApp are now being harnessed by the communities in their efforts to prepare or avoid hazards. This, however, is done in ways that echo communities' values and practices.

> After the flood, many youngsters use mobile phones. Furthermore, they decide on a settlement location considering the network [reception]. They share the news about the weather with each other through WhatsApp messages, and these news influence their decision to go inside the forest for NTFP collection. They share photos of flood and landslide-affected places and their settlements' photos with each other. This helps assess the impact by sharing knowledge between [community] members and helps them better prepare for storing food items and deciding on safe locations. For example, in a settlement, which had been affected by landslide and flood, villagers sent photos of their affected settlement to others and people from other settlements assessed the situation seeing this photo, or they even came in person to see the impact and the cracks, and provided different perspectives and knowledge.

Community member, Cholanaickan

> The use of phones became very useful during this time. They [people in affected villages] pass messages and warn the villages downstream about the increasing water levels and floods. Usually the first house near the river or whoever sees the change would share this information with others.
>
> **Community member, Kattunayakan**

People also made use of disaster relief resources provided by the government. Some people now move to temporary relief camps during the monsoon period, especially during heavy rain. Others began taking part in official evacuation and support actions, gaining new skills and knowledge.

> Earlier, we did not have vehicles inside the village, but now we do, which helped us to evacuate and rescue others. Children also learned how to cope with this kind of disaster while the adults did rescue and relief work. They also observe and later imitate the adults, and learn.
>
> **Community member, Kattunayakan**

8.5 Conclusions

The recent occurrence of extreme hydrological events is posing new hazards for local indigenous communities in the Nilambur area. Documenting these lived experiences of floods and landslides of local communities is important in understanding the coping practices of the affected communities, and can be very relevant to considering coping mechanisms in other regions.

Beyond the heavy rains causing floods and landslides, these events entail significant changes to the entire ecology, from plants and animals to people's economy, social interactions, and their culture as a whole. However, as expressed by the words of the people themselves, this situation not only poses new challenges but also fosters new opportunities. What might look like a driver for departing from more traditional ways of relating to the environment and other villages also resulted in the enhancement of cross-generational interactions and interest on the part of the young generation in local knowledge. As such knowledge and the skills related to it were gradually fading away due to other processes of external interventions like boarding schools, the social dynamics related to landslides and floods described in this paper form a new chapter in the ever-changing and dynamic story of people in the Nilambur region.

A complex dynamic of risk management is now being constructed, one in which notions such as community resilience and vulnerability seem to be too simplified to encompass people's understanding of their situation and creative coping techniques. While access to government subsidies has been hindered due to landslides and floods cutting off their paths, some families renewed their reliance on forest products for self-consumption (rather than for selling). While landmass movement and changes to animal behaviour resulted in a growing sense of insecurity, they also brought about renewed interest in elders' knowledge and skills and new opportunities for communication and collaboration. While young children are deprived of their autonomy to move and learn through the forest, young adults, who until recently had become gradually estranged from their community lifeways, are now in active conversation with elders. Rather than being passive victims of natural disasters (as they are often portrayed by wealthier neighbours and the local media), communities are constantly active, with different individuals rethinking and negotiating their circumstances differently. As shown in the above examples, some families in both communities learned to shift between external and forest resources according to their need, with the ability to do so varying between families, depending on their relations and attendance to the knowledge and skills of older members of the community. In some communities, elders and young adults discuss and make decisions together, with the looming risk of extreme natural events providing opportunities for reconciliation. Local ecological knowledge is used alongside new means of technology, such as mobile phones, social media, and cars, to provide wider and quicker access to the aforementioned local knowledge. Through those new online networks of support, information, warnings, and knowledgeable advice are being shared between villages even when physical roads have been cut off by landslides. These networks are harnessed to provide alternative modes of maintaining core values and relationships, by allowing people to connect, care, help, and share with relatives when journeys are avoided and physical being together is prevented. By combining different modes of knowledge, skills, and experience of elders and young adults, and by harnessing new technologies, people work together to reduce their own vulnerability and support their relatives. Thus, just as societies are dynamic and ever-changing, so are notions of resilience and vulnerability complex and ever-changing, constantly adapting to new situations. While such processes are likely true anywhere, anytime, extreme events, such as natural hazards, no doubt boost such processes, which may take different and unexpected directions. The long-term implications of all those new dynamics are still unknown, but taken together, they highlight the complexity of the situation. One thing remains clear: these communities are never stagnant, but constantly learning and adjusting.

Acknowledgements The materials in this paper were collected as part of a project which was funded by the UCL-IIT Delhi Strategic Partner Funds and was connected to the Extreme Citizen Science: Analysis and Visualisation project (ECSAnVis). We would like to thank Prof. Muki Haklai, Prof. Jerome Lewis and all the Extreme Citizen Science group in the Department of Geography, University College London, for all their help and support. We also wish to express our deepest gratitude towards all the communities involved in this project, as well as Keystone Foundation (and Anita Varghese) who hosted and supported it, and the National Biodiversity Authority of India.

References

Abrahms B (2021) Human-wildlife conflict under climate change. Science 373(6554):484–485. https://doi.org/10.1126/science.abj4216

Aleen Yoosuf N, Unaisudheen TP (2021) Impact of flood on biodiversity of Kerala: a case study from Malappuram district of Kerala, India. Int Res J Environ Sci 10:8–19
Berkes F, Tsai HM, Bayrak MM et al (2021) Indigenous resilience to disasters in Taiwan and beyond. Sustain 13(5):2435. https://doi.org/10.3390/su13052435
Bhattarai GP, Cronin JT (2014) Hurricane activity and the large-scale pattern of spread of an invasive plant species. PLoS ONE 9(5):e98478. https://doi.org/10.1371/journal.pone.0098478
Bird-David N (1990) The giving environment: another perspective on the economic system of gatherer-hunters. Curr Anthropol 31(2):189–196. https://doi.org/10.1086/203825
Bird-David N (1999) ‘Animism’ revisited: personhood, environment, and relational epistemology. Curr Anthropol 40(S1):67–91
Bird-David N (2017) Us, relatives: scaling and plural life in a forager world. University of California Press, Berkeley CA
Bird-David N, Naveh D (2008) Relational epistemology, immediacy, and conservation. J Study Religion Nat Cult 2(1):55–73. https://doi.org/10.1558/jsrnc.v2i1.55
Call for Justice (2024) Report of the fact-finding committee on the implimitation of the forest right act, 2006. https://imgs.mongabay.com/wp-content/uploads/sites/30/2024/04/04105633/Report-2024-14-3_Final1.pdf
Chartier L, Zimmermann A, Ladle R (2011) Habitat loss and human–elephant conflict in Assam, India: does a critical threshold exist? Oryx 45(4):528–533. https://doi.org/10.1017/S0030605311000044
Čuda J, Rumlerová Z, Bruna J et al (2017) Floods affect the abundance of invasive Impatiens glandulifera and its spread from river corridors. Divers Distrib 23(4):342–354. https://doi.org/10.1111/ddi.12524
Danladi A, Ho C, Ling G (2018) Importance of indigenous knowledge in flood risk reduction: a review. J Adv Res Appl Sci Eng Technol 11(1):7–16. https://www.semanticscholar.org/paper/Importance-of-indigenous-knowledge-in-flood-risk-a-Danladi-Ho/c74164025ca179b6a8deabdc9855c8697c424329
Das AK, Stalin N, Muthumperumal C, Swamy P (2013) Wild plants used by Muthuvan and Kattunaikkan tribal communities of Palakkayam settlement in Nilambur of Malappuram district, kerala. Med Plants 5(2):82. https://doi.org/10.5958/j.0975-6892.5.2.013
Development Studies Wing, Kerala Institute for Research Training and DEVELOPMENT Studies of Scheduled Castes and Scheduled Tribes (2017) Scheduled tribes of Kerala census 1961–2011. https://repository.tribal.gov.in/bitstream/123456789/75207/1/ST_Census.pdf
Devkota RP, Maraseni TN, Cockfield G, Devkota LP (2013) Flood vulnerability through the eyes of vulnerable people in mid-western Terai of Nepal. J Earth Sci Clim Chang 4:132. https://doi.org/10.4172/2157-7617.1000132
Devkota RP, Cockfield G, Maraseni T (2014) Perceived community-based flood adaptation strategies under climate change in Nepal. Int J Glob Warm 6(1):113. https://doi.org/10.1504/ijgw.2014.058758
Felding FC (2013) The risks of climate change adaptation how policies of adaptation, lower the adaptive capacity of indigenous communities. A case study of the Mishing Tribe Majuli Island Assam, Northeast India. Bachelor Degree Thesis, Lund University. https://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=3803423&fileOId=3803429
Global Forest Watch (2024) India Deforestation Rates & Statistics | GFW. https://www.globalforestwatch.org/dashboards/country/IND/?category=undefineda. Accessed 17 Jan 2024
Haridas R, Nesari TM, Kunhikannan C (2022) Utilization of nontimber forest products by primitive tribal groups of Kerala-cholanaikkan and kattunaikan. Book Publisher International (a part of SCIENCEDOMAIN International):62–82 https://doi.org/10.9734/bpi/rhas/v2/3076a
Hilhorst D, Baart J, Van Der Haar G, Leeftink FM (2015) Is disaster “normal” for indigenous people? indigenous knowledge and coping practices. Disaster Prev Manag: Int J 24(4):506–522. https://doi.org/10.1108/DPM-02-2015-0027

Hosonuma N, Herold M, De Sy V, De Fries RS, Brockhaus M, Verchot L, Angelsen A, Romijn E (2012) An assessment of deforestation and forest degradation drivers in developing countries. Environ Res Lett 7(4):044009. https://doi.org/10.1088/1748-9326/7/4/044009
Kakkoth S (2014) Square pegs in round holes: perceptions of hunter-gatherer: school dropouts of Kerala, South India. East Anthropol 67:433–450
Kakkoth S (2009) Social support for hunter-gatherers: care or curse? Econ Polit Wkly 44(36). https://www.epw.in/journal/2009/36/special-articles/social-support-hunter-gatherers-care-or-curse.html
Karla S (2017) A study of deforestation in India. Int J Sci Res Sci Technol (IJSRST) 3(8):1333–1335
Keystone Foundation (2007) Honey trails in the blue mountains: ecology, people and livelihood in the Nilgiri biosphere reserve, India. Keystone Foundation, Kotagiri https://books.google.co.in/books?id=FD0gAQAAMAAJ
Kumar SV, Bhagavanulu DVS (2008) Effect of deforestation on landslides in Nilgiris district–a case study. Photonirvachak 36(1):105–108. https://doi.org/10.1007/s12524-008-0011-5
Kumari R, Banerjee A, Kumar R et al (2020) Deforestation in India: consequences and sustainable solutions. In: IntechOpen eBooks. https://doi.org/10.5772/intechopen.85804
Kunnathepeedikayil S (2020) The long-term mental health consequences of floods and landslides in Thrissur District, Kerala, India. Doctoral dissertation, Harvard University
Lavi N (2022a) 'We only teach them how to be together': parenting, child development and engagement with formal education among the Nayaka in South India. Anthropol Educ Q 53:84–102
Lavi N (2022b) The freedom to stop being free: rethinking school education and personal autonomy among Nayaka children in South India. Hunt Gatherer Res 5(1–2):39–66
Lavi N, Bird-David N (2014) At home under development: a housing project for hunter-gatherers Nayaka of the Nilgiris. East Anthropol 66:407–432
Lavi N, Friesem DE (2019) Towards a broader view of hunter gatherer sharing. McDonald Institute Monographs Series, Cambridge
Lavi N (2018) 'Developing' relations: rethinking the experience of aid and development interventions, a case study from the Nayaka of South India. Doctoral Dissertation, University of Haifa
Meena SR, Ghorbanzadeh O, van Westen CJ et al (2021) Rapid mapping of landslides in the Western Ghats (India) triggered by 2018 extreme monsoon rainfall using a deep learning approach. Landslides 18:1937–1950
Ministry of Tribal Affairs, Government of India (2024) https://tribal.nic.in/fra.aspx. Accessed 13 June 2024
Naveh D (2016) Social and epistemological dimensions of learning among Nayaka hunter-gatherers. In: Terashima H, Hewlett BS (eds) Social learning and innovation in contemporary hunter-gatherers. Springer, Tokyo, pp 125–134
Naveh D (2007) Continuity and change in Nayaka epistemology and subsistence economy: a hunter gatherer case from South India. Doctoral Dissertation, University of Haifa
Ninkova V, Hays J, Lavi N et al (2024) Hunter-gatherer children at school: a view from the global south. Rev Educ Res. https://doi.org/10.3102/00346543241255614
Okonya JS, Kroschel J (2013) Indigenous knowledge of seasonal weather forecasting: a case study in six regions of Uganda. Agric Sci 4(12):641–648. https://doi.org/10.4236/as.2013.412086
Parthasarathy KSS, Deka PC, Saravanan S et al (2021) Assessing the impact of 2018 tropical rainfall and the consecutive flood-related damages for the state of Kerala, India. Disaster Resil Sustain 379–395
Paulraj J, Andharia J (2015) Resilience of indigenous peoples to disasters: an exploration of practices of Konyak community, Nagaland. Eur Sci J 1(10):147–160
Peterson N (1993) Demand sharing: reciprocity and the pressure for generosity among foragers. Am Anthropol 95:860–874
Peterson N (2013) On the persistence of sharing: personhood, asymmetrical reciprocity, and demand sharing in the indigenous Australian domestic moral economy. Aust J Anthropol 24:166–176

Ramachanra TV, Shivamurthy V, Setturu B (2021) Landslides in western Ghats & coastal area–causes, triggers and solutions. Dep State Bull 2021(3):25–45

Rohini CK, Aravindan T, Das KSA et al (2018) People's attitude towards wild elephants, forest conservation and human-elephant conflict in Nilambur, southern Western Ghats of Kerala, India. J Threat Taxa 10(6):11710–11716. https://doi.org/10.11609/jott.3487.10.6.11710-11716

Santha SD, Gahana P, Aswin VS (2014) Local knowledge, early warning and coastal hazards: participatory inquiry among fishworkers in Kerala, India. Action Res 12(3):273–292. https://doi.org/10.1177/1476750314532504

Shaffer LJ, Khadka KK, Van Den Hoek J, Naithani KJ (2019) Human-elephant conflict: a review of current management strategies and future directions. Front Ecol Evol 6:1–12. https://doi.org/10.3389/fevo.2018.00235

Sirur S (2024) More than 15 years on, implementation of forest right act is lagging, new report finds. Mongabay-India. https://india.mongabay.com/2024/04/more-than-15-years-on-implementation-of-forest-right-act-is-lagging-new-report-finds. Accessed 4 April 2024

Sithole D, Tagwireyi C, Marowa T et al (2023) Climate change mitigation in Zimbabwe and links to sustainable development. Environ Dev 47. https://doi.org/10.1016/j.envdev.2023.100891

UNDRR (2007) http://www.undrr.org/terminology/vulnerability. Accessed 30 Aug 2007

Vadakkuveettil A, Grover A (2022) Disaster within a disaster: social vulnerability of Muthuvan tribes in times of floods. Disaster & Dev 11(1):1–123. https://nidm.gov.in/PDF/Journal/NIDMJOURNAL_JanJun2022.pdf#page=11

Vasantha KS, Bhagavanulu DVS (2008) Effect of deforestation on landslides in Nilgiris district—a case study. J Indian Soc Remote Sens 36:105–108

Yunus AP, Fan X, Subramanian SS et al (2021) Unraveling the drivers of intensified landslide regimes in western Ghats, India. Sci Total Environ 770:145357. https://doi.org/10.1016/j.scitotenv.2021.145357

Chapter 9
Memories of Disaster: Tracing the Material and Immaterial Remains of the 1648 Intagan Landslide

Anton Larsson

Abstract Geoarchaeological studies of disasters rely on the preservation of material records. The subdiscipline of historical archaeology supplements these with written and oral accounts that require extensive criticism. In this case study, I investigate the 7 October 1648 Intagan landslide, one of the deadliest geological disasters in Scandinavian history. It has generated a vast scattered corpus of written and cartographic sources. Archaeological finds around the former riverport Åkerström have been attributed to the landslide, but these do not stand up to closer examination.

Keywords Historical archaeology · Early modern · Cultural memory · Folklore · Landslides

9.1 Introduction

There is something that attracts people to the materiality of past disasters and the idea thereof; a strange curiosity of sorts, a desire to make the cataclysmic tangible. This may be why the cities of Pompeii and Herculaneum have been so alluring to souvenir-hunting tourists over the centuries; in addition to providing insights into Roman lifeways, they allow a glimpse into the catastrophic.

However, even disasters with far-reaching effects on entire regions can be difficult to trace; Pompeiis are rare indeed. A grand volcanic eruption that dims the sun for months may leave behind only the faintest of tephra layers or sedimentary traces in ice cores (Riede et al. 2020). The impact of the enormous Mesolithic submarine landslide at Storegga, which was followed by a tsunami that reached shores along the North Sea, can only be traced through scattered pockets of deposited sand (cf. Nyland et al. 2021). The archaeological record tends to be indirect, especially in more localised disasters.

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_9

Historical archaeology—the study of periods for which written and oral sources are available—can provide new perspectives on past disasters, a recent example being the Azores earthquake of 1522 (Gerrard et al. 2021). Interpreting and critiquing such evidence, however, can be challenging.

The 7 October 1648 Intagan landslide, which has been described as "one of the worst natural disasters in [Nordic] history" (Avenius 1998, 46–author's translation), began in the Dano-Norwegian[1] hamlet Intagan, temporarily blocked off the Göta River, and devastated the Swedish riverport of Åkerström (Fig. 9.1). This comparatively small-scale event, which features both in regional histories and the local imagination, has been studied in-depth by geoscientists (Frödin 1919; Järnefors 1957; Sundborg and Norrman 1963). Their interpretations of the event have focused on geology and not on human lives, although many people have longed to locate evidence of the material realities of the disasterscape (c.f. Kapur 2010). In the present study, I provide a historical, cartographical, and archaeological overview of the Intagan landslide and its aftermath and attempt to establish whether any tangible archaeological remains exist.

9.2 Background

The Göta River, approximately 93 km long, drains Lake Vänern into the Kattegat. From the Middle Ages until 1658, when Sweden annexed the Norwegian province of Bahusia (Sw. *Bohuslän*, No. *Båhuslen,* Da. *Bohuslen*), it served as the national border between Norway (later the union of Denmark-Norway) and Sweden. The border followed the river from modern-day Gothenburg by the sea up to Åkerström, where it turned westward (marked as "parish border" on Fig. 9.1). This diversion, in place since 1273 at least (Kalén 1933), allowed unhindered Swedish control of commerce to and from Vänern and its adjacent inland regions. Before the opening of the Trollhätte Canal in 1800, ships moving through the river faced a key obstacle: the rapids and waterfalls at Trollhättan. In the seventeenth century, an overland route called Edsvägen ("The Portage Road") was used instead. It passed through Åkerström to the towns of Brätte and Vänersborg (established in 1644), both on Vänern's southern shore; these hubs were used for loading and unloading cargo. The route played an important role in an iron trade crucial to the Swedish economy. When the Trollhätte Canal was completed, it became obsolete (Bring 1911; Lundén 1954).

The scale of operations along Edsvägen was substantial. Iron and forestry products such as tar and timber went south, while foodstuffs and consumer goods went north (Lundén 1954, 119). The famed naturalist Carl Linnaeus, visiting in 1746, reported that nearby farmers kept hundreds of horses requiring extensive pasturage. Drivers would run convoys loaded with iron twelve to fifteen carts long (Fig. 9.2; Linné

[1] Dano-Norwegian is used here to describe traditionally Norwegian areas that by the seventeenth century were under the control of Denmark as part of the union of Denmark-Norway and largely administered by Danes; it should not be confused with an ethnonym.

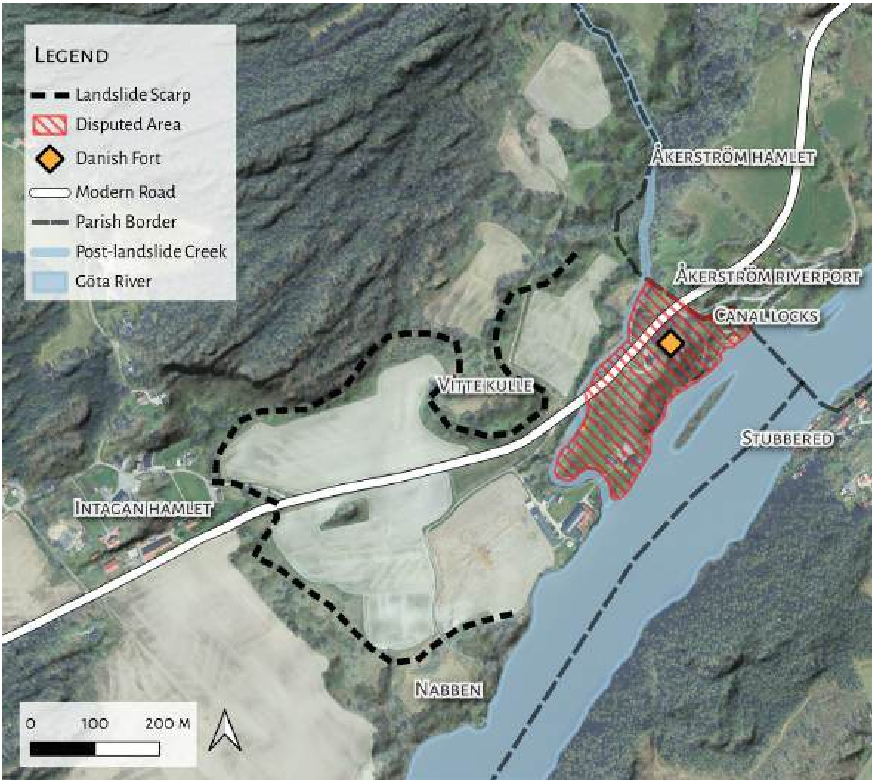

Fig. 9.1 Satellite imagery of the Intagan-Åkerström area, with topographic features enhanced and key features marked. Illustration: Paula Molander (2023)

1747, 207–208). Åkerström (earliest written known attestation: 1542; OÄL 1906, 102) was the name both of a riverport and a peasant hamlet somewhat uphill, in the parish of Naglum (later Vassända-Naglum). The riverport, whose inns and quays were well-known, was the southern end of the Edsvägen overland route and the extent of Swedish territory on the Göta River's western side. It was a key node in the trade network. On the opposite side of the border, across a small creek acting as a boundary marker (known variously as Nödinge å, Marieströmsån, and Brandsboån), was the Dano-Norwegian hamlet of Intagan in the parish of Hjärtum, attested to in 1528 and partially owned by the Crown (OGB 1942, 12). On the eastern side of the river, opposite Intagan and Åkerström, was the Swedish parish of Gärdhem. These two settlements would become the shared scene of one of the worst geological disasters in Scandinavian history.

The wider Göta River Valley has a high landslide frequency because of its notoriously unstable glaciomarine clay soils, some classified as quick clay; the Intagan-Åkerström area was no exception (see Järnefors (1957) for an in-depth examination of the site's geotechnical aspects). The 1648 Intagan landslide, named so because it

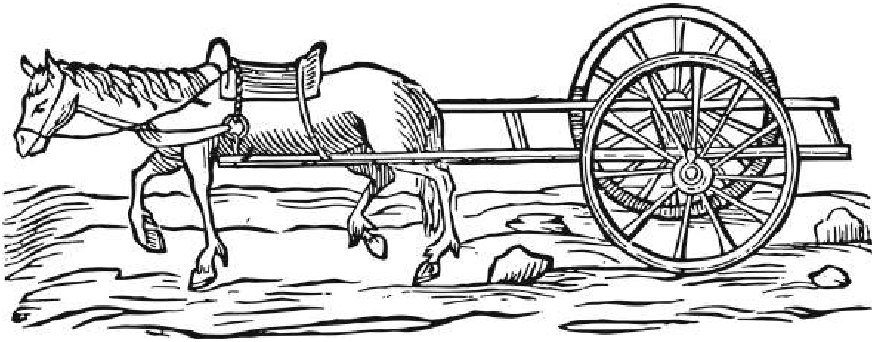

Fig. 9.2 *Edsmärren*, roughly translated as "the Portage Mare", which hauled goods between the Åkerström riverport and Lake Vänern. Illustration: Carl von Linné (1747:208), modified for clarity by Paula Molander (2023)

began on the Dano-Norwegian side of the border before spreading to the Swedish side, has left a relict disasterscape visible to this day. It measured some 270,000 m^2, creating a scarp line almost 2 km in length, with a very large hollow beneath. The difference between the floor of the hollow, which is now farmland (Fig. 9.3), and the original land surface above the scarp varies from a handful of metres up to around 10 m.

The disaster occurred in the autumn, a season of high precipitation when the landslide frequency is heightened. Although the clergyman Rhodin suggested that

Fig. 9.3 Drone photograph of the Intagan scarp, looking towards the south. The green fields above represent the original land surface, the harrowed ones below the new (formed by the landslide). In between is the scarp slope itself, today wooded and used as livestock pasture. Photo: Paula Molander (2023)

it might have been caused by a combination of riverine erosion and an earthquake (Hjärne 1702, 169), Rudolf Kjellén (1910, 25) dismissed the landslide as pseudo-seismic early on. The second-hand account of Grotte and others (see below) indicate that it was triggered by lightning strikes, supporting the view that heavy seasonal rainfall was a key factor (Järnefors 1957, 12). Present-day topography and the fragmentary historical record have together allowed a partial reconstruction of the events of 7 October 1648, although this was not a straightforward task.

9.3 Historical Data

Information on the 1648 landslide is scattered and biased. Most accounts are second-hand; local church records are lacking, and Danish forces retreating from Bohus Castle in 1658 burnt many regional historical documents. The strongest written source is a letter written by the priest Andreas Laurentius Grotte (1605–1664) to Christoffer Torstensson (d. 1658), a local noble patron, on 15 October 1648. Grotte had visited the scene on 9 October and talked to survivors. The now-lost document was transcribed and printed by the priest and antiquarian Johan Oedman (1746, 170–173). Although Oedman likely modernised some spellings, the seventeenth-century grammar seems intact, and several superfluous details with no relevance to the disaster were reproduced. Oedman (1746, 171) was shown the original letter by the astronomer Birger Wassenius (1687–1771), brother of the vicar of Vassända and Naglum, Torsten Wassenius (1687–1771).

Two nearly contemporary Dano-Norwegian sources are the Geelkerck map at the National Archives of Norway in Oslo (Fig. 9.5; see Sect. 9.3.2) and a written inspection document signed on 11 March 1649 by the Danish regional commander Iver Krabbe (1602–1666), which is held at the National Archives of Denmark in Copenhagen. There are also brief legal documents from the courts at Gothenburg for the years following the event; these deal principally with inheritance disputes amongst the relatives of those who perished (Almquist 1929, 287; Svenungsson 1960, 250). Other legal documents may exist in regional court archives.

Several individuals compiled second-hand information. The Lidköping pastor Jonas Rudberus (1636–1697) produced an undated late seventeenth-century account based on intelligence from the nobleman Nils Posse of Säby, whose family owned properties at the Åkerström riverport. Rudberus' account, reprinted by Ljungström (1884), does not seem to have been preserved in the original. The naturalist Urban Hjärne reproduced two accounts in his 1702 treatise on geology: the first was submitted by the priest Andreas Rhodin (1649–1715), who had briefly surveyed the site sometime in the late seventeenth century and interviewed the unnamed still-living widow of a likewise unnamed survivor (Hjärne 1702, 168); and the second account was submitted by the archivist Elias Palmskiöld (1667–1719) from his *Diario Historico* in the Royal Archives (Hjärne 1702, 416).

All extant sources were produced by learned Lutherans, either clergymen or state officials. Women are either fatalities, bereaved relatives or unnamed sources.

Although the disaster originated on the Dano-Norwegian side of the border, most of the accounts were written by Swedes. Only two are immediately contemporaneous with the landslide; the rest contain second-hand descriptions of its wake and the long-lived memories of survivors. The material is, therefore, biased and likely to exclude certain perspectives. In the following section, I summarise the events of 7 October 1648 as described in the written sources (see Sect. 9.3.1.). The principal source is Grotte's letter (Oedman 1746, 170–173), unless specified otherwise. These accounts are then compared with the data provided by the Geelkerck map (see Sect. 9.3.2.).

9.3.1 The Landslide

The landslide began around 2 o'clock in the afternoon of 7 October 1648.[2] Survivors who has been outdoors along the river told Grotte (who visited the scene on 9 October) that it started with a mast-like fire descending from the skies followed by two loud bangs similar to artillery shots, all occurring within an instant. Rhodin's account, or rather that of the widow of a survivor, refers to a "great darkness/and as if a great Fire pillar burning in the black sky" (Hjärne 1702, 168–author's translation). According to Rudberus, it all began when a pitch-black fog crept up from the river; this was followed by an opening-up of the heavens and the casting-down of fire, then two thunder strikes, and finally earthly tremors (Ljungström 1884, 18).

Parts of the Dano-Norwegian farms at Intagan immediately collapsed: "field and meadow, with woods and people and all else there" (Ljungström 1884, 18–author's translation). A vast tract of land, which according to Grotte measured around 27 ells deep (c. 16 m) and a hundred fathoms wide (c. 178 m), slid from the Dano-Norwegian side into the Göta River. This matches the landscape topography and geoscientific data (Järnefors 1957). The river became obstructed, resulting in a tsunami-like wave and water levels temporarily rising upstream to a height between 20 and 30 ells (c. 12–18 m). According to Rudberus, the flooding reach a depth of 29 ells (c. 17 m; Ljungström 1884, 18).

The wave engulfed the Swedish riverport Åkerström, drowning many (including the innkeeper Anders Mårtensson, his wife, their five children, and numerous guests). The building occupied by the unnamed survivor in Rhodin's account was ripped apart timber by timber, killing seven or eight people and livestock; the man managed to hold on to a door floating in the wreckage (Hjärne 1702, 168). A stone's throw away on the Dano-Norwegian side, Anders Mathesson and his wife and children all died. Numerous two-storey warehouses by the Swedish-held rivershore were destroyed, along with their quays. According to Rudberus, the wave destroyed two inns at Åkerström belonging to Sir Nils Posse of Säby; thirteen merchants' warehouses; and an inn on the opposite side of the river at a place called Knurrebo (present-day

[2] This was exactly one week before the signing of the Peace of Westphalia (14 October 1648), according to the Julian calendar (which was used in Scandinavia at the time). According to the Gregorian calendar, the landslide occurred on 17 October, and the Peace was signed on 24 October.

Stubbered; see Fig. 9.1) owned by Gabriel Bengtsson Oxenstierna (Ljungström 1884, 18). The innkeepers, Olof and Håkan, their wives, children, and several visitors lost their lives.

Alongside the demolished structures, a shipment of large wooden masts two fathoms thick (c. 3.5 m) was smashed to pieces. A shipment of iron bars was hurled high onto the riverbank and into the water. At least five riverboats from Gothenburg were sunk, and the debris from the destroyed houses washed up as far as Trollhättan. According to Rudberus, wooden chests washed out of Åkerström were found half a mile upstream (c. 5–6.5 km, depending on which historical definition of a mile is used). The wave travelled south to Lilla Edet (c. 16 km), destroying sawmills, dams, and piers (particularly along the Dano-Norwegian west bank). The riverine trade was blocked for an unspecified time (Ljungström 1884, 18).

Grotte describes how, when he came to view the site from Knurrebo on the eastern side on 9 October, the rapids at Åkerström had calmed and, although the river had managed to push through debris and over the vast swathes of clay covering the area "like great houses or mountains" (Oedman 1746, 172–author's translation), the flooding–to a depth of several fathoms (1 fathom = 1.78 m)–remained. Everywhere was engulfed in a stench of sulphur that evoked Hell itself, an olfactory experience which may be attributed to the local clays being rich in iron sulphides (Järnefors 1957, 16), exposed to the air by the landslide.

According to Rudberus, a small lake eventually formed within the landslide hollow, the rest being a muddy wetland (Ljungström 1884, 18); this was later drained and turned into farmland. Part of the debris remained on the opposite side of the river, by the present-day Stubbered, becoming a fertile hay meadow that was submerged when the water level rose in the early twentieth century. The boundary creek, which formerly met the Göta at Åkerström, took a new course, with the mouth moving c. 350 m southwest (Fig. 9.4). This change to a border marker that had existed since the Middle Ages might easily have led to a territorial dispute (see Sect. 9.4), but there was no known challenge to the legal ownership of the land (now situated on the wrong side of the creek; Fig. 9.1).

It is difficult to estimate the number of casualties. Grotte states that "over 85 people were pitifully drowned" (Oedman 1746, 171–author's translation) when the wave hit the Åkerström riverport. He then adds that 29 men, women, and children from Tunhem *gäll* drowned. This area (Grotte's own ecclesiastic domain) covered the Swedish eastern bank of the Göta but not the Dano-Norwegian side, nor the settlements of Intagan and Åkerström or the Swedish zone on the western bank north of the border. Grotte writes that the tally of 114 dead was a bare minimum and that no bodies had been recovered at the time of writing; it is not clear here whether or not he is referring to his parish alone (Oedman 1746, 72).

Geelkerck's (1648) map legend, produced in the aftermath of the landslide, loosely describes 100 Swedish and 18 Norwegian fatalities (a total of 118 deaths). The 1649 Dano-Norwegian account claims that "over a hundred people" (Svenungsson 1960, 249–author's translation) died within the span of half an hour; like Geelkerck, these officials may have had limited information given the length of the river and the presence of a national border.

Fig. 9.4 Drone photograph of the former boundary creek as it meets the Göta River, looking towards the east. This is the new position of its mouth, shifted from its original position by the landslide. On the other side sits the parish of Gärdhem, where a section of rivershore formed by debris would have been visible until it was flooded in the early twentieth century. Photo: Paula Molander (2023)

On the Dano-Norwegian side, the principal damage to Intagan was the loss of meadows and fields all the way up to the farm. A tenant farmer, Peder Pederssen, is stated to have drowned at the same time, and his unnamed widow is said to have moved, leaving the houses abandoned and unproductive. No royal taxes could therefore be collected (Svenungsson 1960, 249). Local court records from 1661 show that another tenant farmer from Intagan, Pehr Anderssen, died in the landslide, and the loss of his possessions left his widow Kristin Gunnarsdotter destitute. This proved an issue for their heirs, as a neighbour, Erik in Lund, sued them for a copper kettle and a pair of oxen he loaned to Anders the day before the landslide. The court ordered the heirs to remunerate Erik for the lost oxen but not for the kettle—thirteen years after the fact (Svenungsson 1960, 250).

Although Rudberus's account is secondary in the loosest sense of the word, the high stated death toll of 127 (Ljungström 1884, 18) may seem reasonable, but not when the situation on the Dano-Norwegian side of the border is taken into account. Regardless which source is used, it seems probably that no one knew the exact number. Only a handful of male casualties are named: in several cases, these men's wives and children are also stated to have died, but they are all nameless. This is a glaring omission. The men were also of some stature in local society: tenant farmers of the Crown, innkeepers, and riverboat masters. Pehr Anderssen's wife survived, and her name—Kristin Gunnarsdotter—made it into the court records. Little is known

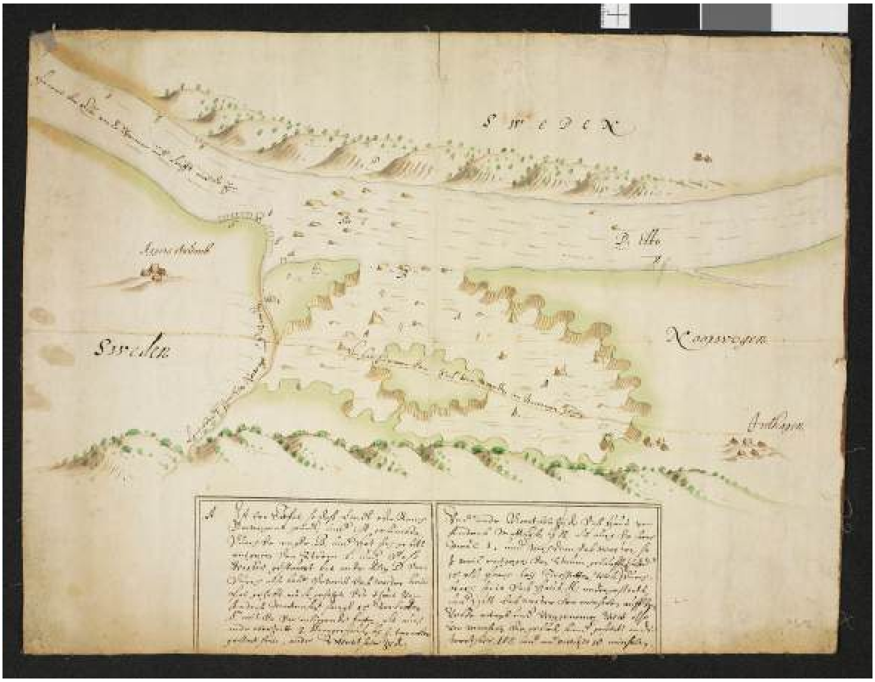

Fig. 9.5 The Geelkerck map, likely produced shortly after the 7 October 1648 landslide. Photo: National Archives of Norway, Oslo (2023)

of the deceased beyond the inheritance disputes with which they were connected. I have, however, managed to discover the fate of another survivor.

In 1660, a junior clergyman called Petrus Haquini Signerus (the Latinised form of *Peter Håkansson of Signerud*) requested permission from the Diocese of Karlstad to marry a woman called Elisabeth Nilsdotter Hungvidia, with whom he had had sexual intercourse. One of the arguments made to the consistory was that he had survived the landslide at Åkerström. During the disaster, fearing for his life and in great peril, the teenaged Petrus—according to his statement—promised God that if He saved him, he would "take one such as wife, who had trespassed against the Sixth Commandment"[3] (Hammarin 1845, 91–author's translation). Such a woman was—partly as a result of his actions—Elisabeth, daughter of Nicolaus Magni Hungvidius, the conrector of a religious school in Karlstad (and later vicar of the parish of Varnhem).

Petrus was born into a peasant family, probably during the 1630s, at Signerud in the Dalian parish of Tydje. In 1660 he was made extraordinary chaplain of his home parish; in 1663 he became a regular chaplain of the parish of Steneby, then parish curate. He is recorded as having died in 1672, while Elisabeth remarried and lived in Dalsland until 1712 (Hammarin 1848, 165; Olsson 1964, 6).

[3] "You shall not commit adultery".

I used the above information to piece together another part of the puzzle. The widow that Andreas Rhodin interviewed sometime in the late seventeenth century lived in Dalsland; she told him that her husband, then a *djäkne* (student), had been teaching the children of the people living on the land closest to the river when the tragedy occurred. This aligns with two other sources from the immediate aftermath. First, Grotte mentions that “two persons, who were in the houses at [Åkerström], were saved and had drifted on wreckage up to Nyckelberget” (Oedman 1746, 172–author’s translation), a cliff around 1 km upstream from Åkerström. Local court records in Gothenburg also mention a *djäkne*, a landslide survivor who had petitioned the court for restitution, though the details are unclear (Almquist 1929, 287). It is likely that Rhodin, Grotte, and the court recorders are all referring to Petrus Haquini Signerus, whom the memory of the landslide stayed with for the rest of his life. This connection has not been made in previous scholarship.

Bar inheritance disputes, the long-term material effects of the disaster are unclear. Disruption to the vital riverine commerce is likely to have been substantial but temporary; more research is needed on this from an economic history perspective. In 1664, after the 1658 Swedish annexation of the region, Norra Intagan (Northern Intagan) was placed under the control of the nearby Swedish town Vänersborg, remaining so until 1917. By 1664, the grasslands around Norra Intagan were sufficiently fertile to provide pasture for the horses used daily for overland shipping between the lakeside town and Åkerström (Svenungsson 1960, 251).

9.3.2 The Geelkerck Map

There has never been a visual representation of the landslide, either published, described, lost, or otherwise–or so I thought until I read Johan Kalén’s (1933, 64) treatise on Bahusian boundary markers, where I found a vague reference to a map by the Dutch military engineer Isaac van Geelkerck (c. 1615–1672), said to be held in the collections of Oslo University Library (Fig. 9.5). I later discovered that it had also been published in an almost illegible daily newspaper (C.K. 1950, 3), but never examined in-depth.

Geelkerck was in Dano-Norwegian service at the time of the disaster, and the map is today held in the cartographic collections of the National Library of Norway. It was likely sketched from the hillocks north of the landslide, with the disasterscape towards the south-east, overlooking the landslide zone, the river (*De Elbo*), and the opposite riverbank. The Dano-Norwegian southern half of the western shore is titled *Noorwegen* and the Swedish northern half and eastern shore are part of *Sweden*. The hamlets of *Aggersströmb* (Åkerström) and *Inthagen* (Intagan) are clearly marked. The original country road, crossing from north to south from Sweden to Norway is outlined, as is the boundary creek and the Göta River. Several key features of the disasterscape are identified, with a partial legend written in German.

The map depicts the long landslide scarp, protruding mounds of clay debris, and isolated trees left standing in the muddy carnage of the landslide hollow, which is marked “A”. The debris by the narrow mouth of the landslide hollow, as it meets the river, is marked “B”. The mass of partially submerged debris that for a time had completely cut off the river is marked “C”. According to Geelkerck’s legend, this debris had run up to the cliffs on the opposite side of the river (marked “D”) and dammed up the Göta. The drowned riverport of Åkerström is shown, with the outline of a total of 16 flooded and destroyed buildings marked on the Swedish side by the riverport quays. Of these, 15 are probably merchant warehouses (marked “F”); a central larger building (marked “E”) was the inn of Anders Mårtensson. On the opposite side of the river, at Knurrebo (Stubbered), three destroyed buildings are outlined; these are described as *Koongerhausen*, at least one of which was likely another inn (based on the written accounts).

On the Dano-Norwegian side of the border, the destroyed residence of Anders Mathesson is also outlined and marked “H”, while the water mill along the boundary creek is marked “I”. According Geelkerck, the flooding reached a quarter of a mile upstream and rose 18 cubits high at Trollhättan; this is difficult to convert accurately into metric terms, but would seem to match the approximate measurements given by other sources. Another building on the Dano-Norwegian side, on the western riverbank to the south of the landslide by present-day Nabben, is marked “K”; according to Geelkerck, the post-landslide wave collapsed this structure and engulfed people in the fields, carrying them downstream. This building might have been the home either of Peder Pederssen or Pehr Anderssen, the two other known Dano-Norwegian fatalities.

Although the map is difficult to georectify because of its skewed perspective, it features every known feature of the landslide based on the written descriptions and the geological makeup of the site. The outline of the scarp, though drawn artistically, matches relatively closely the findings of modern geoscientists, and other details fit the textual accounts, such as the references to the Swedish Anders Mårtensson and the Dano-Norwegian Anders Mathesson and the mounds of clay debris (which Grotte describes as “clay cliffs … like great houses or hills”; Oedman (1746), 172–author’s translation). In sum, the Geelkerck map is a valuable source for understanding and visualising the Intagan landslide.

9.4 Cultural Impact

The cultural memory of 1648 was transmitted in writing and through oral tradition over the following centuries. In a 1678 treatise on waterfalls, the German clergyman and naturalist John Herbinius (1632–1676) recounted a 1665 journey to the waterfalls at Trollhättan and his stay at a rebuilt Åkerström inn. Although the description is brief, it is clear that Herbinius initially questioned the scale of the disaster until an unnamed local gave him a tour of the landslide scarp; his reaction was one of awe and horror (Herbinius 1678; Hagberg 2015).

On 7 October 1748 (the centenary of the landslide), the local vicar Torsten Wassenius (1692–1764) held a commemorative sermon in Vassända Church. The text was later printed for public consumption. Wassenius considered the landslide an act of God, divine retribution for the sinful acts committed along the busy Edsvägen route and in the inns at Åkerström (such as drinking, swearing, and poor church attendance). The sermon also includes references to local folklore and memories of the landslide seen through a religious lens. According to Wassenius (1748), tradition held that an angel appeared to warn the locals of their impending doom (29); a man called Måns from Hålleröd (a hamlet c. 2 km southwest of Intagan, in the parish of Hjärtum) was heading to Åkerström when a sudden pain in his leg induced by the Lord forced him to sit and rest on a hillock, whence he witnessed the disaster unfurl in front of him (33); and God sped up the journey of some caravaneers heading from Åkerström and slowed it down for others heading towards it, thus sparing some lives (21; 34).

Wassenius further incorporated the 1648 landslide into Swedish nationalist mythology by remarking that the Lord had added Norwegian land from Hjärtum to the Swedish parishes of Naglum and Gärdhem by moving the creek and clay across the river, albeit the border was never legally changed (Wassenius 1748, 22). He interpreted this as a portent of God's will that the province of Bahusia be annexed by Sweden in the 1658 Treaty of Roskilde (Wassenius 1748, 34). Later writers made claims that the landslide led to a formal boundary dispute (e.g. Anonymous 1914, 2) and that Dano-Norwegian forces were repulsed when attempting to take back territory it had shifted (Lindström 1977, 14). These stories, which often feature religious portents, are likely spurious (cf. Svenungsson 1960, 251).

Wassenius, a native of the area, also highlighted the impact of the landslide on the affected communities. He claimed that his paternal grandfather, who was in Åkerström when it took place, survived (Wassenius 1748, 6). He also claimed that previous generations placed such importance on the disaster that "that they henceforth counted their age/saying that they were so and so old when [the landslide occurred], or had been born so and so many years thereafter" (1748, 5–6–author's translation). Torsten and his brother Birger had been born at Mankärr, only 11 km north of Åkerström. Their father, the cavalryman Jonas Börjesson, was born there sometime during the year of the disaster. Their paternal grandfather, known only as Börje, is likely to have been a farmer involved in trafficking iron on the Edsvägen route (Johansson 2009, 30).[4]

The memory of the event influenced the way farmers approached the landscape: on a 1780 survey map of Intagan, the small tilled fields in the landslide hollow (expanded in the nineteenth century to cover it entirely) are called *Jordfalls Lyckorne* (the Earthfall Enclosures; Wessborg 1780).

In the early twentieth century, local historian Lars Manfred Svenungsson (1960, 173) recorded two more folktales. One such was that an unknown person—not explicitly an angel—had wandered the area before the event, warning the locals of what

[4] According to Johansson (2009, 44), Torsten's brother Birger wrote a letter to the Mayor of Mariestad, Jonas Wollin, in which he stated that their father Jonas had been born on the same day and hour of the landslide, which sounds implausible. I have not been able to verify the information or the letter.

was to come. Another was that a priest had been out riding in a carriage when the landslide occurred; the vehicle had been so close to the scarp that one of the wheels came into contact with the moving soil, and the whole thing nearly dropped into the abyss. A third piece of folklore, unattributed and possibly modern in origin, has it that all the guests and the bridal couple at a wedding party in Åkerström perished (e.g. Avenius 1998).

Locals have reported hearing stories of the landslide from older generations when growing up, and new residents are often told about it (Lenken 1998, 8; Hakopuro 2017). The 1648 Intagan was evoked in the wake of landslides in the Göta River Valley and Western Sweden, such as the 1892 Kviberg (Anonymous 1892), the 1946 Sköttorp (Anonymous 1946, 10), 1950 Surte (Anonymous 1950, 7), 1957 Göta (Anonymous 1957, 7), and 1977 Tuve (Anonymous 1977, 9) events; in reports on foreign landslides, from the 1963 Vajont Dam disaster in Italy (Anonymous 1963, 1) to the 2020 Gjerdrum landslide in Norway (Öhman 2021, 6); as a reminder of the intermittent but inherent danger of living in a geologically unstable region; and as a means of placing the hazards and disasters faced by communities in a historical context. People have visited Intagan to witness the relict disasterscape (Fig. 9.6), but it has not been developed as a geocultural heritage site, despite its great potential.

Fig. 9.6 Visitors to the Intagan in 1981, with the original land surface and the new (formed by the landslide) divided by the scarp slope. Photograph: Åke Hillefors (1981), Gothenburg Natural History Museum, GNM7032:002

9.5 The Archaeological Record

In light of the cultural significance of the Intagan landslide, the question arises: Have there been any relevant archaeological finds, and if not, is there any possibility of such?

9.5.1 Past Finds

The line between "archaeological artefact", "general waste", and "useful resource" is a thin one. Only a few years after the disaster, materials were recovered: court records from Gothenburg indicate that in 1680 a group of riverboat masters were granted permission to salvage bar iron scattered by the flood wave from the river depths (Almquist 1929, 287), and decades later, Torsten Wassenius claimed that bar iron, unsalvageable because of the rapids, could be glimpsed upstream from Åkerström, and that "finds of iron and copper in the river are now and again/even in this year [1748] recovered" (Wassenius 1748, 20—author's translation). These finds, treated as historical evidence of the landslide rather than economic assets, were possibly the last to have been unequivocally connected to it.

According to Per Adolf Granberg's (1801) history of the Trollhätte Canal, archaeological finds were unearthed in 1779, when a set of canal locks named after Crown Prince Gustav Adolf were built at Åkerström (Fig. 9.7). The labourers found "remains of houses that had been destroyed by the great Earthfall of 1648" (Granberg 1801, 10–author's translation). Although contemporary documentation is lacking, the story is most likely authentic; Granberg had access to canal company archives and still-living staff. It is however difficult to determine whether the fragments were from buildings destroyed in 1648 because—in addition to the conflicts soon to be outlined–Åkerström is believed to have been burnt in 1564 during the Northern Seven Years' War (Lundén 1954, 111).

In 1900, a sequence of archaeological discoveries received much attention in the local press. Numerous artefacts were recovered from excavations as part of construction work in the upper channel of the canal locks at Åkerström (Fig. 9.1). The listed finds included a rather well-preserved small sword, another sword of unknown type, a copper kettle, a tin plate, and a well-preserved brass money box containing well over 100 coins. This Early Modern assemblage was immediately assumed to be from the great landslide of 1648; the money box and weaponry were placed in the care of engineer Carl Wallström (Anonymous 1900, 2). In 1902, a newspaper mentioned the 1900 excavation, adding out that finds had been made several times before and were likely "memories" (Anonymous 1902, 2—author's translation) of the landslide.

By 1930, the details of the 1900 find were being diluted. Svenungsson (1930, 116) noted that the artefacts attributed to the 1648 landslide included two iron strongboxes containing thousands of coins (most of them minted in 1632 and some as large in diameter as small coffee cups) as well as loose coins. He added that many of the

Fig. 9.7 Late eighteenth-century survey map of the Åkerström riverport by the Göta river and the hamlet of the same name further north, featuring the newly constructed canal locks and the possible fort marked *Danska Skansen*. Illustration: Hans Lindskog (1782), modified for clarity by Anton Larsson (2023)

coins had been kept by the labourers and were still sometimes shown amongst the locals—a claim I have no reason to dispute.

The Trollehätte Canal Company eventually donated the numismatic finds to the Swedish History Museum in Stockholm, where they were registered as SHM inv. 12078 before making their way to the Royal Coin Cabinet. The coins are now scattered across collections, and their original container was likely discarded; according to an undated inventory list, it was “a money box of brass with ornamentation above and below as well on the lid, containing six silver coins and 127 copper coins” (ATA n.d.–author’s translation).

The coins listed were mostly Swedish in origin but included a Danish silver coin and two copper coins minted in Utrecht and Reckheim (today Dutch and Belgian towns respectively). The earliest coins in the cache date to the 1620s, starting with a silver *öre* minted in 1624 during the reign of King Gustav II Adolf of Sweden; most of the contents were minted by the government of Queen Christina of Sweden between 1633 and 1645. This fits with the idea that the brass box was buried, along with the other finds made in 1900, in the landslide. However, two small copper coins—a 1/4 *öre* minted in 1656 and a 1/8 *öre* minted in 1666 (from the reigns of Kings Charles X

Gustav and Charles XI of Sweden, respectively; ATA n.d.) representing a *terminus post quem* for the entire cache. Providing that its contents had been left undisturbed, the brass box cannot have been buried in 1648.

The remainder of the 1900 finds have also been dispersed, but with less documentation. Only a blurred photograph survives of the small sword, which was held in the collections of the Trollhättan Antiquarian Society until it was stolen sometime in the twentieth century. As with the coins, it may be of late-seventeenth-century provenance (Lundén 1954, 315–316).

The parish of Hjärtum saw extensive fighting both before and after the Treaty of Roskilde in 1658 (through which Sweden annexed the region), including during the Krabbe War (1657–1658) and the Gyldenløve War (1676–1679). Another sword, dated to the early eighteenth century, was found at nearby Ström during canal refurbishments in 1910; cannonball finds were once a relatively everyday occurrence in the area (Svenungsson 1960, 162). It has been suggested that the rebuilt Åkerström was likely raided in the prelude to the 1676 Battle of Vänersborg, which saw the town looted and torched by Dano-Norwegian forces to disrupt the transport of iron through Edsvägen (Svenungsson 1960, 280). The money box is likely to have been either a stray loss or an intentional deposit. Numerous known coin hoards are likely to have been hidden during the aforementioned conflicts, particularly the Gyldenløve War (cf. Kjellgren 2004; Jonsson 2011).

People have long been eager to rediscover traces of the 1648 landslide in finds from the area. It seems to me that there has been an expectation that the remains of old Intagan and Åkerström will be discovered below ground; the brunt of the damage, however, would have been caused by the tsunami-like flood wave following the landslide, not by the movement of the land. Buildings were ruined and washed away, but they were not entombed in clay. Archaeological remains recovered from the area in 1779, 1900, and possibly other years might date from before or after 7 October 1648.

9.5.2 Potential Features

In short, none of the archaeological finds made in 1900 are likely to have any connection to the 1648 landslide. The building remains discovered in 1779 might have been tied to it; equally, they might have been traces of buildings from any period in the riverport's history. The chance of locating 1648-related finds appears low because of the successive generations of canal locks built between the mid-eighteenth and early twentieth centuries; past riverine dredging; and the extensive construction of modern residences in the vicinity of former Åkerström. If authentic finds or structures from the 1648 landslide were indeed to be made, they would count as protected archaeological remains: any abandoned finds or sites pre-dating 1850 are today protected under the 2014 Cultural Environment Act.

There are still unexplored avenues for archaeological study at Intagan and Åkerström, for example, the rocky outcrops that survived the landslide. Geelkerck's (1648)

Fig. 9.8 Drone photograph of the modern road running through the landslide hollow and past Vitte kulle, looking towards the west. A wind turbine has been built atop the hill. Photo: Paula Molander (2023)

depiction of the pre-landslide road between Sweden and Norway, which was later replaced, shows that it ran further to the north, crossing the hillock that cuts the long landslide scarp in half (Fig. 9.8). Based on historical maps, the outcrop had been known since the mid-eighteenth century at least as Vitte kulle (Fig. 9.1).

Digital elevation modelling (DEM) data reveal a feature measuring c. 45 × 5 m running along the southwest side of Vitte kulle that could be interpreted as a faint road bank flanked by two ditches. In-depth surveying has been hindered by heavy overgrowth. If correctly identified, this would match part of the road depicted by Geelkerck (1648). It was possibly left intact when the rest of the route collapsed into the river (Fig. 9.5). If so, it would be very similar to a site on the other side of the Göta, where a road on the border of the parishes of Fors and Rommele was torn apart by the 1703 Skrehall landslide; scattered sections have survived as earthwork formations resembling those on Vitte kulle (Larsson 2023). Archaeological finds made in 1927 and 1931 along Edsvägen some distance north of Åkerström show that early modern roads in the area could have quite complex internal structures (Lundén 1954, 118).

A second site of interest can be found on another rocky outcrop. A survey map of Åkerström from 1782 (Fig. 9.7) shows a rectangular feature called *Danska Skansen* (the Danish Fort) on top of a riverside hillock, albeit slightly outside of the map's extent (Lindskog 1782), on the former national border and within the area of land that might have been disputed in the aftermath of the landslide (Fig. 9.1). Because the site indicated is heavily overgrown, it has not been possible to establish whether it is folkloric or archaeologically relevant. As it is not shown on Geelkerck's (1648) map, it may pre- or post-date the landslide. The plateau would certainly have been suitable militarily. Dano-Norwegian forces might have fortified the hillock in the mid- to late seventeenth century; several similar riverside positions were strengthened with earthworks and palisades at the time, for instance, Ållebergs kulle near Sanna and Jutekullen (named after the Jutes of Denmark; OGB 1942, 10) near Bondeström (Svenungsson 1960, 160–161).

9.6 Conclusion

The events of 7 October 1648 and their aftermath can be reconstructed using historical sources, notably the Geelkerck map, which has largely escaped the attention of scholars. The landslide and its many casualties had a powerful impact on local communities, and memories still reverberate amongst locals, whether through oral or textual transmission. The disaster has, therefore, remained relevant across almost four centuries, whether as a religious portent, a nationalist symbol, or a stark reminder of the risks of living along the Göta River.

There has been a strong desire to find evidence of the landslide other than topographical features alone, a thirst which has not been quenched by archaeological finds at Åkerström, none of which have any provable connection to 7 October 1648. The will to link material discoveries to intangible memories has been a factor here.

The historical archaeology of early modern transport, conflict, and industry remains largely unexplored in the Göta River Valley, and the 1648 landslide site's status as a piece of dark geocultural heritage (cf. Scarlett and Riede 2019) is likewise undeveloped. The area should be monitored by archaeologists, though any new discoveries are unlikely to be more than tangentially related to the disaster itself.

The relatively short period since the landslide allows us to attempt to reconstruct and understand the events of 7 October 1648 through historical and cartographic sources. Had these materials not existed, the site would have been as anonymous as the hundreds of other substantial, more ancient landslide scars across the Göta River Valley. We must bear in mind that it is likely impossible to identify most past hazards and disasters through the archaeological record, even when they might have had effects spanning centuries; Pompeiis are rare indeed.

Acknowledgements I thank the National Archives of Norway and the University of Oslo Library for their help in locating the Geelkerck map and Professor Kurt Villads Jensen and the Department of History at Stockholm University in translating its legend; the Trollhättan Antiquarian Society for providing me with valuable information; the local residents of Åkerström for their hospitality; and Paula Molander (Gothenburg University) for her cartographic assistance.

References

[ATA] Antikvariska-topografiska arkivet (n.d.) Unpublished archival records held in the Antiquarian Topographic Archive, Stockholm

[OÄL] Ortnamnen i Älvsborgs län (1906) Ortnamnen i Älvsborgs län D. 12 Väne härad. Kungl. Ortnamnskommittén, Stockholm

[OGB] Ortnamnen i Göteborgs och Bohus län (1942) Ortnamnen i Göteborgs och Bohus län 10 Ortnamnen i Inlands Torpe härad. Institutet för ortnamns- och dialektforskning vid Göteborgs Högskola, Gothenburg

Almquist H (1929) Göteborgs historia: grundläggningen och de första hundra åren. D. 1 Från grundläggningen till enväldet (1619–1680). Jubileumsutställningens publikationskommitté, Gothenburg

Anonymous (1892) Jordskredet vid Säfveån. Göteborgskuriren (44):2

Anonymous (1900) Från gamla tider. Trollhättans Tidning (24):2

Anonymous (1902) Ett jordskred i Göta älf som kostade ett 100-tal människor lifvet. Göteborgsposten (289):2

Anonymous (1914) Farliga ställen på västra stambanan. Göteborgs Aftonblad 2

Anonymous (1946) Ett jordskred vid Göta älv för 300 år sedan. Göteborgs Handels- och Sjöfartstidning (30):10

Anonymous (1950) Göta älv-dalen ofta hemsökt. Aftonbladet (264):7

Anonymous (1957) 2.500 kvm rasade vid Surte-katastrofen. Göteborgs Handels-och Sjöfartstidning (132):7

Anonymous (1963) Svenska ras. Svenska Dagbladet (277A:2):1

Anonymous (1977) Ras i dalen sedan 800 år: 1648 dog 85. Dagens Nyheter (327):9

Avenius M (1998) Hela gästgiveriet försvann i vattnet. Populär Historia 1998(4):46–48

Bring S (1911) Trollhätte kanals historia till 1844. Kungl. Vattenfallsstyrelsen, Stockholm

C.K. (1950) Katastrofer i älvleran. Göteborgs Handelsoch Sjöfartstidning (226A):3–4

Frödin G (1919) Jordskreden och markförskjutningarna i Göta älvs dalgång mellan Trollhättan och Lilla Edet. Meddelanden från Kungl. Vattenfallsstyrelsen: 19. Vattenfallsstyrelsen, Stockholm

Geelkerck I v (1648) Kart 2306. National Archives of Norway, Oslo

Gerrard C, Forlin P, Froude M et al (2021) The archaeology of a landslide: unravelling the Azores earthquake disaster of 1522 and its consequences. Eur J Archaeol 24(3):388–411. https://doi.org/10.1017/eaa.2021.4

Granberg PA (1801) Trollhätte canalfartens historia. Gothenburg

Hagberg J (2015) Johannes Herbinius och Trollhättefallen. Meddelanden/föreningen För Västgötalitteratur 2015(3):3–6

Hakopuro P (2017) Historien om jordskredet i Åkerström. TTELA 2017–03–18. https://www.ttela.se/nyheter/lilla-edet/historien-om-jordskredet-i%C3%A5kerstr%C3%B6m-1.4200887. Accessed 21 Oct 2024

Hammarin J (1845) Carlstads Stifts Herdaminne: Första delen. G. Wallencrona, Karlstad

Hammarin J (1848) Carlstads Stifts Herdaminne: Tredje delen. G. Wallencrona, Karlstad

Herbinius J (1678) Dissertationes de admirandis mundi cataractis supra & subterraneis, earumque principio, elementorum circulatione, ubi eadem occasione æstus maris reflui vera ac genuina causa asseritur, nec non terrastri ac primigenio paradiso locus situsque verus in Palæstina restituitur, in tabula chorographica ostenditur, & contra utopios, Indianos, Mesopotamios, aliosque asseritur: Auctore M. Johanne Herbinio. Amsterdam

Hjärne U (1702) Den korta anledningen, til åthskillige malm och bergarters, mineraliers och jordeslags &c. efterspörjande och angifwande. Kongl. Booktr, J. H. Werner, Stockholm

Järnefors B (1957) Skredet vid Intagan år 1648. Serie C., Avhandlingar och uppsatser: 539. Sveriges geologiska undersökning, Stockholm

Johansson P (2009) Birger och Torsten Wassenius–två bröder från Vänersborg i frihetstidens Sverige. Vänersborgs Söners Gille: Årsskrift 2009:29–51

Jonsson K (2011) Myntskatterna under det skånska kriget 1675–1679. In: Thelin B, Wijk M (eds) Moneta 5: Meddelanden från Skånes numismatiska förening. Skånes numismatiska förening, Malmö

Kalén J (1933) Bohuslänska gränsmärken. Gumperts, Gothenburg

Kapur A (2010) Vulnerable India: a geographical study of disaster. SAGE, Delhi

Kjellén R (1910) Sveriges jordskalf: försök till en seismisk landsgeografi. Göteborgs högskolas årsskrift 15:2. Gothenburg

Kjellgren R (2004) Sveriges mynthistoria: landskapsinventeringen. 11 Myntfynd från Bohuslän. Kungl. Myntkabinettet, Stockholm

Larsson A (2023) The 1703 Skrehall landslide: a historical archaeological perspective on disasterscapes. Rural Landsc: Soc, Environ, Hist 10(1)

Lenken P (1998) Det är bara Åkerström som står i älven. Göteborgsposten (185):8

Lindskog H (1782) Charta öfver Frälsehemmanet Åkerström uti Elfsborgs Höfdingedöme Wene Härad och Naglums Sokn Författad År 1782 af Hans Lindskog. Vassända-Naglums socken, Åkerström nr 1, Storskifte på inägor. O200–84:1. Lantmäteristyrelsens arkiv

Lindström B (1977) Utflykt i trollhättebygden: Hälltorpsbron och Åkerström. Trollhättan (148):13

Linné, C v (1747) Carl Linnæi Wästgöta-resa, på riksens högloflige ständers befallning förrättad år 1746. Stockholm

Ljungström CJ (1884) Wäne härad samt staden Wenersborg beskrifna af Claës Joh. Ljungström. Efter hans död utgifna 1884. Stockholm

Lundén G (1954) Det forna Vassända-Naglum och Brätte stad. Trollhättan

Nyland A, Walker J, Warren G (2021) Evidence of the Storegga Tsunami 8200 BP? an archaeological review of impact after a large-scale marine event in Mesolithic Northern Europe. Front Earth Sci 9(2021). https://doi.org/10.3389/feart.2021.767460

Oedman J (1746) Chorographia Bahusiensis Thet är: Bahus-Läns Beskrifning. Lars Salvius, Stockholm

Öhman M (2021) Kvicklera finns i Alingsås–men statsgeologen manar till lugn. Alingsås Tidning 6

Olsson V (1964) Signerud. Provinstidningen Dalsland 6(18)

Riede R, Barnes GL, Elson MD et al. (2020) Prospects and pitfalls in integrating volcanology and archaeology: a review. J Volcanol Geotherm Res 401(2020). https://doi.org/10.1016/j.jvolgeores.2020.106977

Scarlett JP, Riede F (2019) The dark geocultural heritage of volcanoes: combining cultural and geoheritage perspectives for mutual benefit. Geoheritage 11(2019):1705–1721. https://doi.org/10.1007/s12371-019-00381-2

Sundborg Å, Norrman J (1963) Göta älv: hydrologi och morfologi med särskild hänsyn till erosionsprocesserna, Stockholm

Svenungsson LM (1930) Hjärtum: En sockens beskrivning: Något ur dess historia. Hjärtum

Svenungsson LM (1960) Hjärtum-Västerlanda, Inlands Torpe: häradshistorik, new ed. Hjärtum

Wassenius T (1748) Guds werck, beprisad af barnabarn, och lemnad efter-werlden til hogkommelse, tå thet stora werk, som Herren Gud giord then 7. octobr. åhr 1648 i grentsen af Waszenda församling wid Åkerström, blef samma församlings inwånare, hundrade åhr therefter, til sinnes fördt, vti en enfaldig wecku-predikan, i Waszenda kyrkjo den 7. octobris. 1748. Skara

Wessborg L (1780) Geometrisk Charta Öfwer Norre Intagans Ägor uti Bohus Lähn Torpe Härad och Hjertums Socken belägne uprättad Åhr 1780 i Maÿ M: af L. Wessborg. Hjärtums socken, Intagan nr 1–3, Storskifte. N37–24:1. Lantmäteristyrelsens arkiv

Chapter 10
Lower Limb Diaphyseal Morphology Reveals Diverse Mobility Strategies in the Creation and Maintenance of Resilient Landscapes: Coastal Hunter-Gatherers from Japan and Latvia

Daniel H. Temple, Gunita Zarina, and Ilga Zagorska

Abstract Persistent places reference locations that are continuously or repeatedly used during long-term regional occupation. Persistent places are defined by access to concentrations of natural resources and the construction of features that help focus reoccupation such as dwelling structures, processing facilities, or ceremonial centres. Recent studies reveal diversity in the temporal cycles governing the occupation of persistent places but emphasize the value of social memory. This study extends these findings to patterns of mobility in hunter-gatherer communities from aquatic environments, centring coastal communities of the Late/Final Jomon period and the lacustrine community at the Zvejnieki site in Latvia using long bone diaphyseal robusticity. Hunter-gatherers from the Late/Final Jomon period express a pattern of femoral diaphyseal morphology that indicates travel over greater distances and interaction with complex terrain. Hunter-gatherers from the Zvejnieki site express a femoral diaphyseal morphology that is consistent with reduced mobility and interaction with flatter terrain. However, cemeteries at both locales reveal spatial affiliation with the ancestral dead, persistent usage of animal remains as burial ornaments, and emerging inequality in relation to diet and grave good usage. These results illustrate diverse patterns of mobility, while emphasizing the importance of social memory and ancestral affiliation in relation to persistent place.

Keywords Jomon · Zvejnieki · Functional adaptation · Resilience · Hunter-gatherers · Persistent place

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_10

10.1 Introduction

10.1.1 Resilience and Mobility

Resilience theory was developed to understand survival through flexibility in ecological communities (Holling 1973). Resilience explores *what* is maintained, *how* it is maintained, and the deeper capacity to fundamentally collapse or transform the identity of socio-ecological systems in response to environmental perturbation (Walker et al. 2004; Folke 2006). Socio-ecological systems reference the interaction between humans and the natural environment where resource usage is governed by human and natural systems, including socio-political institutions, redistribution and communication networks, ideology and world view, conformity in social identities and agencies, and local climates (Berkes and Folke 1998; Redman and Kinzig 2003). Transformation references the instantiation of systems with entirely new feedback mechanisms that render previous identities unrecognizable (Walker et al. 2004), while collapse refers to contractions of complexity and size (Tainter 1988, 2016). Collapse is often identified as an antithesis to resilience, though new theoretical explorations have identified archaeological cases where simplification may indicate adaptive transformation (Hudson 2020).

When studying resilience, it is important to clearly define the target of study (resilience *of what*), associated feedback mechanisms, and socio-ecological stressors (*to what*) that challenge system identities (Carpenter et al. 2001). Resilience evaluates cycles of growth and decline in human communities in relation to connectedness and potential. Connectedness refers to the degree of interdependence in feedback mechanisms that exist between characteristics of the socio-ecological system, while potential references the availability of resources in the socio-ecological system. High levels of connectedness and reduced potential often result in drastic transformation in response to stressors as the need to shift multiple aspects of the socio-ecological system becomes imperative due to high levels of interrelation between resources and the feedback mechanisms within the system. Resilience theory is now a key paradigm in predicting challenges and consequences associated with global climate change as the production of sustainable communities helps offset the devastating impacts of this ecological stressor.

Mobility in response to climate change was initially viewed as a failure to adapt, specifically referencing circumstances where populations were forced to move following ecological disturbances that challenged livelihoods (Schenshul and Dodman 2013). However, the study of mobility in relation to climate change has expanded to include the ways in which mobility reduces vulnerability and enhances sustainable lifestyles; these behaviours are seen as mollifying environmental risk by reducing pressure on local resources and enhancing social networks. For example, mobility is associated with movements of fishing encampments to allow recovery time following harvesting (Castillo 2011; Donald and Mitchell 1994; Watanabe 1973). Mobility reduces risk by diversifying access to natural resources, which mitigates seasonal resource stress (Kofinas et al. 2010; Oteros-Rozas et al. 2012; Warner et al. 2012) and increases ecological knowledge through expanded social networks (Berkes and Jolly 2001; Tompkins and Adger 2004). Mobility also allows populations to thrive in the wake of natural disasters, disease epidemics, or lost infrastructure. In this respect, mobility represents an essential characteristic of resilient communities and becomes especially important in terms of resilient occupation of archaeological sites, as the capacity to invest in diverse socio-ecological strategies helps reduce risk associated with climate change, natural disasters, or seasonal exploitation of resources.

10.1.2 Bioarchaeological Studies of Resilience, Resilient Landscapes, and Mobility

Detailed material evidence of human behaviour, local ecologies, and high-resolution dating can be used to test hypotheses relating to the creation and maintenance of sustainable socio-ecological systems during periods of ecological perturbation (Jordan and Weber 2016; Redman 2005; Zvelebil and Weber 2013). In this sense, archaeological research has the distinct capacity to provide a time series understanding regarding the question of resilience *of what*, *to what* by identifying behaviours and feedback mechanisms associated with the socio-ecological system and contextualizing these factors into high-resolution environmental reconstructions. Much of this literature finds that interconnectedness, inequality, and isolation have dire consequences for the survival of populations during periods when climate change imperils resource availability (Hegmon et al. 2008; Hudson et al. 2012; Nelson et al. 2016; Temple and Stojanowski 2019), though excessive diversity in socio-ecological systems and reliance on global social networks may also reduce resilience (Fitzhugh et al. 2016; Folke 2006). Hunter-gatherer communities are of interest to resilience studies given their long-standing population histories, land tenure, unique world views, and assumptions that these groups were simply replaced by agriculture (Temple and Stojanowski 2019). Hunter-gatherers engage in reciprocal relationships with nature, which differ from the focus on care and dominion observed in agricultural communities (Ingold 1988, 2000). Understanding socio-ecological systems through this ideological context permits questions surrounding resilience *of what*, *to what* to proceed in ways that may help further illuminate the deeper feedback mechanisms associated with this process.

Persistent places reference locations that are repeatedly used during long-term regional occupation, acting as a conjunction of particular human behaviours in relation to a landscape (Schlanger 1992, 97). Persistent places are defined by attributes including access to concentrations of natural resources and the construction of features that help focus reoccupation such as dwelling structures, processing facilities, and ceremonial centres. Finally, persistent places may also be associated with reoccupations that are independent of cultural features (such as dwelling structures) but dependent on cultural materials such as lithic assemblages (Schlanger 1992;

Shaw et al. 2016). The capacity to maintain persistent places over extended periods of time, and specifically across climatic perturbations, identifies a subcategory of these locales as resilient landscapes. Diverse patterns of occupation are identified in the context of persistent places in hunter-gatherers (Allen and Littleton 2007; Gamble 2017; Temple and Kusaka 2024; Thompson 2010). These patterns are associated with resource fluctuation, availability, and ideological behaviours that tie persistent places to deeper social memory. Diverse patterns of occupation portend variation in mobility patterns surrounding resilient site occupation, and these patterns may help further elucidate behaviours relating to long-term cycles of occupation and reoccupation of landscapes.

Mobility has myriad definitions within anthropology (Kelly 2013; Sheller and Urry 2006). Sheller and Urry (2006) identify multiple theoretical points of departure and methods for the study of mobility. Of particular importance is the break from static concepts of sedentary versus nomadic binaries and understanding mobility from corporeal perspectives, specifically in the context of forming and reforming space through movement. Methodologically, two concepts of mobility are also relevant to this chapter, namely the keeping of time–space diaries and the performance of memory (Sheller and Urry 2006); here, the body may be used as a locus point or referent to past habitual activities (i.e. Bourdieu 1977). Behavioural ecological evaluations of mobility identify residential and logistical mobility to differentiate between residential moves and those associated with the exploitation of resources (Binford 1980; Kelly 2013). Behavioural ecological approaches demonstrate that variation in mobility among coastal and terrestrial hunters is primarily explained by logistical movement rather than residential moves (Kelly 2013).

For the purposes of this study, mobility is defined in a biomechanical context (i.e. Carlson and Marchi 2014), which has the capacity to address time series and embodied evidence of mobility, and identify the structure of mobility in hunter-gatherer communities. Cross-sectional properties of long bone diaphyses act as a time-series, embodied record of human habitual activity (i.e. Ruff et al. 2006; Temple et al. 2021). Bone functional adaptation (or "Wolff's Law") incorporates the concept that bones subjected to increased loading deposit greater amounts of skeletal tissue on periosteal and endosteal surfaces, while those subjected to strains below optimal levels resorb bone to reduce tissue maintenance (Lanyon 1982; Ruff et al. 2006; Woo et al. 1981). Clinical, experimental, and bioarchaeological research demonstrates increases in diaphyseal rigidity/strength in bones associated with raised intensity and duration of physical activity, while declines are associated with disruptions or reductions in mechanical loading (Bass et al. 2002; Bridges et al. 2000; Holt 2003; Jones et al. 1977; King et al. 1969; Larsen 1982; Ruff et al. 1984, 1994; Shaw and Stock 2009a, b). Bioarchaeological studies of resilience have identified similar patterns of mobility and manual behaviour, suggesting continuity in habitual activity consistent with hunting following climatic shifts and socio-ecological reorganization (Cameron and Stock 2019; Temple 2019). The ratio of anteroposterior (A-P) to mediolateral (M-L) bending rigidity is an index of diaphyseal cross-sectional shape (Ruff 1987). Elevated mobility increases A-P bending of the lower limb bones (see Ruff et al. 2015 and references therein) and thus increases the ratio (Ruff 2019).

Sexual dimorphism in mobility indices may be used to differentiate logistical and residential mobility patterns (Ruff 1987; 1999). Greater relative A-P bending rigidity is also found among samples from regions with complex terrain and should be carefully evaluated in relation to cross-sectional properties (Holt et al. 2018; Holt and Whittey 2019; Marchi 2008; Marchi et al. 2011; Ruff 1999; Ruff and Larsen 2014; Stock and Pfeiffer 2004). The cross-sectional properties of bone provide a valuable method to study mobility in ways that address the primary theoretical and methodological parameters of anthropological studies of mobility to gain insight into cycles of site occupation and reoccupation.

The goal of this chapter is to explore mobility strategies related to resilient site occupation across ecological perturbations such as climate change in two maritime hunter-gatherer communities. Mobility strategies are identified at hunter-gatherer sites occupied across different terrains and over extended periods of time. These behaviours are contrasted with archaeological mortuary practices to identify the ways in which hunter-gatherers maintained ideological affiliations with landscape. Here, it is predicted that diverse strategies in mobility will be found as a method to support resilient site occupation, though continued spatial affiliation with the dead will be documented. In this sense, this chapter explores the strategies used to maintain resilient site occupation (*of what*) across periods of climate change (*to what*). This chapter also discusses feedback mechanisms (mortuary practices) in relation to these behaviours.

10.2 Materials

The maintenance of resilient landscapes is dependent upon cycles of reoccupation and communal ability to exploit diverse resources across cultural and environmental perturbations. Hunter-gatherers from the Middle to Late/Final phases of the Jomon period in Japan and Mesolithic to Neolithic occupation of Zvejnieki, Lake Burtnieks, Latvia establish important contrasts in this respect and were chosen for this study. Each settlement is located in different ecological zones. Jomon sites include coastal settlements that are bordered by mountainous terrain, suggesting that both elevated distance (repetition) and interaction with complex terrain (intensity) were required to maintain diverse patterns of resource exploitation, and this may have varied between regions (see below). In contrast, the Zvejnieki site was located adjacent to a freshwater lacustrine ecosystem (Lake Burtnieks, Latvia) on low-relief terrain and surrounded by wooded regions where faunal game was readily accessible (see below).

Comparative cross-sectional properties were derived from the European database (Ruff 2018), including Early Upper Paleolithic, Late Upper Paleolithic, Mesolithic, and Neolithic remains (Table 10.1). These measurements provide valuable contextual information as patterns of mobility, and engagement with terrain have been established according to detailed chronological, cultural, and ecological data that are relatively unmatched in global perspective (Ruff 2018). Table 10.2 lists the behavioural characterizations of these groups summarized in Holt et al. (2018) and

Table 10.1 Sample composition for the European database (Ruff 2018)

Time period	N Male	N Female
Early upper paleolithic	9	5
Late upper paleolithic	14	7
Mesolithic	36	14
Neolithic	155	106

Table 10.2 Description of the mobility environment and approximate dates for human remains from the European database that are included in this work (Ruff 2018; Holt et al. 2018)

Group	Mobility environment	Approximate dates
Early upper paleolithic	High residential and logistical mobility; large geographic range; large game	33,000 – 26,00 BP
Late upper paleolithic	High residential and logistical mobility; large geographic range; large game	22,000 – 11,000 BP
Mesolithic	Declining residential mobility; elevated logistical mobility; smaller game; larger settlements	8550 – 4000 BP
Neolithic	Reduced residential and logistical mobility; agriculture; ceramics; permanent villages	5350 – 2050 BP

Dates are listed for human skeletal remains included in this work, are not representative of complete cultural periods, and are regionally specific

dates provided by Ruff (2018). Some caution must be exercised as Jomon remains are derived from geographically disparate regions. However, while cross-sectional analyses of long bone diaphyses from East Asia provide valuable information on Paleolithic groups, studies of cross-sectional geometry in agricultural communities are often equally temporally and spatially heterogeneous when compared with the Jomon period (Shackelford 2007; Takigawa 2006). In this sense, the temporal and ecological control afforded to the European database is considered appropriate for comparative purposes.

10.2.1 Jomon Period Sites

The Jomon period is associated with a hunter-gatherer culture that thrived in the Japanese islands between approximately 16,000 and 2300 BP (Imamura 1996). Jomon period hunter-gatherers were the descendants of Paleolithic microblade populations that likely entered the Japanese islands via North-East Asia from Hokkaido around 20,000 BP (Ikawa-Smith 2004). The Jomon period comprises six phases: Incipient (16,400–8500 BP), Initial (8500–5000 BP), Early (5000–4200 BP), Middle (5500–4400), Late (4400–3250), and Final (3250–2300 BP). Phases of the Jomon period are defined on the basis of mobility, site size, and site complexity (Habu 2004;

Imamura 1996). This study focuses on the Middle to Final phases of the Jomon period due to the broad comparability of site types (Kobayashi 1992).

Locations for each Jomon period site are shown in Fig. 10.1. Sex-specific numbers of remains for each comparison are listed in Table 10.3. The first site (Ota) is dated to the Middle phase of the Jomon period and is located along the Seto Inland Sea in Onomichi City in the Sanyo region of Japan. Currently, this site is dated based on pottery chronologies between approximately 5000 and 3800 BP. Around 55 individuals were excavated from the Ota site in 1926. All remains included in this study have a relatively narrow diet, with $\delta^{15}N$ isotope values ranging between 13.2 and 15.3 consistent with an elevated level of maritime dependence (Kusaka et al. 2010). One individual with a $\delta^{15}N$ value of 7.7 is, however, included and, if necessary, will be addressed as a potential outlier in the biomechanical analysis as this diet suggests a substantial reduction in maritime resource consumption.

The second site (Tsukumo) is located along the Seto Inland Sea in the modern city of Kasaoka in the Sanyo region of Japan. Approximately 72 burials were excavated at the Tsukumo site between 1920 and 1922. Radiocarbon analysis of human skeletal remains from the Tsukumo site identified at least three periods of occupation: one early burial dating to approximately 5000 BP, one dating from approximately 4170 to 3540 BP, and a larger occupation lasting from approximately 3290 to 2930 BP (Kusaka 2023; Yamada et al. 2020). Human remains from the Tsukumo site that were included in this study date to the latest, larger occupational period (Kusaka et al. 2023; Yamada et al. 2020).

Two sites located near Tahara Town in the Aichi prefecture are also included in this study: Inariyama and Yoshigo. Remains from the Inariyama site revealed three cycles of occupation, one dating between 3230 and 2850 BP, a second dating between 2700 and 2350 BP, and a third, smaller occupation dating between 2300 and 2130 BP (Kusaka et al. 2018). Approximately 60 individuals were excavated from the site. Stable isotope analysis indicates a shift from a focus on maritime to terrestrial resources between the first and second phases of site occupation (Kusaka et al. 2018). The work also identified differences in burial position indicative of changes in mortuary practices from flexed to extended between the first and second phases at Inariyama: flexed burial positions are found throughout the occupation of the site, while extended burial positions begin at approximately 2740 and continue until 2190 BP. Individuals included from the Inariyama site date between 2900 and 2350 BP. These same individuals have $\delta^{15}N$ values that range from approximately 7.3 to 9.8, indicating a diet that featured a relatively larger contribution from terrestrial mammals (Kusaka et al. 2018).

The Yoshigo site is a large shell mound with approximately 305 burials. Radiocarbon analyses of select human remains and mollusc shells suggest an occupational period of 3300 to 2800 BP (Kusaka et al. 2009; Watanabe 1963). However, both flexed and extended burials from the Late and Final phases of the Jomon period, as well as pottery dated to the Early phase of the subsequent Yayoi agricultural period, are found at Yoshigo (Kiyono 1969; Saito et al. 1952), indicating that a later occupation of the site is likely. Recent stable isotope analysis found that individuals interred within the east cluster consumed fewer aquatic resources and may have been

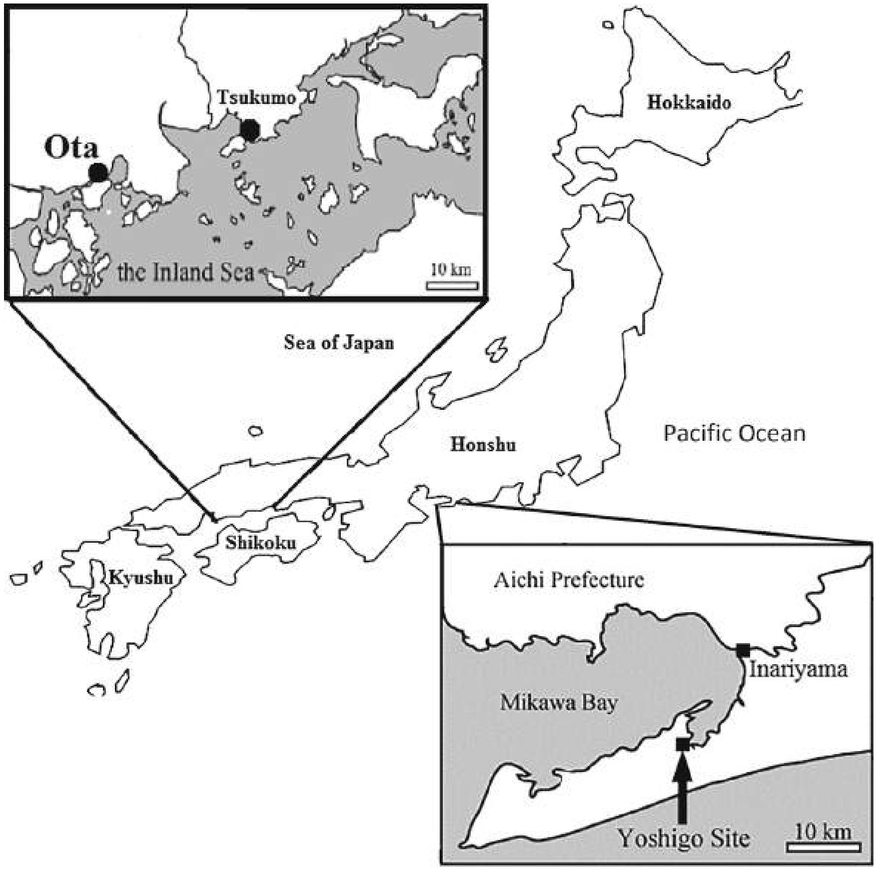

Fig. 10.1 Map depicting the location of sites from the Middle and Final phases of the Jomon period included in this chapter. Ota is dated to the Middle phase of the Jomon period and located in the Sanyo District. Remains from Tsukumo are dated to the Late/Final phases of the Jomon period and located in the Sanyo District. Remains from Inariyama and Yoshigo included in this study are dated to the Late/Final phases of the Jomon period and located in Aichi prefecture. Please refer to these temporal periods and locations in Fig. 10.4

affiliated with the latest occupation of the site (Kiriyama and Kusaka 2017). This time period likely overlaps with the initial stage of occupation at the Inariyama site and may reflect a general trend towards terrestrial resource consumption. Human remains from the Yoshigo site that are included in this study have burial positioning and nitrogen isotope ranges that are consistent with the earlier occupation of the site ($\delta^{15}N$ values between 14.3 and 16.0), indicating a maritime-heavy diet (Kiriyama and Kusaka 2017), though radiocarbon dating is necessary to confirm these findings.

As previously noted, one challenge for bioarchaeological research in exploring resilience theory and climate change is to provide a clear definition of resilience *of*

Table 10.3 Sample composition for the Middle-Late/Final Jomon period and Zvejnieki site remains included in this study including numbers of remains with radiocarbon dates

Males	N I_x[a]	N I_y	N J	N I_x/I_y	N radiocarbon
Aichi	11	11	11	13	0
Middle	5	5	5	6	0
Sanyo	14	14	14	14	14
Zvejnieki	55	55	55	55	31
Females	N I_x	N I_y	N J	N I_x/I_y	N radiocarbon
Aichi	13	13	13	14	2
Middle	2	2	2	2	0
Sanyo	8	8	8	7	5
Zvejnieki	8	8	8	8	4

[a] Refer to Table 10.4 for a definition of the cross-sectional properties

what, *to* what (Carpenter et al. 2001, 767). This study focuses on landscape occupation across periods of climatic perturbation. Climatic conditions across the Middle to Late/Final phases of the Jomon period may be described as fluctuating, especially in relation to coastal site occupation. These fluctuations date to the occupation of each site and are identified at local, regional, and global levels. The Middle phase of the Jomon period terminates with a climatic cooling event that reduced annual temperatures by 3 ºC, and this change is associated with the occupation of the Ota site. Cooling trends between the Middle and Late/Final phases of the Jomon period are associated with a rise in beech (*Fagus*), hemlock (*Tsuga soeboldii*), Japanese fur (*Abies firma*), and general coniferous forests (Tsukada 1986). C_{37} alkenone cores recovered from coastal sites off the northern coast of Honshu in Mutsu Bay were used to reconstruct sea surface temperatures (Kawahata et al. 2009). Higher temperatures occurred between 8400 and 4100 BP, while a period of intensive, sustained cooling was noted between 4100 and 2300 BP with a temperature decline of approximately 2 to 3 degrees C. Remains from the Tsukumo, Inariyama, and Yoshigo sites experienced a reduced magnitude of change in ambient temperature but accentuated fluctuations in the local environment (Kawahata et al. 2017; Wang et al. 2005). This includes a global decline in solar activity that dates concomitantly with remains used in this study from Tsukumo (Mayewski et al. 2004). C_{37} alkenone cores from Hiroshima Bay and oxygen isotopes point to multiple drying events that overlap with the remains included in this study from Inariyama and Yoshigo at 2700 BP (Kawahata et al. 2017). Finally, evidence of changes in sea level is noted for the Inland Sea and Mikawa Bay timed to the Late/Final phases of the Jomon period (Kawase 1998). These findings address the emerging question of resilience *to what* and may be identified for each set of human remains associated with this study: Ota (high magnitude, regional climatic cooling), Tsukumo (global climatic cooling, sea level change), Inariyama (cooling, drying, sea level change), and Yoshigo (cooling, drying, sea level change). Shifts in local climate emphasize resilient occupations of the Middle-Final Jomon period sites included in this chapter, while dates illustrate long-term site occupations that occurred across periods of climatic change including cooling, drying, and shifts in sea level.

10.2.2 Zvejnieki

The Zvejnieki site is located on the northern shore of Lake Burtnieks, a freshwater lake that receives upflow from approximately seven streams (Fig. 10.2). Sex-specific numbers of individuals included in this study are listed in Table 10.3. Pottery, bone and stone implements, and pendants tentatively date the occupation of the site to between the Middle Mesolithic and Late Neolithic (Larsson et al. 2017; Zagorskis 2004). Human remains from approximately 325 burials were excavated between 1965 and 1971 (Zagorskis 2004), as well as 2005 and 2009 (Larsson et al. 2017). Grave goods include arrowheads, fish hooks, harpoons, and spears, indicating a reliance on marine and terrestrial resources, but especially lacustrine resources (Zagorskis 2004). Stable isotope and zooarchaeological analyses agree that the primary diet of populations that occupied Zvejnieki exploited lacustrine resources, principally anadromous fish such as pike and bream (Eriksson et al. 2003; Lõugas 2006). Hunting in the surrounding pine forests was also likely, with zooarchaeological identifications of elk, boar, and other terrestrial mammals (Lõugas 2006). Stable isotope and zooarchaeological analyses of faunal remains from the settlement suggest a dietary transition from hunting to animal husbandry between the Middle and Late Neolithic components of the site (Eriksson et al. 2003). However, when isotopically compared to other Neolithic sites, continuity with hunting and gathering, especially reliance on the lake as a primary source of food, is documented (Eriksson et al. 2003; Henderson et al. 2022; Lõugas 2006). In addition, ancient DNA analysis suggests strong population continuity across the Neolithic transition for the Baltic region, whereas considerable evidence of gene flow is documented across Europe (Jones et al. 2017). Radiocarbon dates of artefacts place an early occupation of the site at 9400 to 9100 BP, while radiocarbon dates for select human remains suggest an occupation between 9000 and 2700 BP (Bronk Ramsey 2013; Eriksson et al. 2003; Larsson et al. 2017; Mannermaa et al. 2007; Zagorska 1997). Radiocarbon methods estimate dates for human remains used in this study between 7700 and 2200 BP. All other burials included in this chapter ($n = 28$) were assigned to cultural periods based on artefact chronologies and dates between the Mesolithic and Late Neolithic occupation (Zagorskis 2004).

Dates for the Zvejnieki Mesolithic and Neolithic burials included in this study are placed within the Boreal to Subboreal chronozones of the Holocene. The Boreal phase dates between 9000 and 7500 BP and is associated with the expansion of hazel and pine as well as mixed oak during later phases. The Atlantic phase dates between 7500 and 5000 and is associated with the Holocene climatic optimum, specifically the expansion of deciduous alder, elm, and lime species. The Boreal phase of occupation at Zvejnieki corresponds to expanding pine forests surrounding the site combined with a mild, dry climate, though continued warming during the second half of the

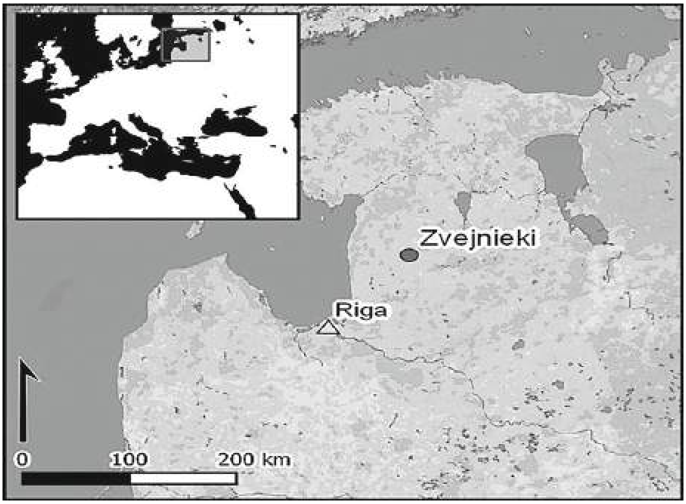

Fig. 10.2 Location of the Zvejnieki archaeological site

Boreal phase is noted (Kalnina 2006; Ozola et al. 2010). Analyses of pollen and charcoal distributions indicate human impact on the local environment during the Boreal, one that led to open meadows and pastures in the immediate vicinity of the site (Kalnina 2006; Ozola et al. 2010). The Atlantic phase at the site is associated with the replacement of pine with birch, alder, and hazel. In addition, evidence of a rise in the water table of Lake Burtnieks by approximately 3 m is noted at the onset of the Atlantic period and attributed to increased precipitation, with a waning, then waxing human impact on the local environment (Eberhards 2006; Kalnina 2006). The Subboreal chronozone dates between 5000 and 2500 BP. This phase is associated with an expansion of ruderal species and a decline in spruce species indicating an expansion of fields, meadows, and pastures and a reduction of woodland habitats (Ozola et al. 2010). These climatic reconstructions indicate that both the occupation of Zvejnieki and the burials included in this study represent a resilient occupation of the landscape, where the site was maintained across multiple climatic periods that shifted ambient temperature, aridity, lake levels, and local terrestrial biomes.

10.3 Methods

10.3.1 Osteometric Measurements

Individuals included in this study range in age between 18 and 55 years to control for age-related changes in bone surface deposition and age-related bone loss (Pearson and Lieberman 2004; Ruff et al. 2006; Ruff 2019). Age at death for each individual, long bone measurements, and sex were estimated using standard bioarchaeological methods (Buikstra and Ubelaker 1994). Sex estimation provides a morphological estimate of a trait that has substantial biological and cultural flexibility (Geller 2008). In this sense, morphological identification of sex represents a limitation of this work. That being said, biomechanical analysis and mortuary practices often identify circumstances that allow for complex, interactive interpretations of sex and gender within social context (Ocobock and Lacy 2024; Sofaer-Derevenski 2000; Temple et al. 2021; 2023). All femora were scanned at 50 per cent of bicondylar length, which differs slightly from the biomechanical length measurements proposed by previous work (Ruff and Hayes 1983; Ruff 2002). Little difference (less than three per cent) is, however, identified across femoral second moments of area when cross-sectional properties are estimated locations slightly distal and proximal (five percent) from the midshaft (Mongle et al. 2015). Body mass was estimated using maximum femoral head breadth, and in a few select instances for the Zvejnieki site, the superior-inferior breadth of the humeral head. Equations for estimating body mass were generated from Ruff et al. (2018, 2020).

10.3.2 Cross-Sectional Properties

Long bone diaphyses from the Jomon period and Zvejnieki archaeological sites were scanned using Stratech QA and SA + portable digital CT scanners, respectively. Cross-sectional properties estimated for femoral images obtained by the SA + digital scanner were calculated using software available for the machine and tested daily by scanning an object with known properties. The QA scanner provided cross-sectional images of long bones that were measured using ImageJ and Moment Macro software (Ruff 2016). Cross-sectional properties from the European database were estimated using SA+ , medical CT, and external contour and biplanar radiographic methods. These methods of estimating cross-sectional properties allow for comparison with those used for the Jomon and Zvejnieki sites (O'Neill and Ruff 2006). Cross-sectional properties used in this study are listed and defined in Table 10.4. All second moments and polar second moments of area were standardized by body mass * bone length^2 (Ruff 2019).

Table 10.4 Cross-sectional properties of long bone diaphyses included in this chapter

Property	Abbreviation	Units	Definition
Second moment of area about the x-axis	I_x	mm^4	Anteroposterior bending rigidity
Second moment of area about the y-axis	I_y	mm^4	Mediolateral bending rigidity
Polar second moment of area	J	mm^4	Torsional/Twice average strength

10.3.3 Statistical Comparison

Biomechanical indicators of mobility in the Jomon and Zvejnieki remains were compared to one another and remains from Early Upper Paleolithic, Late Upper Paleolithic, Mesolithic, and Neolithic Europe (see Table 10.3). Sexual dimorphism in femoral shape indices were calculated as ((male–female)/female) * 100 and graphed using comparative data from Ruff (1999, 2019). Second moments of area and polar second moments of area were compared using one-way ANOVA with a Games-Howell post-hoc test. Femoral shape indices were compared using a Kruskal–Wallis test. In addition, distributions of cross-sectional properties were compared according to overlap in interquartile ranges to estimate differences, similarities, and distributions of cross-sectional parameters.

10.4 Results

10.4.1 Sexual Dimorphism

Sexual dimorphism in femoral shape indices is displayed in Fig. 10.3. Hunter-gatherers from the Middle and Late/Final phases of the Jomon period have accentuated levels of sexual dimorphism. These levels of sexual dimorphism are comparable to those of hunter-gatherers from the Great Basin, who are at the upper range of this distribution (Ruff 1999). Hunter-gatherers from Zvejnieki have intermediate levels of sexual dimorphism in femoral shape indices, despite having comparatively reduced femoral shape indices and strength/rigidity measures. While the group that includes Zvejnieki has a select few agricultural communities distributed at the lower range, Zvejnieki is distributed at the upper range of these intermediate values.

10.4.2 Male Comparisons

Box plots for male cross-sectional properties are shown in Fig. 10.4. Results from the Kruskal–Wallis test identify significant differences in femoral shape indices across groups for individuals identified as male ($H = 66.1$, $p \approx 0.001$), and significant differences are reported according to Bonferroni corrections, which are used to reduce the likelihood of a type 1 error, especially among smaller samples. Male femoral shape indices do not differ between any Jomon group. Males from the Middle phase of the Jomon period have significantly greater femoral shape indices than those from Zvejnieki ($p \approx 0.002$) and Neolithic agriculturalists ($p \approx 0.04$). Males from the Late/Final phases of the Jomon period from Sanyo have significantly larger femoral shape indices than those from Zvejnieki ($p \approx 0.02$) and Neolithic agriculturalists ($p \approx 0.05$). Similar results are found for Jomon period males from Aichi compared to those from

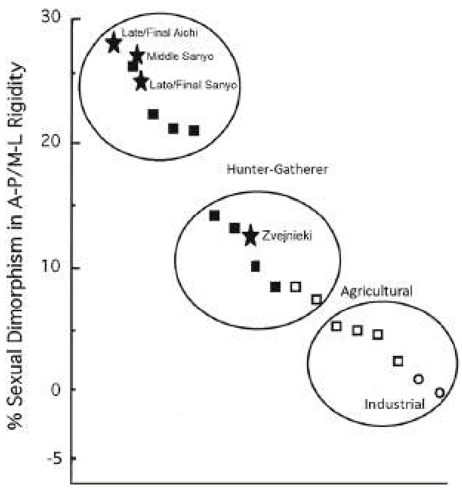

Fig. 10.3 Range of dates for possible site occupation at Ota based on pottery chronologies (squares). Range of possible dates for individuals included in this study based on radiocarbon dates for Inariyama, Tsukumo, and Yoshigo (squares). Dates for possible climatic shifts at across the probable occupation of each site or dates for individuals included in this study (circles). References to these events can be found in Sect. 1.2.2

Zvejnieki ($p < 0.003$) and Neolithic agriculturalists ($p \approx 0.007$). Zvejnieki males have reduced femoral shape indices compared to Early Upper Paleolithic ($p \approx 0.0001$), Late Upper Paleolithic ($p \approx 0.005$), and Mesolithic ($p \approx 0.05$) hunter-gatherers and do not differ from Neolithic agriculturalists. Additionally, male femoral shape indices at Zvejnieki are significantly smaller than those of hunter-gatherers from the Middle phase of the Jomon period ($p \approx 0.02$) and those from the Late/Final phases of the Jomon period from the Aichi Peninsula ($p \approx 0.003$) and Sanyo District ($p \approx 0.02$).

Significant differences were observed across males for anteroposterior bending rigidity (I_x) ($F = 10.89$; $p < 0.001$). Jomon anteroposterior bending rigidity did not significantly differ between groups, nor from any comparative group. A substantial overlap in interquartile ranges for anteroposterior bending rigidity is found between all Jomon groups and the Early Upper Paleolithic, Late Upper Paleolithic, and Mesolithic hunter-gatherers. Interquartile ranges for anteroposterior bending rigidity for Jomon groups from Aichi and Ota (Middle Phase) are greater than, and show minimal overlap with, Neolithic and Zvejnieki males. Overlap is observed between Jomon period males from Sanyo and those from Zvejnieki. For Zvejnieki males, anteroposterior bending rigidity values were significantly smaller when compared to Late Upper Paleolithic ($p \approx 0.001$), Mesolithic ($p \approx 0.001$), and Neolithic ($p \approx 0.001$) communities from Europe.

Significant differences in femoral mediolateral bending rigidity (I_y) were observed across all groups ($F = 3.31$; $p \approx 0.002$), though fewer differences and more overlap in interquartile ranges typify these comparisons. Jomon males did not differ from one another in femoral mediolateral bending rigidity or from any comparative group. A substantial overlap in interquartile ranges for Jomon male mediolateral bending rigidity values was observed with all hunter-gatherer, Neolithic, and Zvejnieki femora. Zvejnieki males had significantly reduced femoral mediolateral bending rigidity when compared to Mesolithic ($p \approx 0.004$) and Neolithic ($p \approx 0.05$) groups and were comparable to the Jomon femora.

Significant differences across males were found in femoral strength/rigidity (J) ($F = 5.80$, $p < 0.001$). However, overall male femoral strength/rigidity did not differ between the Jomon and any comparative group, except for a finding of significantly reduced strength/rigidity in hunter-gatherers from the Late/Final phases of the Jomon period from Sanyo and Mesolithic Europe. All three Jomon period groups overlap with the upper quartile of Zvejnieki femoral strength/rigidity. Zvejnieki male femoral strength/rigidity was significantly reduced compared to Late Upper Paleolithic, Mesolithic, and Neolithic remains, yet no differences or overlap in interquartile ranges were observed with all three Jomon groups.

10.4.3 Female Comparisons

Box plots for female cross-sectional properties are found in Fig. 10.4. Significant differences in female femoral shape indices were identified across groups ($H = 38.8$, $p \approx 0.0001$). No significant differences in female femoral shape indices were found once Bonferroni corrections were made. This likely reflects the comparatively small sample of female remains available for study. However, the distributions of femoral shape indices hint at some interesting patterns. Femoral shape indices among Jomon period females were intermediate, falling below and failing to overlap with Upper Paleolithic sites, and overlapping with Mesolithic and Neolithic sites. Femoral shape indices were greater than, and showed minimal overlap with, the Zvejnieki

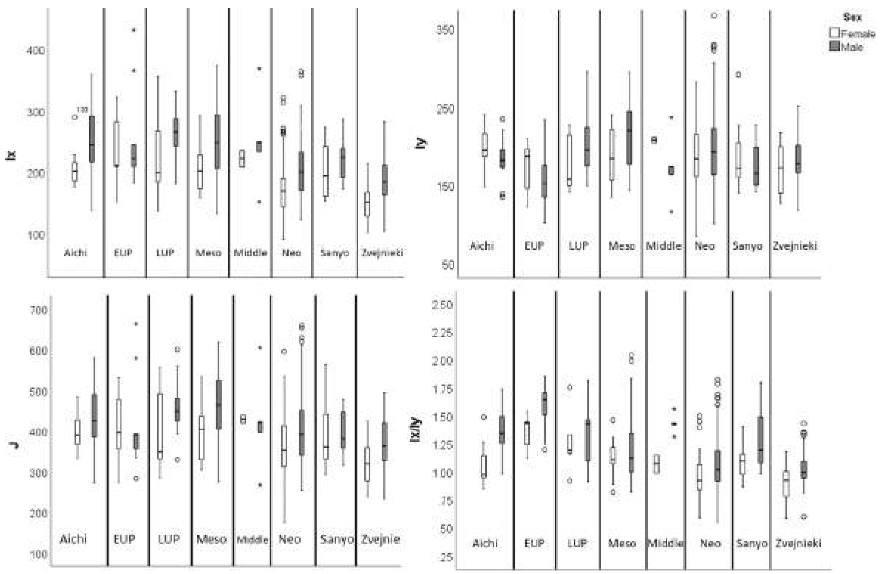

Fig. 10.4 Sexual dimorphism (male–female/female*100) of femoral shape indices (Ix/Iy) from Jomon period and Zvejnieki sites with comparative data drawn from images in Ruff (1999, 2019)

site. The interquartile ranges of these groups were distributed mostly above 1.0, indicating a slight deviation from circularity. Interquartile ranges for femoral shape indices for Zvejnieki females did not overlap with any hunter-gatherer group, but did overlap with Neolithic sites. In contrast to Jomon period sites, the interquartile ranges for Zvejnieki female femoral shape indices overlapped with 1.0, indicating greater circularity in femoral diaphyseal shape.

Significant differences were observed across individuals identified as female for anteroposterior bending rigidity (I_x) ($F = 4.7, p \approx 0.001$). Significantly greater anteroposterior bending rigidity was found in Jomon period females from Aichi compared to the Neolithic ($p \approx 0.05$) and Zvejnieki ($p \approx 0.04$) sites. Interquartile ranges for this variable were elevated among all Jomon period female samples, and overlap with all hunter-gatherer groups was found. In contrast, this variable either did not overlap, or slightly overlapped, with interquartile ranges for the Neolithic and Zvejnieki sites. Zvejnieki females had significantly reduced anteroposterior bending rigidity when compared to Jomon period females from Aichi and the Mesolithic. However, interquartile ranges for anteroposterior femoral bending rigidity at Zvejnieki is reduced and interquartile ranges for this variable do not overlap with hunter-gatherers from any other group. A similarity and a substantial overlap in interquartile ranges of anteroposterior bending rigidity with Neolithic females were identified for Zvejnieki females.

No significant differences in mediolateral bending rigidity (I_y) ($F = 0.53, p < 0.81$) and femoral strength/rigidity (J) ($F = 1.82, p \approx 0.08$) were identified across groups. A considerable overlap in interquartile ranges was also observed for mediolateral bending rigidity and femoral bending strength/rigidity between Jomon females and those from other groups. Similar results are reported for Zvejnieki females, indicating relatively comparable mediolateral bending rigidity and femoral bending strength/rigidity.

10.5 Discussion

Accentuated sexual dimorphism in femoral shape indices are observed in hunter-gatherers from the Jomon period, while remains from Zvejnieki have intermediate sexual dimorphism in femoral shape indices relative to hunter-gatherers. Accentuated sexual dimorphism in femoral shape indices are observed among hunter-gatherers with high degrees of residential and logistical mobility (Ruff 1987), but also among hunter-gatherers with reduced residential mobility but higher levels of male logistical mobility (Ruff 1999; Stock and Pfeiffer 2004; Stock and McIntosh 2016; Temple et al. 2021). This trend exists in contrast to the agricultural transition where reductions in sexual dimorphism for femoral shape indices are found in association with declining residential and logistical mobility among females and males (Ruff and Larsen 2014). When considered within the context of the archaeological record for these sites (i.e. Habu 2004; Zagorska 2004), it is likely that the elevated and intermediate levels of sexual dimorphism are consistent with hunter-gatherers from residentially stable locales that centred aquatic resources and experienced higher levels of logistical mobility among males. In this sense, femoral shape indices identify comparable residential mobility patterns between these groups. However, it is important to point out that sexual dimorphism in Jomon femoral shape indices were greater than in Zvejnieki. This finding indicates differing patterns of logistical mobility between the two groups. Here specifically, it is argued that the capacity to occupy these sites across broad periods of climate change is associated with similar residential occupations of each site, but variation in logistical mobility (see below).

Jomon male femoral shape indices are elevated compared to agricultural communities and those from the Zvejnieki site. Jomon femoral shape indices are comparable to Early Upper Paleolithic, Late Upper Paleolithic, and Mesolithic hunter-gatherers. This is associated with increased anteroposterior bending rigidity (I_x) but no corresponding change in mediolateral bending rigidity (I_y). Few differences in male femoral strength/rigidity (J) are observed between the Jomon remains, those from Zvejnieki, and all other time periods. These findings are similar to previous studies that identified variation in femoral shape indices and anteroposterior bending rigidity, but less variation in mediolateral bending rigidity and femoral strength/rigidity in relation to mobility and terrain (Higgins 2014; Hill et al. 2020; Holt et al. 2018; Holt and Whittney 2019; Ruff 2019). In particular, hunter-gatherers from coastal and lacustrine environments who travelled greater distances and traversed rugged terrain have elevated anteroposterior bending rigidity and a corresponding increase in femoral shape indices (Holt and Whittney 2019; Ruff and Holt 2018; Stock and Pfeiffer 2001; Stock et al. 2010). Similar results were also found when samples were combined according to subsistence economy and compared according to terrain: groups from regions with more complex terrain had greater femoral shape indices (driven by elevated I_x) and femoral strength/rigidity (Holt and Whittney 2019). However, when controlled for subsistence economy, significantly greater femoral shape indices (driven by elevated I_x), but not strength/rigidity, were found in hunter-gatherers from mountainous terrain (Holt and Whittney 2019). Jomon period sites featured in this chapter were derived from coastal regions that blend into wooded, mountainous terrain. For example, sites from the Middle and Late/Final phases of the Jomon period from Sanyo are bordered by mountainous terrain to the west. This terrain reaches an elevation of approximately 800 m within 50 km of the Ota (Middle phase) site and 730 m within 50 km of the Tsukumo site. However, both sites are within 100 km of mountainous terrain that reaches 1300 m in elevation. Sites on the Aichi Peninsula are circumscribed by complex terrain with elevations reaching 600 m and are within 100 km of multiple mountain ranges that reach heights between 400 and 2500 m. Given the accentuated femoral robusticity observed among the Jomon period hunter-gatherers, it is likely that hunting terrestrial mammals would have ranged into these complex terrains. Taken together, these results are consistent with a resilient site occupation supported by elevated logistical mobility and likely interaction with complex terrain.

Zvejnieki male femoral shape indices are reduced compared to other hunter-gatherers and comparable to agricultural communities. This is driven by diminished anteroposterior and comparable mediolateral bending rigidity when evaluated against other hunter-gatherer communities. Similar results are observed for femoral strength/rigidity. Zvejnieki males have consistently smaller values than hunter-gatherers and comparable values to agricultural communities. This is consistent with previous studies that found reduced femoral robusticity in hunter-gatherers that relied on aquatic resources and did not traverse complex terrain (Ruff and Garvin 2018; Stock and Pfeiffer 2001). The Zvejnieki diet was dependent on lacustrine and terrestrial resources throughout the Neolithic period, though potential evidence of animal husbandry is found in the Late Neolithic period (Eriksson et al. 2003). Despite clear evidence of an economy focused on fishing and hunting, it is important to point out that the Zvejnieki site was surrounded by pine forest during the Boreal phase of occupation and deciduous broadleaf biomes during the Atlantic and Subboreal (Lõugas 2006). Relief maps of the Baltic Sea region indicate that the largest hills within 50 km of Zvejnieki are not steeper than 121 m. These findings suggest that the Zvejnieki site afforded proximate access to both lacustrine and terrestrial resources, and hunting forays would not interact with complex terrain. Proximate access to these resources and less complicated regional terrain is likely associated with reduced femoral robusticity among Zvejnieki hunter-gatherers and suggests a strategy of reduced mobility and decreased interaction with complex terrain in the maintenance of resilient occupation at this site.

The hunter-gatherer sexual division of labour is often simplified as a binary process (Cobb 2005; Gellar 2008; Lacy and Ocobock 2024). Biomechanical research demonstrates that consideration of the sexual division of labour among hunter-gatherers does, however, require greater care in interpretation in terms of mobility and manual habitual activity (Temple et al. 2021, 2023). A substantial degree of sexual dimorphism is observed in Jomon femoral shape indices indicating greater logistical mobility among males. However, female mobility patterns remain an integral component in understanding resilient site occupation. Trends in femoral robusticity among individuals identified as females from the Middle and Late/Final phases of the Jomon period are comparable to those for males, with some notable differences. For example, female femoral shape indices are intermediate—lower than Upper Paleolithic and Mesolithic sites but greater than the Neolithic and Zvejnieki sites. In contrast, female anteroposterior femoral bending rigidity is comparable to Upper Paleolithic and Mesolithic sites and greater than Neolithic and Zvejnieki ones, while mediolateral bending rigidity and femoral strength/rigidity are comparable across all sites. Previous studies document elevated femoral shape indices among females who engaged with complex terrain, though this still occurs against the backdrop of elevated sexual dimorphism (Marchi 2008; Stock and Pfeiffer 2004). Similar results are also found when terrain categories are compared using combined female and male cross-sectional measurements, which suggests that females from regions with complex terrain engaged with these landscapes (Holt et al. 2018). However, elevated sexual dimorphism does indicate that these patterns still reflect differences in degrees of mobility and terrain interaction between females and males from these sites. In this sense, resilient site occupation among coastal communities during the Middle and Late/Final phases of the Jomon period was supported by elevated female mobility and movement across rugged terrain, especially when compared to agricultural communities and the Zvejnieki site, but these activities were limited compared to males from the same sites.

Individuals identified as female at the Zvejnieki site express a femoral morphology that is, by and large, comparative to less mobile agricultural communities and differs from hunter-gatherer groups. Femoral shape indices were reduced and bending rigidity and femoral strength/rigidity were equally diminished. This suggests lower mobility and interaction with less complex terrain. Intermediate levels of sexual dimorphism in femoral shape indices suggest that differences in female and male habitual activity may, however, have been less pronounced than what was observed in hunter-gatherers from the Middle to Late/Final phases of the Jomon period. In this sense, it is likely that females were less mobile and engaged with less complex terrain than their male counterparts, but the magnitude of these differences was reduced, likely owing to less mobility and reduced complexity in terrain interaction among males. Similar results are observed in comparatively sedentary agricultural communities, where reductions in sexual dimorphism indicate a movement towards comparable magnitudes of interaction with local landscapes between females and males (Ruff 2019). However, sexual dimorphism in femoral shape indices still rank intermediately among hunter-gatherers, suggesting that differences in logistical mobility were pronounced compared to agricultural counterparts. The overall picture for Zvejnieki females suggests that resilient site occupation was maintained through reduced mobility and interaction with complicated terrain.

The ideological structure of persistent places has been addressed by previous studies and should be considered in exploring resilient site occupation (Gamble 2017). The Middle and Late/Final phases of the Jomon period feature spatial affiliation with ancestral populations: in many cases, later-stage burials are placed above and adjacent to ancestral occupants of the cemetery (Kiyono 1969; Temple 2020). In addition, the incorporation of animal remains as pendants and funerary goods is documented following a shift towards more carbohydrate-heavy foodstuffs during the Late/Final phases of the Jomon period (Temple 2019). Recent stable isotope analysis of human remains from the Yoshigo site provides preliminary evidence of dietary differentiation in individuals buried with these items (Kiriyama and Kusaka 2017). At the Zvejnieki site in Latvia, Neolithic burial rights sought spatial affiliation with Mesolithic graves (Nilsson-Stutz et al. 2013; Nilsson-Stutz and Larsson 2016). A considerable number of Zvejnieki burials are also equipped with pendants fashioned from mammal teeth (Zagorskis 2004). Despite a possible shift towards Neolithic domesticates, animal pendants were maintained as grave goods, suggesting continued ideological relationships with these agents (Eriksson et al. 2003). However, the function of animal pendants may have shifted as use-wear analysis suggests that the items were worn in life and death among Mesolithic site occupants but were exclusively used for funerary practices during the Neolithic period (Osipowicz et al. 2023). Animal pendants are associated with differences in diet beginning at the earliest stages of life across time periods (Henderson et al. 2022; Schulting et al. 2019), and animal bones (or amulets) are often contemporaneous with burials (Mannermaa et al. 2007). While the meaning of burial items may change, the continued use of these agential items in graves illustrates continuity in reciprocal relationships with nature across long time spans (Macāne 2022) and is instrumental in the ideological identification of Zvejnieki as a resilient landscape. Overall, these findings illustrate comparable patterns of spatial affiliation with the dead and the use of animal remains as symbolic referents that may reflect emerging inequality during resilient site occupations in both regions. Such findings highlight the ways in which hunter-gatherers form resilient site occupations through ideological methods attributable to reciprocal relationships with the natural environment (i.e. Ingold 1988, 2000).

Results from this study support previous work on resilient landscapes that address waves of site occupation in terms of ecological and symbolic behaviour (Thompson 2010). These studies identified variation in the temporal rhythms associated with resilient site occupation across landscapes in North America. This chapter adds to the complexities identified by Thompson (2010) by documenting variation in the mobility strategies and terrain interaction associated with resilient landscape occupation. While this study has only contrasted hunter-gatherer communities from two aquatic environments, these findings augment a growing body of literature that demonstrates great diversity in hunter-gatherer lifeways and establishes the basis for testing future hypotheses on human remains from larger, more geographically diverse regions. This work also supports the importance of social memory as a hallmark of resilient site occupation in hunter-gatherer communities (Gamble 2017). Both sites feature mortuary practices with good grave usage and a spatial orientation that suggests recurring reciprocal relationships with nature and symbolic affiliation with the dead. Finally, the concept of mobility presented in this chapter is limited to biomechanical approaches. Migration should also be identified using genetic, stable isotopic, and even zooarchaeological evidence, which adds complexity to the findings reported here by exploring different concepts of mobility (e.g. Kusaka et al. 2009; Macāne 2022; Shinoda and Kanai 1999).

10.6 Conclusion

Femoral cross-sectional properties from Jomon period sites and Zvejnieki were compared with the goal of understanding patterns of mobility in relation to the resilient occupation of landscapes. Each site is centred around aquatic resources (maritime and lacustrine) and provides access to terrestrial hunting. All sites were continuously occupied or reoccupied over extended time frames.

Cross-sectional geometry reveals variation in the intensity and repetition of habitual activity and patterns of terrain interaction in these groups. Increases in femoral shape indices reflecting anteroposterior strengthening, without a corresponding increase in femoral strength/rigidity, are consistent with elevated interaction with complex terrain (Higgins 2014; Holt and Whittey 2019). This trend is observed in hunter-gatherers from the Jomon period, but not at Zvejnieki. Diaphyseal strength/rigidity is intermediate among Jomon period femora and comparable to both hunter-gatherer and agricultural sites. Femoral strength/rigidity at Zvejnieki is diminished and comparable to that of agricultural groups with reduced logistical and residential mobility. Exploitation of terrestrial resources required travelling greater distances and interacting with complex terrain at Jomon period sites, while Zvejnieki was located around Lake Burtnieks and surrounded by woodlands with less complex terrain. Results from cross-sectional geometry provide embodied evidence (or space–time diaries of behaviour) of mobility strategies consistent with these ecological features. Overall, these findings demonstrate the value of cross-sectional geometry in identifying the diverse mobility strategies that facilitate resilient site occupation. It is, however, important to point out that ideological features of resilient site occupation were comparable between the two groups. Grave goods reference reciprocal relationships with nature, and spatial affiliation with the dead across extended durations of time is reported at all sites. These behaviours promote long-standing social memory and provide ideological ties between people and landscapes.

References

Allen H, Littleton J (2007) Hunter-gatherer burials and the creation of persistent places in Southeastern Australia. J Anthropol Archaeol 26(2):283–298

Bass SL, Saxon L, Daly RM et al (2002) The effect of mechanical loading on the size and shape of bone in pre-, peri-, and postpubertal girls: A study in tennis players. J Bone Min Res 17(12):2274–2280

Berkes F, Folke C (1998) Linking social and ecological systems: management practices and social mechanisms for building resilience. Cambridge University Press, Cambridge

Berkes F, Jolly D (2001) Adapting to climate change: social-ecological resilience in a Canadian West Arctic community. Ecol Soc 5(2):18

Binford LR (1980) Willow smoke and dogs' tails: hunter-gatherer settlement systems and archaeological site formation. Am Antiq 45(1):4–20

Bourdieu P (1977) Outline of a theory of practice. Cambridge University Press, Cambridge

Bridges PS, Blitz JH, Solano MC (2000) Changes in long bone diaphyseal strength with horticultural intensification in West-Central Illinois. Am J Phys Anthropol 112(2):217–238

Bronk Ramsey C (2013) OxCal 4.2 manual. https://c14.arch.ox.ac.uk/oxcalhelp/hlp_contents.html

Buikstra JE, Ubelaker DH (eds) (1994) Standards for data collection from human skeletal remains. Arkansas Archaeological Survey Research Seminar Series no. 44. Fayetteville, AR

Cameron ME, Stock JT (2019) Biomechanics, habitual activity, and resilience among Southern African hunter-gatherers and herders. In: Temple DH, Stojanowski CM (eds) Hunter-gatherer adaptation and resilience: A bioarchaeological perspective. Cambridge University Press, Cambridge, pp 110–140

Carlson KJ, Marchi D (2014) Introduction: Towards refining the concept of mobility. In: Carlson KJ, Marchi D (eds) Reconstructing mobility: Environmental, behavioral and morphological determinants. Springer, New York, pp 1–12

Carpenter S, Walker B, Anderies JM et al (2001) From metaphor to measurement: Resilience of what to what. Ecosystems 4:765–781

Castillo RCA (2011) When fishing is no longer viable: Environmental change, unfair market relations, and livelihood in a small fishing community in the Philippines. COMCAD Working Paper 105

Cobb H (2005) Straight down the line? A queer consideration of hunter-gatherer studies in Northwest Europe. World Archaeol 37(4):630–636

Donald L, Mitchel DH (1994) Nature and culture on the Northwest Coast of North America: The case of the Wakashan salmon resources. In: Elanna LJ, Burch ES (eds) Key issues in hunter-gatherer research. Berg Explorations in Archaeology, Oxford, pp 95–117

Eberhards G (2006) Geology and development of the paleolake Burtnieks during the Late Glacial and Holocene. In: Larsson L, Zagorska I (eds). Back to the origin: New research in the Mesolithic-Neolithic cemetery and environment, northern Latvia. Almquist and Wiksell International, Lund, pp 25–52

Eriksson G, Lõugas L, Zagorska I (2003) Stone-age hunter-fisher-gatherers at Zvejniecki, Northern Latvia: Radiocarbon, stable isotope, and zooarchaeology data. Before Farming: Archaeol Anthropol Hunt Gatherers 1(2):1–25

Fitzhugh B, Gjesfjeld E, Brown W et al (2016) Resilience and population history of the Kuril Islands, Northwest Pacific: A study in complex human ecodynamics. Quat Int 419(17):165–193

Folke C (2006) Resilience: The emergence of a perspective for social-ecological systems analysis. Global Environ Chng 16(3):253–267

Gamble L (2017) Feasting, ritual practices, social memory, and persistent places: New interpretations of shell mounds in Southern California. Am Antiq 82(3):427–451

Geller PM (2008) Conceiving sex: fomenting a feminist bioarchaeology. J Soc Archaeol 8(1):113–138

Habu J (2004) Ancient Jomon of Japan. Cambridge University Press, Cambridge

Hegmon M, Peeples M, Kinzig AP et al (2008) Social transformation and its cost in the Prehispanic U.S. Southwest. Am Anthropol 110(3):313–324

Henderson RC, Zarina G, Czermak A et al (2022) Life histories at stone age Zvejnieki based on stable isotope profiles of tooth dentin. J Archaeol Sc Rep 44:103496

Higgins R (2014) The effects of terrain on long bone robusticity and cross-sectional shape in lower limb bones of bovids, Neandertals, and Upper Paleolithic humans. In: Carlson KJ, Marchi D (eds) Reconstructing mobility: Environmental, behavioral, and morphological determinants. Springer, New York, pp 227–252

Hill EC, Pearson OM, Durband AC et al (2020) An examination of long bone diaphysis of Holocene foragers from Roonka. South Australia. Am J Phys Anthropol 172(4):682–697

Holling CS (1973) Resilience and the stability of ecological systems. Ann Rev Ecol System 4:1–24

Holt B (2003) Mobility in Upper Paleolithic and Mesolithic Europe: Evidence from the lower limb. Am J Phys Anthropol 122(3):200–215

Holt B, Whittey E (2019) The impact of terrain on lower limb bone structure. Am J Phys Anthropol 168(4):729–743

Holt B, Whittey E, Niskanen M et al (2018) Temporal and geographic variation in robusticity. In Ruff CB (ed) Skeletal variation and adaptation in Europeans: Upper Paleolithic to the twentieth century. Wiley Blackwell, Hoboken, pp 91–132

Hudson MJ (2020) Slouching towards the Neolithic: Complexity, simplification, and resilience in the Japanese archipelago. In: Robbins Schug G (ed) The Routledge handbook of the bioarchaeology of climate and environmental change. Routledge, New York, pp 379–395

Hudson MJ, Aoyama M, Hoover KC (2012) Navigating hunter-gatherer resilience: Networks and insularity in the prehistory of the Ryukyu Islands. In: Damm C, Saariviko J (eds) Networks, interaction and emerging identities in Fennoscandia and beyond. Suomalais-Ugrilainen Seura, Helsinki, pp 49–66

Ikawa-Smith F (2004) Humans along the Pacific Margin of Northeast Asia before the last glacial maximum. In: Madsen DB (ed) Entering America: Northeast Asia and Beringia before the Last Glacial Maximum. University of Utah Press, Salt Lake City, pp 285–304

Imamura K (1996) Prehistoric Japan: New perspectives on insular East Asia. University of Hawaii Press, Honolulu

Ingold T (1988) The appropriation of nature: Essays on human ecology and social relations. University of Iowa Press, Iowa City

Ingold T (2000) The perception of environment: essays on livelihood, dwelling, and skill. Routledge, London

Jones HH, Priest JD, Hayes WC et al (1977) Humeral hypertrophy in response to exercise. J Bone Joint Surg 59(2):204–208
Jones ER, Zarina G, Moiseyev V et al (2017) The Neolithic transition in the Baltics was not driven by admixture with early European farmers. Curr Biol 27:576–582
Jordan P, Weber AW (2016) Persistent foragers: New insights into Holocene hunter-gatherer archaeology in northern Eurasia. Quat Inter 419(17):1–4
Kalnina L (2006) Paleovegetation and human impact in the surroundings of the ancient Burtnieks lake as reconstructed from pollen analysis. In: Larsson L, Zagorska I (eds) Back to the origin: New research in the Mesolithic-Neolithic Zvejnieki cemetery and environment, northern Latvia. Almquist and Wiksell International, Lund, pp 53–74
Kawahata H, Yamamoto H, Ohkushi K et al (2009) Changes of environments and human activity at Sannai Maruyama ruins in Japan during the Mid-Holocene hypsithermal climatic interval. Quat Sc Rev 28(9–10):964–974
Kawahata H, Matsuoka M, Togami A et al (2017) Climatic change and its influence on human society in western Japan during the Holocene. Quater Int 440:102–117
Kawase K (1998) Late Holocene paleoenvironmental changes in the Yahagi River lowlands, Central Japan. Geogr Rev Jpn 71A:411–435. In Japanese with English abstract
Kelly RL (2013) The lifeways of hunter-gatherers: the foraging spectrum. Cambridge University Press, Cambridge
King JW, Brelsford HJ, Tullos HS (1969) Analysis of the pitching arm of the professional baseball pitcher. Clin Orthped 67:116–123
Kiriyama K, Kusaka S (2017) Prehistoric diet and mortuary Practices in the Jomon period: Isotopic evidence from human skeletal remains from the Yoshigo Shell Mound. J Archaeol Sc: Rep 11:200–210
Kiyono K (1969) Study of Japanese shell middens. Iwanami Shoten, Tokyo [In Japanese]
Kobayashi T (1992) Patterns and levels of social complexity in Jomon Japan. In: Aikens CM, Nai Rhee S (eds) Pacific Northeast Asia in prehistory: Hunter-fisher-gatherers, farmers, and sociopolitical elites. Washington State University Press, Pullman, pp 91–98
Kofinas GP, Chapin FS, Burn Silver S et al (2010) Resilience of Athabascan subsistence systems to interior Alaska's changing climate. Can J for Res 40(7):1347–1359
Kusaka S, Ikarashi T, Hyodo F et al (2008) Variability in stable isotope ratios in two Late-Final Jomon communities in the Tokai coastal region and its relationship with sex and tooth Ablation. Anthropol Sci 116(2):171–181
Kusaka S, Atushi A, Takanori N et al (2009) A strontium isotope analysis on the relationship between ritual tooth ablation and migration among the Jomon people of Japan. J Archaeol Sc 36(10):2289–2297
Kusaka S, Hyodo F, Yumoto T et al (2010) Carbon and nitrogen stable isotope analysis on the diet of Jomon populations from two coastal regions of Japan. J Archaeol Sc 37(8):1968–1977
Kusaka S, Yamada Y, Yoneda M (2018) Ecological and cultural shifts of hunter-gatherers of the Jomon period paralleled with environmental changes. Am J Phys Anthropol 167(3):377–388
Kusaka S (2023) Radiocarbon dates and diet of the Tsukumo human skeletal remains. In: Harunari H (ed) What drove history, vol 1. Natural history and Paleolithic-Jomon archaeology. Yuzankaku, Tokyo, pp 251–262 [In Japanese]
Lacy S, Ocobock C (2024) Woman the hunter: the archaeological evidence. Am Anthropol 126(1):19–31
Lanyon LE (1982) Mechanical function and bone remodeling. In: Sumner-Smith G (ed) Bone in clinical orthopedics. Saunders, Philadelphia, pp 273–304
Larsen CS (1982) Functional implications of postcranial size reduction on the prehistoric Georgia Coast. J Hum Evol 10(6):489–502
Larsson L, Nilson Stutz L, Zagorska I et al (2017) New aspects of the Mesolithic-Neolithic cemetery at Zvejnieki, Northern Latvia. Acta Archaeol 88(1):57–93

Lõugas L (2006) Animals as subsistence and bones as raw material for settlers of prehistoric Zvejnieki. In: Larsson L, Zagaroska I (eds) Back to the origin: New research in the Mesolithic-Neolithic Zvejnieki cemetery and environment, Northern Latvia. Grahns Tyckeri AB, Lund, pp 25–52
Macāne A (2022) Stone age companions: Humans and animals in hunter-gatherer burials in north-eastern Europe. University of Gothenburg Department of Historical Studies, Gothenburg
Mannermaa K, Zagorska I, Jungner H et al (2007) (2007) New radiocarbon dates of human and bird bones from Zvejnieki Stone Age burial ground in Northern Latvia. Before Farming 1:1–12
Marchi D (2008) Relationships between lower limb cross-sectional geometry and mobility: The case of a Neolithic sample from Italy. Am J Phys Anthropol 137(2):188–200
Marchi D, Sparacello V, Shaw C (2011) Mobility and lower limb robusticity in a pastoralist Neolithic population from north-western Italy. In: Pinhasi R, Stock JT (eds) Human bioarchaeology of the agricultural transition. Wiley-Blackwell, New York, pp 317–346
Mayewski PA, Rohling EE, Stager JC (2004) Holocene climate variability. Quatern Res 62:243–255
Mongle CS, Wallace IJ, Grine FE (2015) Cross-sectional structural variation relative to midshaft along hominin diaphyses. II. The hindlimb. Am J Phys Antrhopol 158(3):398–407
Nelson MC, Ingram SE, Dugmore AJ (2016) Climate challenges, food security, and vulnerability. Proc Natl Acad Sci USA 113(2):298–303
Nilsson Stutz L, Larsson L (2016) Disturbing the dead. Archaeothanatological analysis of the Stone Age burials at Zvejnieki, Latvia (excavated 2006–2009). J Archaeol Sc: Reports 10:715–724
Nilsson Stutz L, Larsson L, Zagorska I (2013) The persistent presence of the dead: Recent excavations at the hunter-gatherer cemetery at Zvejnieki (Latvia). Antiq 87(338):1016–1029
Ocobock K, Lacy S (2024) Woman the hunter: The archaeological evidence. Am Anthropol 126(1):19–31
Osipowicz G, Orlowski J, Zagorska I (2023) Towards understanding the influence of Neolithization for communities using the Zvejnieki cemetery, Latvia: a technological and functional analysis of osseous artefacts discovered in the Late Mesolithic burial no 57 and Neolithic burial no 164. Quart Int 665–666:65–81
Oteros-Rozas E, Gonzales JA, Martin-Lopez B et al (2012) Ecosystem services and social-ecological resilience in transhumance cultural landscapes: learning from the past, looking for a future. In: Plieninger T, Bieling C (eds) Resilience and the cultural landscape: Understanding and managing change in human-shaped environments. Cambridge University Press, Cambridge, pp 242–260
Ozola A, Cernina A, Kalnina L (2010) Reconstruction of paleovegetation and sedimentation conditions in the area of the ancient Lake Burtnieks, Northern Latvia. Est J Earth Sc 59(2):164–179
Pearson OM, Lieberman DE (2004) The aging of Wolff&apos "law": Ontogeny and responses to mechanical loading in cortical bone. Ybk Phys Anthropol 125(S39):63–99
Redman CL (2005) Resilience theory in archaeology. Am Anthropol 107(1):70–77
Redman CL, Kinzig AP (2003) Resilience of past landscapes: Resilience theory, society, and the longue durée. Ecol Soc 7(1):14
Ruff CB (1987) Sexual dimorphism in human lower limb bone structure: Relationship to subsistence strategy and sexual division of labor. J Hum Evol 16(5):391–416
Ruff CB (1999) Skeletal structure and behavioral patterns of prehistoric Great Basin populations. In: Hemphill BE, Larsen CS (eds) Prehistoric lifeways in the Great Basin wetlands: Bioarchaeological reconstruction and interpretation. University of Utah Press, Salt Lake City, pp 290–320
Ruff CB (2002) Long bone articular and diaphyseal structure in Old World monkeys and apes, I: Locomotor effects. Am J Phys Anthropol 119(4):305–342
Ruff CB (2019) Biomechanical analysis of human skeletons. In: Katzenberg MA, Grauer A (eds) Biological anthropology of the human skeleton. Wiley, New York, pp 189–224
Ruff CB, Larsen CS (2014) Long bone structural analysis and the reconstruction of past mobility: A historical review. In: Carlson KJ, Marchi D (eds) Reconstructing mobility: Environmental, behavioral, and morphological determinants. Springer, New York, pp 13–29

Ruff CB, Larsen CS, Hayes WC (1984) Structural changes in the femur with the transition to agriculture on the Georgia Coast. Am J Phys Anthropol 64(2):125–136
Ruff CB, Walker A, Trinkaus E (1994) Postcranial robusticity in *Homo* III: Ontogeny. Am J Phys Anthropol 93(1):35–54
Ruff CB, Holt BH, Trinkaus E (2006) Who's afraid of the big bad Wolff? Wolff's law and bone functional adaptation. Am J Phys Anthropol 129(4):484–498
Ruff CB, Puymerail L, Machiarelli R et al (2015) Structure and composition of the Trinil femora: functional and taxonomic implications. J Hum Evol 80:147–158
Ruff CB, Burgess ML, Squyres N et al (2018) Lower limb articular scaling and body mass estimation in Pliocene and Pleistocene hominids. J Hum Evol 115(1):85–111
Ruff CB, Squyres N, Junno J-A (2020) Body mass estimation from humeral articular dimensions. Am J Phys Anthropol 173(3):380–499
Ruff CB, Garvin H (2018) Iberia. In: Ruff CB (ed) Skeletal variation and adaptation in Europeans. Wiley Blackwell, Hoboken, pp 281–314
Ruff CB, Hayes WC (1983) Cross-sectional geometry of Pecos Pueblo femora and tibiae – A biomechanical investigation. I. Method and general patterns of variation. Am J Phys Anthropol 60(30):359–381
Ruff CB, Holt B (2018) The Balkans. In Ruff CB (ed) Skeletal variation and adaptation in Europeans. Wiley Blackwell, Hoboken, pp 397–418
Ruff CB (2016) Calculating moments. Retrieved from http://www.hopkinsmedicine.org/fae/mmacro.html. Accessed February 2012
Ruff CB (2018) Introduction. In Ruff CB (ed) Skeletal variation and adaptation in Europeans. Wiley Blackwell, Hoboken, pp 1–14
Saito T, Kimura T, Sumita S et al (1952) The shell mounds of Yoshigo: A report on the archaeological excavations by the commission for the protection of cultural properties, vol I. The Commission for the Protection of Cultural Properties, Tahara Town [In Japanese with English Summary]
Schenshul D, Dodman D (2013) Populating adaptation: Incorporating population dynamics in climate change adaptation policy and practice. In: Martine G, Schenshul D (eds) The demography of adaptation to climate change. UNFPA, IIED and El Colegio de Mexico, New York, London, Mexico City, pp 1–23
Schlanger SH (1992) Recognizing persistent places in Anasazi settlement systems. In: Rossignol J, Windsnider L (eds) Space, time, and archaeological landscapes. Plenum Press, New York, pp 91–112
Schulting RJ, Henderson R, Czermak A et al (2019) Unequal in death and life? Linking burial rights with individual life histories. In: Moreau L (ed) Social inequality before farming? Multidisciplinary approaches to the study of social organization in prehistoric and ethnographic hunter-fisher-gatherer societies. McDonald Institute for Archaeological Research, Cambridge, pp 279–291
Shackelford L (2007) Regional variation in the postcranial robusticity of Late Upper Paleolithic humans. Am J Phys Anthropol 133(1):655–668
Shaw CN, Stock JT (2009a) Habitual throwing and swimming correspond with upper limb diaphyseal strength and shape in modern human athletes. Am J Phys Anthropol 140(1):160–172
Shaw CN, Stock JT (2009b) Intensity, repetitiveness, and directionality of habitual adolescent mobility patterns influence the tibial diaphysis morphology of athletes. Am J Phys Anthropol 140(1):149–159
Shaw A, Bates M, Conneller C et al (2016) The archaeology of persistent places: the Palaeolithic case of La Cotte de St Brelade, Jersey. Antiquity 90(354):1437–1453
Sheller M, Urry J (2006) The new mobilities paradigm. Env Planning A: Econ Space 38(2):207–226
Shinoda K, Kanai S (1999) Intracemetery genetic analysis at the Nakazuma site by mitochondrial DNA sequencing. Anthropol Sc 107(2):129–140
Sofaer-Derevenski J (2000) Rings of life: The role of early metalworking in mediating the gendered life course. World Archaeol 31(3):389–406

Stock J, Pfeiffer S (2001) Linking structural variability in long bone diaphyses to habitual behaviors: Foragers from the southern African Later Stone Age and the Andaman Islands. Am J Phys Anthropol 115(4):337–348

Stock JT, Pfeiffer SK (2004) Long bone robusticity and subsistence behaviour among Late Stone Age foragers of the forest and fynbos biomes of South Africa. J Archaeol Sc 31(7):999–1013

Stock JT, Pfeiffer SK (2016) Lower limb biomechanics and habitual activity among mid-Holocene populations of the Cis-Baikal. Quat Int 405:200–209

Stock JT, Bazaliiskii VI, Goriunova OI et al (2010) Skeletal morphology, climatic adaptation, and habitual behavior among Mid-Holocene Cis-Baikal populations. In: Weber AW, Katzenberg MA, Schurr TG (eds) Prehistoric hunter-gatherers of the Baikal region, Siberia. University of Pennsylvania Press, Philadelphia, pp 193–216

Tainter JA (1988) The collapse of complex societies. Cambridge University Press, Cambridge

Tainter JA (2016) Why collapse is so difficult to understand. In: Faulseit RK (ed) Beyond collapse: Archaeological perspectives on resilience, revitalization, and transformation in complex societies. Carbondale, Center for Archaeological Investigations Occasional Papers 42, Southern Illinois University Press, pp 27–40

Takigawa W (2006) Interregional variation of metric traits of limb bones in Jomon and Modern Japanese. Anthropol Sc 114(2):101–129 [In Japanese with English abstract]

Temple DH (2019) Persistence of time: resilience and adaptability in prehistoric Jomon hunter-gatherers from the Inland Sea region, Japan. In: Temple DH, Stojanowski CM (eds) Hunter-gatherer resilience and adaptation: A bioarchaeological perspective. Cambridge University Press, Cambridge, pp 85–109

Temple DH (2020) Death ritual as a social strategy for ancestral affiliation: Constructing identity and persistent place at Yoshigo Shell Mounds, Aichi Prefecture, Japan. In: Knudson KJ, Stojanowski CM (eds) Identity revisited: The bioarchaeology of identity in the Americas and Beyond. University Press of Florida, Gainesville, pp 136–162

Temple DH, Stojanowski CM (2019) Hunter-gatherer adaptation and resilience: A bioarchaeological perspective. Cambridge University Press, Cambridge

Temple DH, Rosa E, Hunt DR et al (2021) Adapting in the Arctic: Habitual activity and landscape interaction in Late Holocene hunter-gatherers from Alaska. Am J Phys Anthropol 176:3–20

Temple DH, Rosa E, Hunt DR et al (2023) Adapting in the Arctic II: Upper limb diaphyseal robusticity and habitual activity in Late Holocene hunter-gatherers from Alaska. Am J Biol Anthropol 181(3):392–412

Temple DH, Kusaka S (2024) Enduring Jomon: Bioarchaeological explorations of resilience, adaptability, and transformation at Yoshigo Shell Mounds, Aichi Prefecture, Japan. In: Goudge C (ed) Archaeologies of adaptation and resilience to climate change and environmental hazards. University Press of Florida, Gainesville

Thompson VD (2010) The rhythms of space-time and the making of monuments and places during the Archaic. In: Thomas DH, Sanger MC (eds) Trend, tradition, and turmoil: What happened in the Southeastern Archaic. American Museum of Natural History Anthropological Papers, New York, pp 217–222

Tompkins EL, Adger WN (2004) Does adaptive management of natural resources enhance resilience to climate change? Ecol and Soc 9(2):10

Tsukada M (1986) Vegetation in prehistoric Japan: the last 20,000 years. In: Pearson RJ, Barnes GL, Hutterer KL (eds) Windows on the Japanese past: Studies in archaeology and prehistory. University of Michigan, Ann Arbor, Center for Japanese Studies, pp 11–56

Walker B, Holling CS, Carpenter SR et al (2004) Resilience, adaptability, and transformability in social-ecological systems. Ecol Soc 9(2):5

Wang Y, Cheng H, Edwards RL (2005) The Holocene Asian monsoon: Links to solar changes and North Atlantic climate. Science 308:854–857

Warner K, Afifi T, Henry K, Rawe T et al (2012) Where the rain falls: Climate change, security, and migration. CARE France and United Nations University, Paris and Bonn

Watanabe N (1963) Radiocarbon dates of the Jomon and Yayoi periods in Japan. The Quat Res 5(3–4):157–168 [In Japanese]
Watanabe H (1973) The Ainu ecosystem: Environment and group structure. University of Washington Press, Seattle
Woo SLY, Kuei SC, Amiel D, Gomez MA, Hayes WC, White FC, Akeson WH (1981) The effect of prolonged physical training on the properties of long bone: a study of Wolff 's law. J Bone Joint Surg [am] 63:780–787
Yamada Y, Kusaka S, Yoneda M (2020) Re-examination of the society of the Tsukumo shell mound people based on the radiocarbon dating. In: Kasaoka City Board of Education (eds) Kasaoka City Archaeological Excavation Report 6: Tsukumo Shell Mound general research report. Kasaoka City Board of Education, Okayama, pp 411–429
Zagorska I (1997) The first radiocarbon datings from the Zvejnieki Stone Age burial ground. Iskos 11:42–46
Zagorskis F (2004) Zvejnieki (Northern Latvia) stone age cemetery. BAR International Series, Oxford
Zvelebil M, Weber AW (2013) Human bioarchaeology: Group identity and individual life histories—an introduction. J Anthropol Archaeol 32(3):275–279

Chapter 11
Capacity-Building and Resilience in the Face of Rising Sea Levels: Implications from the Baltic Stone Age

Marcel Bradtmöller and Harald Lübke

Abstract This study investigates the resilience and adaptive strategies of prehistoric hunter-gatherer societies in the Baltic region in response to rising sea levels during the Holocene. By focusing on the Maglemosian, Kongemose, and Ertebølle cultures, we analyze how these small-scale societies adapted to environmental stressors over a span of 4000 years. The research employs a multi-scalar approach, integrating archaeological data from both terrestrial and submerged sites in the Greater Wismar Bay. Findings indicate that these groups maintained socio-economic stability and adapted subsistence patterns, demonstrating capacity-building and resilience. The study contributes to understanding long-term human–environment interactions under climate-induced changes.

Keywords Mesolithic · Sea-level change · Baltic Sea · Resilience · Capacity · Hunter-gatherer

11.1 Introduction

In this chapter we address the living conditions of prehistoric small-scale societies faced with a nonlinear rise in sea levels after the last glacial maximum. While rising sea levels are a hazard in terms of the United Nations Disaster Risk Reduction (UNDRR) definition (https://www.undrr.org/drr-glossary/terminology), they cannot be described as an event, unlike other environmental stressors, like landslides or tsunamis, in this volume. Instead, the dynamics of rising sea levels had a constant

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_11

impact on the habitat, even if the velocity of change altered over time. The consequences of rising sea levels can be manifold, including effects on marine productivity (Guedes et al. 2016; Boethius et al. 2021) and new travel routes (Barnett et al. 2020), as well as the direct loss of land (Mannino et al. 2011), encompassing a high impact on the habitat of prey animals and the living space of humans. However, these dynamics have not yet been extensively studied in relation to prehistoric hunter-gather communities (cf. Wicks and Mithen 2014; Mithen and Wicks 2021), with high-detailed regional case studies are generally missing (see Turck and Thompson 2016; Hansson et al. 2019; or Ritchison et al. 2020). Consequently, we designed a qualitative study on a micro-regional scale to analyze the direct and indirect impact of a rising sea level could have on small-scale local communities.

In doing so, we will focus on the capacity of these groups, defined by the UNDRR (https://www.undrr.org/drr-glossary/terminology) as "the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience" (cf. Chmutina and von Meding, Chap. 2).

11.1.1 Adaptation, Reorganization, and Release

Understanding the relationship between human behaviour and environmental change on different scales is challenging. This is due to heterogeneous archaeological data sets and muddied by the process of defining causal connections within observed spatiotemporal correlations (cf. Heitz, Chap. 4). Furthermore, the hazards themselves often cause extra taphonomic issues for the archaeological remains (cf. Walker, Chap. 5; Larsson, Chap. 9).

To investigate diachronic resilience-related dynamics, we will focus on a time-line analysis to identify correlations between environmental change and human system states. The latter are helpful to identify separate system conditions, in our case namely "adaptation", "reorganization", and "release" for the societies under study. While the latter two states are derived from the theoretical adaptive cycle (AC) model (Holling and Gunderson 2002), the adaptation state is used to describe periods of modifications in response to external changes by a group. From an archaeological perspective, the adaptation state encompasses a period of adaptive responses within different domains (Codding et al. 2024), namely subsistence, settlement organization, mobility, and/or exchange networks. Technological innovations can be part of, and drivers behind, the observed system adjustments (Solich and Bradtmöller 2017). "Reorganization" describes more diverse and intense dynamics, such as the introduction of a new resource management system or changing land-use strategies (cf. Rosen and Rivera-Collazo 2012). It is evident that it is difficult to differentiate clearly between adaptation and reorganization (cf. Walker et al. 2006; MathisonSlee et al. 2022). One option to separate these is the fact that within the AC model, "reorganization" generally follows a state of "release" (Holling and Gunderson 2002). The latter can be characterized as a rapid and (nearly) complete disappearance of group-specific characteristics within the archaeological record as well as a decline (or even complete hiatus) of human presence within the area under investigation. Therefore, for operating, several requirements regarding spatial and chronological information need to be fulfilled to identify these states in an archaeological case study. To identify the velocity of a release and a possible population hiatus, a well-established age model based on radiometric dating is necessary (cf. Riede et al., Chap. 13; Stutz, Chap. 14), while for the declaration of a complete disappearance of formal patterns within the archaeological record, a defined spatial focus is necessary (cf. Heitz, Chap. 4).

Furthermore, the micro-region under study is embedded in the super-regional, nested socio-economic framework of Northern Europe. This framework encompasses the distribution area of three successive archaeological cultures, and the link between these scales can cause both positive and negative feedback loops throughout the system, which can be important for understanding regional dynamics (Holling and Gunderson 2002; Redman and Kinzig 2003).

From a methodological point of view, we want to test what archaeological data requirements are necessary to analyze the direct and indirect impacts of a rising sea level on small-scale local communities. While resilience studies on hunter-gatherer societies are scarce, this is of special importance (cf. Bradtmöller et al. 2017). In doing so, we trial the following null hypothesis: if they were collected without a specific research focus, even well-established archaeological datasets for hunter-gatherer communities are not suitable for detecting resilience-related dynamics. Related dynamics include system loss or the continuation of sustainable habitation when impacted by environmental stressors. And next, if we can falsify the hypotheses and verify the usability of unspecified research data, are pieces of the puzzle still missing?

While the chronological and spatial extent needs to be sufficient for this kind of *longue durée* approach, we also need considerable depth and resolution from the material studies to identify common behavioural patterns and changes in those patterns. In doing so, we focus on socio-economic characteristics (Solich and Bradtmöller 2017).

11.1.2 Framework of Investigation

Only with a complex set of data can temporal correlations between environmental and socio-economic dynamics of different sizes be observed. And even then, it is complicate to establish causation (cf. Heitz, Chap. 4). The case study encompasses the *longue durée* of nearly 4,000 years, observed from two spatial scales. The super-regional level is located within Northern Europe and encompasses the extended area of three related archaeological techno-complexes/cultural units (Fig. 11.1): the late Maglemosian culture from 7,300 to 6,000 calBC (Jensen et al. 2020); the Kongemose culture from 6,500 to 5,500 calBC (Sørensen 2017); the Ertebølle culture from 5,500 to 4,000 calBC (Hartz and Lübke 2006). We must mention at this point that we are using the classic continental European subdivision of the Mesolithic in this paper (Gramsch 1973). According to this, the Older Mesolithic consists of the Early and Middle Mesolithic, which is essentially characterized by the appearance of Microlithic points and triangular microliths, corresponding roughly to the Preboreal and Boreal periods of the early post-glacial. The Younger Mesolithic, on the other hand, is characterized by the occurrence of rectangular microliths, mainly trapezoids, less frequently rhombic forms. It corresponds more or less to the Atlantic period. It is divided into the Late Mesolithic and the Terminal Mesolithic, which existed parallel to the older Neolithic LBK and Epi-LBK cultures (Kind 1997). Following this subdivision, the younger Maglemose culture can be assigned to the Middle Mesolithic, the Kongemose culture to the Late Mesolithic, and the Ertebølle culture to the Terminal Mesolithic.

In doing so, we investigate the dynamics within an area that encompassed most of Swedish Scania to Northern France and up to the western part of the British Isles. The area of the associated communities generally became smaller over time. This was partly associated with mobility affected by environmental change, like the flooding of Doggerland and the emergence of the English Channel. Another factor was the arrival of external farming communities to the south around 5,500 calBC (cf. Terberger et al. 2018).

These long-lasting techno-complexes were not homogeneous either in terms of their archaeological remains or their socio-economic behaviour. Furthermore, several large-scale mobility/immigrational events have been suggested for the entire time frame (cf. Manninen et al. 2021) and support the supposition that we are not dealing with isolated populations. However, several distinct elements within the material legacy, like the use of barbed bone points (cf. Groß et al. 2019), trapezoid projectile

Fig. 11.1 Distribution areas of the main techno-complexes. In the background: *Drainage systems* and *Atlantic main land* compiled by ZBSA (https://zbsa.eu/Atlantic, see reference there)

implements (Jensen et al. 2020; Sørensen 2017) or pottery vessels, and transverse arrowheads (Povlsen 2013; Hartz 1999) seem to justify this traditional division. Therefore, their distribution areas can be interpreted as context areas after Uthmeier (2004) and Weißmüller (1995), which points to a shared reservoir of concepts for the production and shaping of tools (cf. Söderlind 2018, 2024), which also implies an internal communication network.

Our second, regional scale case study area is located in the southern part of the German Mecklenburg Bay (Fig. 11.1, black square). While the Danish straits can be interpreted as the centre of these context areas, especially for the Kongemose and Ertebølle period, the micro-region under study can be seen as a bridge to the Central European mainland. While an in-depth synthesis of the super-regional scale is outside the scope of this chapter, as we focus on very general adaptive cycle dynamics, we provide in the following section a concise summary of the archaeological and environmental record of the micro-region under study.

11.2 The Greater Wismar Bay

The primary focus of this case study is the sheltered multi-sectioned Wismar Bay. The bay complex includes Poel Island (37 km^2) in the centre, and in the east, Wustrow (10 km^2), a large spit island, and the Salzhaff lagoon (Fig. 11.2). In the east, the study area is bordered by a 12 km coastal tongue that surrounds the terminal moraine called "Kühlung". In front of this northernmost part and near the so-called "Trollegrund", a huge, submerged beach lake is located (Fig. 11.2, dotted white line). While not investigated by archaeological survey in detail, human settlement activity at its shoreline is well-documented by the numerous beach finds. Several smaller streams flowed into the lagoon and bay, of which the Hellbach River (Fig. 11.2, white stripe) is the largest and longest. These water streams connect the coastal area with the hinterland.

The mapped area of investigation, Greater Wismar Bay (GWB), was chosen as the case study region primarily for its comprehensive submarine archaeological record, which is well-preserved by two blocking shallows, Lieps and Hannibal, at its entrance (Lübke 2002a, 2000b 2006; Hartz et al. 2014). Furthermore, the coastal and environmental development over the last 9,000 years is well-known due to comprehensive investigations during the last 25 years (Statteger and Leszczyōska 2023). This is of special importance, because we want to investigate the impact of atmospheric dynamics on the hunter-gatherer societies and focus on the implications of an ever-changing landscape related to the global rise in sea levels after the Last Glacial Maximum (cf. Nunn 2021).

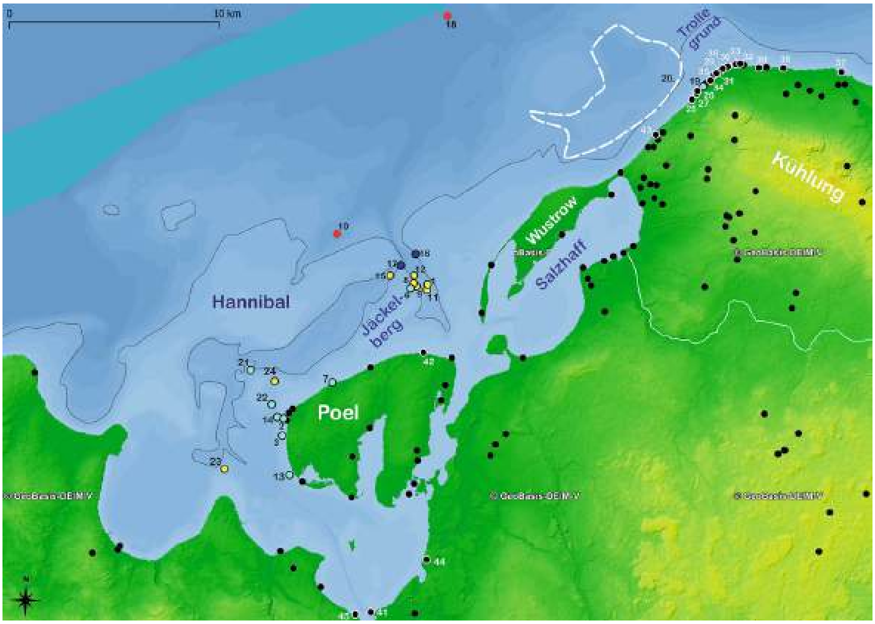

Fig. 11.2 Distribution map of Mesolithic sites within the case study region. Black dots: Survey finds. Black dots with white border: Organic beach finds, light blue dots: Ertebølle submarine sites, yellow dots: Kongemose submarine sites, red dots: late Maglemose or older submarine sites. Numbering see Tables 11.1, 11.2 and 11.3. In the background: DGM5-MV

11.2.1 The Archaeological Record

In total, 97 sites are of varying relevance for the study at hand (Table 11.1). The available information is strongly related to the documentation context. Many of the subaquatic sites (N = 24, Table 11.2) are already well-known and have been published within the framework of the Sinking Coasts (SINCOS) I and II projects (Hartz et al. 2014). Within a range of 2 km from the actual coast to the hinterland, 73 additional sites have been identified. Fifty-two sites are located on mineral soils and are close to being fully documented by field surveys with hundreds of flint artefacts. However, these artefacts were neither well-analyzed nor published and only preliminarily classified as Mesolithic by the occurrence of specific tool types like core adzes, which hampers their integration into a chronological model of system dynamics. The latter is easier for the third group of sites, which encompasses 21 locations at the shoreline with chronologically relevant organic beach finds (Table 11.3). These finds are often found after storm events with a north-westerly direction and are associated with blocks of peat, indicating high-level settlement activities on the old lake's shores, today submerged. Finds include base antler axes (N = 7), T-shaped antler axes (N = 6), undefined antler axes (N = 4), and pressure sticks (N = 13), which are characteristic tools for the Mesolithic pressure technique (Table 11.4).

Table 11.1 List of all Mesolithic sites from the GWB and the hinterland (defined by ~2 km distance to the actual shoreline)

Mesolithic site categories	Number
Subaquatic site	24
Coastal and nearby sites without chronologic- relevant organic artefacts	52
Coastal sites with organic beach finds	21
Total	**97**

Only a few have been examined previously, but direct dates were generally missing (Schacht 1983; Häußler 1995). All were typologically classified by the authors for this chapter. Additionally, one piece could be dated—a pressure stick, nearly 30 cm in length, found in the city area of Wismar—to the Kongemose period (5830–5710 calBC; ALM1981_115, 104, Figs. 11.1, 11.3) and supports the Mesolithic attribution of this artefact type. While not exclusively Mesolithic by age (cf. Lübke et al. 2024), the occurrence of this tool types at these beaches gives us a clear sign of human presence during our study timeframe (cf. Groß and Lübke 2019). This is supported by the fact that the GWB shows the highest density of these finds along the whole Mecklenburg–Vorpommern coast.

Primary data about on-site human activities, local environment conditions, and the habitat comes primary from the well-documented, frequently excavated subaquatic sites. This means that we know more about the archaeological legacy of the human presence in flooded regions than on land and is mainly caused by extensive third-party funded research projects, which conducted extensive subaquatic fieldwork in our case study region and beyond until 2008.[1] By focusing on the period of the Littorina transgression, human dynamics from 6200 to 2000 BC was documented by numerous field campaigns with over 500 m^2 of excavated settlement and 150 radiocarbon dates. While comprehensive analyses of the comprehensive lithic assemblages are only partly available (cf. Mahlstedt 2007), a detailed study of the wooden artefacts and features broadens the technology database at hand (Klooß 2015). Additional, detailed archaeozoological information sheds light on subsistence patterns, as well as environmental reconstructions (Hartz et al. 2014).

The oldest directly dated human activities in Wismar Bay are from “Jäckelberg-NNW” and “Jäckelberg-Huk” and show an archaeological assemblage from 11 m depth, similar to Kongemose sites on the Danish Island (Sørensen 2017) and Schleswig–Holstein (Bokelmann 2000; Hartz and Briel 2020). The most recent relevant occupation can be found at “Timmendorf Nordmole III” around 4,000–3,800 calBC, a coastal hunting station in the transitional phase between Ertebølle and Early Neolithic Funnelbeaker culture (Lübke and Schmölcke 2010).

Additional information from slightly older human presence was discovered in lithic debris, found within a core at a depth of 15 m at Poel Neuburg 41, while two

[1] DFG-Individual Research Grant “Stone Age in Wismar Bay” 2001–2002 (Lübke 2006), the following DFG-Research Unit FOR 488 “SINCOS” 2003–2006 (Jöns et al. 2007), and finally the DFG-Package Proposal “SINCOS II” 2006–2010 (Hartz et al. 2014).

Table 11.2 List of all submerged Mesolithic sites from the GWB. Data from unpublished sites comes from the Archive of the Heritage State Department of Mecklenburg-Vorpommern (LAKD-MV)

Number	Site	Kind of documentation	Chronology	Depth (meter)	Literature
1	Poel Neuburg 5 (Jäckelgrund Strand)	Underwater survey	Late	7	Lübke (2002a)
2	Poel Neuburg 12a (Timmendorf-Nordmole I)	Underwater excavation	Terminal	2.5–4	Lübke (2002a), Klooß (2015)
3	Poel Neuburg 12b (Timmendorf-Nordmole III)	Underwater excavation	Terminal	2.5–4	Lübke (2002a), Klooß (2015)
6	Poel Neuburg 16 (Jäckelberg-Nord)	Underwater excavation	Terminal	6–7	Lübke (2002a), Hartz et al. (2014), Klooß (2015)
7	Poel Neuburg 18 (Schwarzer Busch-West)	Underwater excavation	Terminal	1	Lübke (2002a)
8	Poel Neuburg 39 (Jäckelberg Insel West)	Underwater survey/single find	Late	8	Unpublished
9	Poel Neuburg 40 (Jäckelgrund-Furt)	Underwater Excavation	Late		Lübke (2002a), Hartz et al. (2014)
10	Poel Neuburg 41	Coring/Single finds	Late	15	Unpublished
11	Poel Neuburg 42 (Jäckelgrund-Orth)	Underwater excavation	Late	7–8	Lübke (2002a, b), Hartz et al. (2014)
12	Poel Neuburg 45 (Jäckelberg-Huk)	Underwater excavation	Late	8.5	Lübke (2002a), Lübke et al. (2011), Hartz et al. (2014), Klooß (2015)
13	Poel Neuburg 46 (Rustwerder-Hals)	Underwater survey	terminal	2–3	Lübke (2002a)
14	Poel Neuburg 47 (Timmendorf-Nordmole II)	Underwater excavation	terminal	4–5	Lübke (2002a), Hartz et al. (2014), Klooß (2015)
15	Poel Neuburg 49 (Jäckelberg NNW)	Underwater excavation	Late	11	Hartz et al. (2014)

(continued)

Table 11.2 (continued)

Number	Site	Kind of documentation	Chronology	Depth (meter)	Literature
16	Poel Neuburg 58 (Großes Tief—Ost)	Underwater survey	Late	~12	Hartz et al. (2014)
17	Poel Neuburg 59 (Jäckelberg-Nordkap)	Underwater survey	Late	10	Hartz et al. (2014)
18	Poel Neuburg 67 (Binkerwall)	Underwater survey	Early	21	Geersen et al. (2024)
19	Neubukow Salzhaff 3	Underwater survey	Terminal	3–5	Unpublished
20	Neubukow Salzhaff 5/ Kägsdorf 72 (Trollegrund)	Underwater survey	Late/ Terminal	5–9.5	Lübke and Schmolcke (2010), Terberger et al. (2018)
21	Gägelow 2	Underwater survey/single finds	Terminal	5–6	Unpublished
22	Gägelow 3 (Platte-Ost)	Underwater excavation	Terminal	3–4	Lübke (2002a)
23	Gägelow 7 (Hohen Wieschendorf-Huk-Nord)	Underwater excavation	Late/ Terminal	5	Lübke (2002a)
24	Gägelow 10 (Flaggtief-Nordost)	Underwater survey	Late/ Terminal	5–7	Unpublished

of the base antler axes from the Trollegrund paleolake show an older, transverse orientation (7,000–6,500 calBC, cf. Groß and Lübke 2019). Further proof of early human activities within the region is the newly documented Late Pleistocene/Early Holocene structure "Blinkerwall" at Poel Neuburg 67 (Geersen et al. 2024).

11.2.2 The Environmental Dynamics

Due to the comprehensive regional studies conducted during the SINCOS project, as well as within the super-regional area, we are well-informed about the environmental development during the time frame.

The most significant shift within the habitat of these groups did not take place in a single event. Due to rising sea levels during the time frame of the later Maglemosian up to the late Ertebølle culture and into the neolithic Funnelbeaker period, the Southern Baltic Basin experienced glacial isostatic adjustments in the transition from the Ancylus freshwater lake (8,700–7,800 calBC) to the Initial Littorina Sea (7,800–6,500 calBC) and then the Littorina Sea (6,500 calBC until today) (Rosentau et al. 2021). Sea levels continued to rise after the initial stage of the Littorina transgression;

Table 11.3 List of all antler artefacts found at the beaches of the GWB. Data from unpublished sites is coming from the Archive of the Heritage State Department of Mecklenburg-Vorpommern (LAKD-MV)

	Site name	Documentation	Chronology	Specific finds	ID	Literature
25	Meschendorf 8	Beach finding(s)		T-shaped antler axe	IV_80_381	Unpublished
26	Meschendorf 12	Beach finding(s)		Antler axe	ALM1998/ 2087	Unpublished
27	Meschendorf 13	Beach finding(s)		Base antler axe,	ALM 98/1565	Häußler (1995)
28	Kägsdorf Beach	Beach finding(s)		2 × T-shaped antler axes	ALM1998/ 1580	Häußler (1995)
29	Kägsdorf 10	Beach finding(s)		T-shaped antler axe, reuse	ALM73/157	Schacht (1983), Häußler (1995)
30	Kägsdorf 25	Beach finding(s)		T-shaped antler axe	IV_80_378	Unpublished
31	Kägsdorf 27	Beach finding(s)		2 × Worked antler fragment	ALM98/ 1942,2/ ALM98/ 1943,1	Unpublished
32	Kägsdorf 88	Beach finding(s)		Antler axe	ALM 1990/ 174	Unpublished
33	Kägsdorf 101	Beach finding(s)		T-shaped antler axe, Worked antler with cranium	ALM2000/ 667(Axe), ALM2009/ 1164	Unpublished
34	Kägsdorf 104	Beach finding(s)		2 antler pressure sticks	ALM98/1569	Unpublished
35	Kägsdorf 113	Beach finding(s)		Cutted antler fragments	ALM2006/ 1645	Unpublished
36	Kühlungsborn 25	Beach finding(s)		Pressure stick	ALM98/ 1950,2	Unpublished
37	Kühlungsborn 50	Beach finding(s)		2 × Pressure sticks	ALM98/1573	Unpublished
38	Kühlungsborn 120	Beach finding(s)		5 × Antler pressure sticks, 1 × Base antler axe, 1 × semifinished base axe	ALM1989/ 380 (axe preform), ALM1989/ 380 (antler axe), ALM89/ 380 (pressure sticks)	Unpublished

(continued)

Table 11.3 (continued)

	Site name	Documentation	Chronology	Specific finds	ID	Literature
39	Kühlungsborn 243	Beach finding(s)		Base antler axe fragment	ALM1998/ 1204	Unpublished
40	Wismar	Beach finding(s)	1 pressure stick: 5.831–5.711 calBC	1 × Base antler axe, 2 Pressure sticks	ALM81/ 115,103(Axe), InvNr.3785 (Pressure stick), ALM1981_ 115,104 (Pressure stick)	Unpublished
41	Wismar 30	Beach finding(s)		Pressure stick	ALM2016/ 1632,486	Unpublished
42	Gollwitz 8	Beach finding(s)		Base antler axe	ALM2010/ 834	Unpublished
43	Rerik Ost 58	Beach finding(s)		Antler axe fragment	ALM2016/ 1439-IV-80–431	BMVJ2016-0014 (2016)
44	Redentin Bog	Beach finding(s)		Antler axe fragment	Mus. Rostock 4710	Schacht (1983)
45	Wismar Wendorf	Beach finding(s)		Base antler axe	Ehem. Mus. Wismar 56 068)	Schacht (1983)

Table 11.4 Categories for the antler artefacts found at the beach of the GWB. All pieces were classified in the lab

Artefact type	Number
Base antler axe	7
T-shaped antler axe	6
Undefined antler axe (fragment)	4
Pressure stick	13
Worked antler pieces	9
In total	**39**

however, different velocities can be distinguished. Proportionally, the largest increase occurred between 6,570 and 6,000 calBC with the final decay of the Laurentide ice sheet, and additional meltwater sources from Antarctica caused an 18 m rise in sea levels, approximately 3.2 cm per year (Statteger and Leszczyōska 2023).

Wismar Bay, once situated in hinterland and characterized by numerous minor and major rivers, lakes, and mires during the time of the Ancylus lake (Schmölcke et al. 2006), became a coastal region. This transgression was directly observed in Wismar Bay between the human occupation at “Jäckelberg-Huk” (Fig. 11.2, 12) and

Fig. 11.3 Artefacts from the case study region. (1) Pressure stick (Wismar, ALM 1981_115), (2) Worked antler piece (Kägsdorf 98, ALM 1998/1943), (3) Base antler axe (Meschendorf 13, ALM, ALM 98/1565), (4) T-shaped antler axe (Kägsdorf 101, ALM2000/667), (5) & (6) Perforated high shoe-last adze from Poel Island (unpublished & Detershagen 16, ALM 1998/1202, modified after Häußler 1995), (7) Reworked T-shaped antler axe (Rerik Ost 58, ALM2016/1439, modified after BMVJ 2016–0014 (2016))

"Jäckelgrund-Orth" (Fig. 11.2, 11), with the first submerged around 6,000 calBC (Hartz et al. 2014). During this period, the straight coastline of the early Kongemose period transformed into a fjord-like habitat (Fig. 11.4). Soon after, the rate at which sea levels were rising slowed down and Wismar Bay steadily emerged. However, it was not until the end of the Mesolithic before a stable state had been reached around 4000 calBC with an increase of 0.3 cm per year (Harff et al. 2005).

These dynamics not only led to the regional flooding of formerly inhabited areas but also resulted in changes in available prey. An example of the impact of the Littorina transgression is the immigration of both marine fish and mammals (Schmölcke et al. 2006; Sommer et al. 2008) from the Atlantic into the Baltic Sea, with the fish

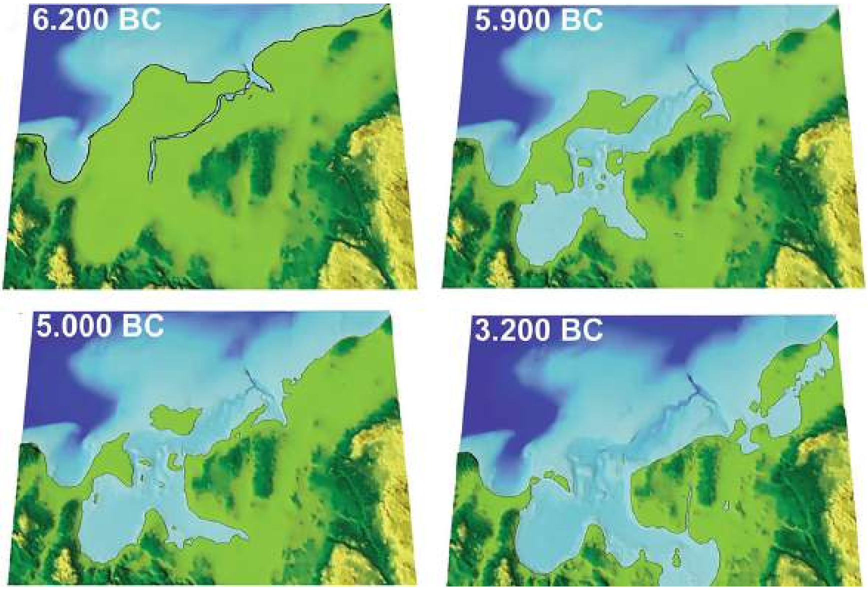

Fig. 11.4 Land loss and landscape development due to the rising sea level within the change of the case study region (modified after Jöns 2020, Fig. 5.4)

community moderately changing from brackish to brackish-marine (Schmölcke and Ritchie 2010). It is interesting to note that some fish and mammal species might be migrated in the wake of a super-regional 8.2 kyr climate cooling (Schmölcke 2008; cf. Hede et al. 2010). This was due to the disruption of the thermohaline circulation caused by the same meltwater inflow that led to the significant rise in sea level after 6,570 calBC. In addition, the number of species increased. However, the Littorina transgression also flooded the land connection between Central Europe and Scandinavia, which had existed since the end of the Ice Age, and prevented or reduced the exchange of fauna and immigration of species (Hartz et al. 2014). This possible impact must also be considered in the following discussion of human mobility. The vegetation before the peak of the Littorina transgression was associated with the Late Boreal and Early Atlantic phases and the early Holocene climatic optimum. Late and Terminal Mesolithic vegetation is described as comprising mixed forests with pine, oak, elm, lime, ash, and hazel, typical of the Atlantic phase in Central Europe. A high percentage of Pinus pollen indicates that larger stands of pine trees survived from the Boreal period, when Pinus was an important component of the landscape (Hartz et al. 2014).

Last, but not least we need to mention the Storrega tsunami, which occurred around 6,125 calBC. While mainly affecting the coastal areas of the North Sea/Atlantic, its impact on the Mesolithic oikumene in total needs to be considered, when discussing super-regional dynamics (cf. Nyland, Chap. 7; Riede et al., Chap. 13).

11.3 System States Within the Regional Archaeological Record

Based on the comprehensive set of radiocarbon dates and material studies, we now try to identify the three system states, namely “adaptation”, “reorganization”, and “release”, within the micro-region.

11.3.1 Patterns of Human Presence

The most intense consequence of a (natural) hazard on a human population is the emergence of a release state, which is possibly encompassing a population hiatus as a regional symptom of a larger population breakdown (cf. Bradtmöller et al. 2012). However, documented examples of this type of loss of resilience are rare in small-scale prehistoric societies (Posth et al. 2023; Maier and Zimmermann 2017; Schulting 2019; Mithen and Wicks 2021). Furthermore, a hiatus within the archaeological record of mobile groups can also be interpreted as immigration to more favourable regions; therefore, scale is of great importance.

On a micro-regional level, the relative chronology of the documented archaeological tool types suggests a continuous settlement pattern in the GWB area, from the Late Maglemosian complex onwards. This is suggested by the appearance of antler axes and pressure sticks all along the coast (with a concentration at the Trollegrund paleolake), as well as the blade and trapeze complex (with the special rhombic trapezes from the Kongemose culture), the handle core pressure concept (Söderlind 2024), lithic core and flake adzes, and Ertebølle pottery vessels and lamps in the excavated record.

A continuous human settlement in the GWB is also supported by the sum calibration curve of the available radiocarbon dates from the bay (Fig. 11.5). It is only possible to observe one particularly high peak, from 4,400 to 3,800 calBC, which can be explained by sampling bias, reflecting the strong research focus on the late Ertebølle site “Timmendorf-Nordmole I”, with a high number of obtained radiocarbon dates (data: Hartz et al. 2014; cf. Contreras and Meadows 2014; Hoebe et al. 2024; Stutz, Chap. 14 for critical views regarding the use of radiocarbon dates). Of more interest is the fact that no clear gap can be identified between 6,500 calBC and 4,000 calBC; therefore, a release event reflecting a demographic downturn for the GWB during this time frame appears unlikely.

11.3.2 Socio-Economic Dynamics

To identify patterns for continuity, adaptation, and more abrupt changes, we need to take a closer look at the socio-economic parameters.

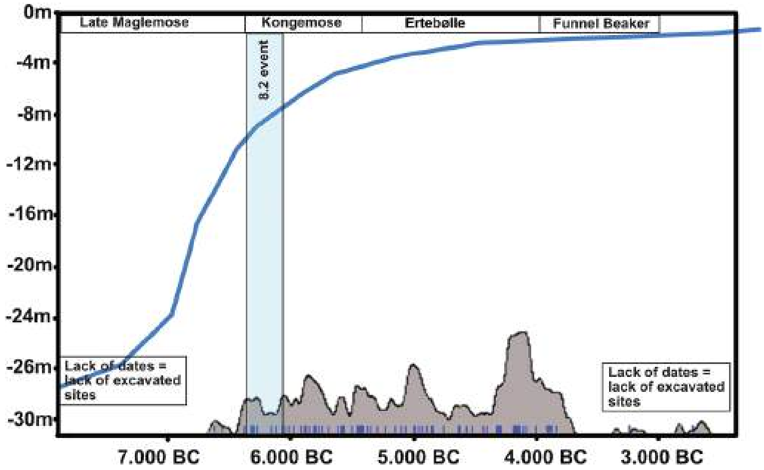

Fig. 11.5 Radiocarbon dates (after Hartz et al. 2014) and sea-level curve (after Statteger and Leszczyōska 2023) for the GWB

11.3.2.1 Settlement Patterns

The older site cluster around Jäckelberg dates from a period when the Greater Wismar Bay was still part of a freshwater ecosystem. The artefact scatters are of a limited extent both in the former terrestrial settlement area and in the shore zone. In addition to the animal bones of typical hunting prey (red deer, roe deer, wild boar, and occasionally aurochs and elk), fish bones and the remains of gathered plant foods, such as hazelnuts, were also found at all the sites. All submerged locations are either at the mouths of streams or at narrow points on offshore islands (Lübke 2006), which is typical for this time frame (Sørensen 2017). Therefore, these stations are reminiscent of the Early Mesolithic, which is characterized by non to less specialized land-use strategies (Groß 2017) with no evidence of division between larger camps with a central function and associated specialized sites.

However, this pattern changes with the more recent sites of the fifth millennium at the west coast of Poel Island. Although the sites discovered near Timmendorf Strand yielded considerably more finds than the sites at Jäckelberg, they are characterized by a much smaller variety of types. There is much to suggest that these were specialized sites, primarily used for fishing with stationary fishing equipment (fish weirs) and, more recently, for hunting sea mammals. A large residential station, similar to those found in the Danish fjords or the Bay of Lübeck with Neustadt LA 156 (Glykou 2016), has not yet been found in the GWB yet. This indicates a change in settlement behaviour in the transition from the Late to the Terminal Mesolithic on the North German Baltic coast, possibly a consequence of adaptation to radical biotope changes resulting from the Littorina transgression.

11.3.2.2 Subsistence

Looking at the dynamics in the subsistence economy, changes did not occur suddenly but were the result of continuous adjustments. Even at the oldest excavated spots at Jäckelberg, fishing activities immediately adapted to the changed biotope: instead of freshwater species in rivers and lakes, more marine fish species were caught in the newly created protected sea bays, without any observable change in technology (cf. Klooß 2015). Furthermore, typical terrestrial forest animals (red deer, roe deer, and wild boar) continue to dominate as hunting prey, whereas marine mammals continue to play no role.

Even at the oldest sites on the west coast of Poel Island (earliest Ertebølle), changes generally appear within fishery. The use of stationary fish weirs and the focus on catadromous fish species, such as eels, represent an economically significant innovation, whereas the hunting of sea mammals still appears to be of secondary importance. This only changes at the stations of the late Ertebølle culture, not only in Wismar Bay (Timmendorf-Nordmole I; III) but also in the Bay of Lübeck (Neustadt LA 156), where sea mammal hunting, especially of seals, is predominant, probably in the open sea and on the sandbanks off the coast.

These gradually emerging, asynchronous changes in the settlement patterns in the subsistence strategies testify to quite stable hunter-gatherer societies that are able to react to immense environmental changes without obvious crisis situations that could have involved release phases.

11.3.2.3 Change and Tradition: Patterns Within the Material Culture

One fact that hampers a weighted diachronic analysis of the material remains is that the excavated sites are not older than 6,400 calBC (Jäckelberg NNW and Jäckelberg Huk, Lübke et al. 2011). We can nonetheless identify patterns of change and ongoing lines of tradition within the assemblages from all sites within the region. Artefact types that show a line of tradition from the Early to Late Mesolithic include, e.g. two (scalene) triangles from Jäckelberg Huk (Lübke et al. 2011). Two other long-lasting types are related to wood working: core and flake adzes. Both generally appear to be from the Maglemosian to the Ertebølle culture, showing an inverse proportion to higher core adzes at the beginning and higher flake adzes towards the end of the Mesolithic (Wenzel 2012). Both can be identified in the study region, with core and flake adzes in the early assemblages (e.g. Jäckelgrund-Ort and Jäckelberg-Huk), as well as the later periods (Timmendorf Nordmole I to III). Furthermore, many of the surface spots have been assigned to the Mesolithic period because of the occurrence of these adzes. The documented base antler axes, ranging in Northern Germany from the Maglemosian to the oldest Ertebølle phase, also support continuity, even if their morphology has changed slightly through time (Groß and Lübke 2019).

However, new artefact types are also known, including trapeze microliths from the Kongemose period onwards. These are regularly found in Northern Germany. Of interest is the fact that the two sites Jäckelberg Huk and NNW have produced the distinct rhombic shape in plain view (Lübke et al. 2011), which is characteristic of the Early Kongemose ´Blak‘ Phase in Denmark and Southern Sweden (Sørensen 2017). The appearance of laminar handle core technology in the GWB within the Kongemose assemblages (Jäckelberg Huk, Jäckelberg NNW) happens during the same time frame as in the overall region (Söderlind 2018). The same is true for pottery technology, while pointed-base vessels and lamps appear in the region during the Late Ertebølle period (Timmendorf Nordmole I, Klooß et al. 2009).

11.4 Linking the GWB to Super-Regional Dynamics

As mentioned before, in resilience research the nesting of dynamics/cycles of different scales is of importance and can help to understand both positive and negative feedback loops throughout the system. Strong spatial connections within the super-regional context area became obvious based on the commonality of specific, widely distributed tool types like common core adzes (Wenzel 2012) or the more distinct antler headdresses, which appear from England up to Eastern Germany (Wild et al. 2021). On the diachronic scale, distinct tool types like slotted bone daggers, known from Southern Scandinavia to Brandenburg (Sørensen 2017; Kotula et al. 2023), show strong lines of continuity. These patterns within the material culture are also reflected by the stability of Mesolithic population genetic markers, viewed on the genome scale, as shown for Denmark recently (Allentoft et al. 2024).

Furthermore, we see a strong spatial communication network with the fast and widespread appearance of innovations from within and outside the context area. Therefore, it is of interest that most of the listed innovations (Sect. 3.2.3) are clearly related to knowledge transfer and some of them possibly to the migration of people from other regions (cf. Manninen et al. 2021). For example, the aforementioned changes in subsistence can "[…] *possibly be adopted from their neighbours in the north, who had developed their skills on the shores of the Kattegat centuries earlier*". (Hartz et al. 2014, 3).

An external influx from eastern hunter-gatherer communities has been suggested with the introduction of laminar handle cores (Söderlind 2018; 2024; Sørensen 2017), pottery container technology (Dolbunova et al. 2023), and T-shaped axes (Lübke et al. 2024). In contrast, innovations from the south, such as blade and trapeze microlithics (Gronenborn 2017; Marchand and Perrin 2017; Perrin et al. 2020; Crombé 2019), and the occurrence of new burial traditions (Terberger et al. 2018) seem to be related to contacts with early farming communities (Fig. 11.6). The most obvious direct links are easily identifiable imports from southern farming communities like polished adzes made of solid rock dating to the Kongemose/Ertebølle period and early copper artefacts from Ertebølle sites (Klassen 2000; 2004). Examples in the GWB include one perforated high shoe-last adze from Poel Island (unpublished, Figs. 11.3 and 11.5), as well as two pieces in the hinterland, found in Zweedorf 145 (unpublished) and Detershagen 16 (ALM 1998/1202, Häußler 1995, Fig. 11.3, 6).

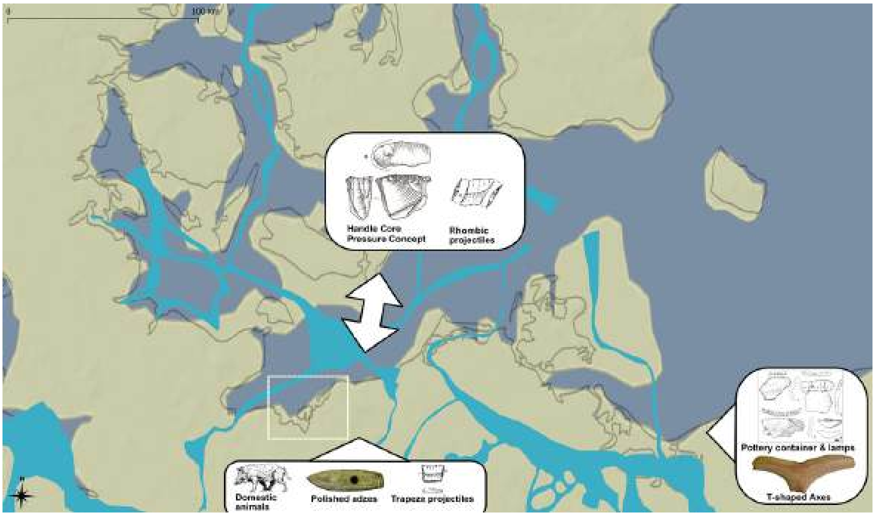

Fig. 11.6 Overview for the mentioned external innovations and their assumed direction of their origin

Another direct line of connection might be the appearance of a pig bone genetically descended from the domesticated pigs of the LBK cultures native to the south (Krause-Kyora et al. 2013). Unfortunately, the article lacks more precise information on its origin. Nevertheless, the piece in question comes from the upper layers of the shore zone of the Timmendorf-Nordmole I site and should therefore date to the final phase of the EBK culture. However, the subject of intense debate was the question of whether this and two other pig bones of similar genetic origin really provide evidence of domestic pig husbandry in the EBK culture (Rowley-Conwy and Zeder 2014a, b; Evin et al. 2014). But even if it was only the hybrids of domestic pigs that escaped in the south, it shows quite clearly the acculturation pressure not only on the terminal Mesolithic hunter-gatherers but also on the natural environment. By summarizing these dynamics we can hypothesize that this super-regional network is a key element for the high resilience of the local entities (cf. Bird et al. 2019).

11.5 Building Capacity and Boosting Resilience … but How?

Following Carpenter et al. (2002), our targets for investigating the *resilience of what* within this chapter were small-scale hunter-gatherer groups, which have lived between 7,300 and 4,000 calBC. Associated with the context areas of Maglemose, Kongemose, and Ertebølle culture these groups were confronted with challenging environmental conditions (*resilience to what*). One of these natural hazards was the

Norwegian Storrega Tsunami, which affected local communities in the North Sea Basin, as discussed by Nyland (Chap. 7), Kilhavn (Chap. 12) and Walker (Chap. 5). Another stressor was the contemporaneous 8.2 kyr cooling event. On the regional scale the 8.2 event caused, e.g. changing migration routes of animal species in the Southern Baltic (Schmölcke et al. 2006) and had possibly a super-regional demographic impact on H-G communities in Denmark and Great Britain (see Riede et al., Chap. 13; Schulting 2019; but see Hansson et al. 2019 for a negative impact indication). However, the most extensive dynamics within the habitat of these people was caused by the post-LGM rise in sea levels, namely the Littorina transgression.

What is interesting is that none of these developments were severe enough to collapse the local system in the time frame. In contrast, most of the socio-economic parameters synthesized diachronically show indications of continuity or adaptation. Within the sphere of subsistence, we observe continuity in the hunting of terrestrial animals, while the increase in fishing and the use of fishing structures, as well as the increase in seal hunting, can be interpreted as an adaptation to a habitat change and not a complete reorganization. In addition, the settlement patterns show an adaptation to the changing habitat (regarding location type) and continuity regarding settlement configuration. For both spheres, a clear change is not visible until the beginning of agriculture, with bigger, more standardized houses and a shift to a clear terrestrial diet (Hartz et al. 2014; cf. Schulting 2019). However, even fishing and fishing technology show a clear traditional Mesolithic legacy within the Neolithic.

The Mesolithic groups show clear signs of population stability, with a long-lasting line of cultural traditions in several aspects. Here, indications of change are possibly related to habitat adaptation. We see specialization tendencies as in the case of seal hunting in the Ertebølle period and possibly a higher degree of permanence, but this does not seem to lower their capacity for adaptation too much (cf. Price and Brown 1985). In doing so, we argue for falsifying the null hypothesis that well-established archaeological datasets for Holocene hunter-gatherer communities lack a clear signal of resilience-related dynamics, even if they were collected without a specific research focus (Sect. 1.2). We find qualified support for long-term adaptability in the face of recurrent environmental stressors, including a long-term rise in sea level. What is also obvious is the strong nesting of local communities within the overall context area and beyond. Was this external feedback in terms of incoming innovations and possibly new groups crucial for building capacity and successful adaptation in the *longue dureé*?

Herewith we are reaching the limit for our scenario building. Important information, like a functional interpretation of the excavated settlements, is almost absent (Mahlstedt 2007). Furthermore, we need to ask how we can better integrate the dozens of open-air sites from the direct coastal hinterland, which non-standardized surveys have added to our observations.

The same question is relevant for the better-documented hinterland sites, primarily situated within glacial river valleys (see Stratbücker et al., in press). How have these rivers enabled mobility and possibly affected territoriality (Hussain and Floss 2016)? This is important to know. While the coastal areas were directly connected to the hinterland via these rivers, the rivers were themselves directly affected by the observed sea-level dynamics, resulting in changing stream directions and mooring up of the valleys (Kaiser et al. 2012). This lack of information about interconnectedness is a clear obstacle to understanding general demographic trends and their systemic connections to the emergence of adaptability and resilience in a gradually drowning landscape.

Are the groups inhabiting the GWB during the Mesolithic an example for a human mindset of constant adaptation (see Stutz, Chap. 14; cf. Wilkins and Schoville 2024 for a discussion regarding the meaning of innovations for our species)? Is change the norm? This could have been one reason for the appearance of many external innovations as well as the appearances of single finds from the Baltic in southern farming settlements (Klassen 2000, 2004). Or, as stated by the former SINCOS team: "*… the Late and Terminal Mesolithic communities did not, or at least not only, experience the environmental changes caused by the rapidly rising sea level as a threat to their habitat, but also as a challenge or even chance to take advantage of a completely altered environment offering many new opportunities"* (Hartz et al. 2014, 4).

If this is the case, this study region would be an interesting example of a contra-doom-and-gloom-scenario (cf. Piper et al., Chap. 6) suitable for communications about rising sea levels (Akerlof et al. 2017). Living in a world where adaptation to rising sea levels will be a crucial part of tackling climate crises, it seems to be a fruitful area for future research. Or as Heitz (Chap. 4, p. xy) has stated "*Hazards– whatever their cause– must first be recognised as such*".

Acknowledgements We would like to thank Daniel Groß and Aaron Stutz for providing fruitful reviews on an early stage of this manuscript, as well as Sonja Grimm for editorial support. The work of this chapter was partly funded by the Interdisciplinary Faculty of Rostock University, as well as the ZBSA/LEIZA.

References

Akerlof K, Covi M, Rohring E et al (2017) Communicating sea level rise: Media, public opinion, and engagement. Oxford Research Encyclopedia of Climate Science Oxford University Press

Allentoft ME, Sikora M, Refoyo-Martínez A et al (2024) Population genomics of post-glacial western Eurasia. Nature 625(7994):301–311. https://doi.org/10.1038/s41586-023-06865-0

Alley RB, Mayewski PA, Sowers T et al (1997) Holocene climatic instability: A prominent, widespread event 8200 yr ago. Geology 25(6):483–486. https://doi.org/10.1130/0091-7613(1997)025%3c0483:HCIAPW%3e2.3.CO;2

Barnett RL, Charman DJ, Johns C et al (2020) Nonlinear landscape and cultural response to sea-level rise. Science Adv 6(45). https://doi.org/10.1126/sciadv.abb6376

Bird D, Bliege Bird R, Codding B et al (2019) Variability in the organization and size of hunter-gatherer groups: Foragers do not live in small-scale societies. J Hum Evol 131:96–108

BMVJ2016 (2016) Jahrbuch Bodendenkmalpflege in Mecklenburg-Vorpommern Band 64

Boethius A, Kjällquist M, Kielman-Schmitt M et al (2021) Early Holocene Scandinavian foragers on a journey to affluence: Mesolithic fish exploitation, seasonal abundance and storage investigated

through strontium isotope ratios by laser ablation (LA-MC-ICP-MS). PloS One 16(1). https://doi.org/10.1371/journal.pone.0245222
Bokelmann K (2000) Zum Beginn des Spätmesolithikums in Südskandinavien. Geweihaxt, Dreieck und Trapez, 6100 cal BC. Offa 56:183–197
Bradtmöller M, Pastoors A, Weninger B et al (2012) The repeated replacement model—Rapid climate change and population dynamics in Late Pleistocene Europe. Quatern Int 247:38–49. https://doi.org/10.1016/j.quaint.2010.10.015
Bradtmöller M, Grimm S, Riel-Salvatore J (2017) Resilience theory in archaeological practice—An annotated review. Quatern Int 446:3–16. https://doi.org/10.1016/j.quaint.2016.10.002
Carpenter S, Walker B, Anderies J et al (2002) From metaphor to measurement: Resilience of what to what? Ecosystems 4:765–781
Codding BF, Roberts H, Eckerle W et al (2024) Can we reliably detect adaptive responses of hunter-gatherers to past climate change? Examining the impact of Mid-Holocene drought on Archaic settlement in the Basin-Plateau Region of North America. Quatern Int 689–690:5–15. https://doi.org/10.1016/j.quaint.2023.06.014
Contreras D, Meadows J (2014) Summed radiocarbon calibrations as a population proxy: a critical evaluation using a realistic simulation approach. J Archaeol Sci 52:591–608. https://doi.org/10.1016/j.jas.2014.05.030
Crombé P (2019) Mesolithic projectile variability along the southern North Sea basin (NW Europe): Hunter-gatherer responses to repeated climate change at the beginning of the Holocene. PLoS ONE 14(7):e0219094. https://doi.org/10.1371/journal.pone.0219094
Dolbunova E, Lucquin A, McLaughlin TR et al (2023) The transmission of pottery technology among prehistoric European hunter-gatherers. Nat Hum Behav 7(2):171–183. https://doi.org/10.1038/s41562-022-01491-8
Evin A, Girdland Flink L, Krause-Kyora B, Makarewicz C, Hartz S, Schreiber S, von Wurmb-Schwark N, Nebel A, von Carnap-Bornheim C, Larson G, Dobney K (2014) Exploring the complexity of domestication: a response to Rowley-Conwy and Zeder. World Archaeol 46(5):825–834. https://doi.org/10.1080/00438243.2014.953711
Geersen J, Bradtmöller M, Schneider von Deimling J et al (2024) A submerged Stone Age hunting architecture from the Western Baltic Sea. PNAS 121(8):e2312008121. https://doi.org/10.1073/pnas.2312008121
Glykou A (2016) Neustadt LA 156—ein submariner Fundplatz des späten Mesolithikums und des frühesten Neolithikums in Schleswig-Holstein. Wachholtz, Kiel/Hamburg
Gramsch B (1973) Das Mesolithikum im Flachland zwischen Elbe und Oder. Veröffentlichungen des Museums für Ur- und Frühgeschichte Potsdam 7. Deutscher Verlag der Wissenschaften, Berlin
Gronenborn D (2017) Migrations before the Neolithic? The Late Mesolithic blade-and-trapeze horizon in Central Europe and beyond. In: Meller H, Daim F, Krause, J, Risch R et al (ed) Migration und Integration von der Urgeschichte bis zum Mittelalter. Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, Halle (Saale), pp 113–128
Groß D, Lübke H (2019) Das obere und mittlere Travetal – Eine mesolithische Fundlandschaft in Holstein, Norddeutschland. In: Baales M, Pasda C (eds) "All der holden Hügel ist keiner mir fremd …". Festschrift zum 65. Geburtstag von Claus-Joachim Kind. Universitätsforschungen zur prähistorischen Archäologie 327. Dr. Rudolf Habelt GmbH, Bonn, pp 485–499
Groß D, Lübke H, Meadows J et al (eds) (2019) Working at the sharp end: from bone and antler to early Mesolithic life in northern Europe. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum 10. Wachholtz, Kiel, Hamburg. Available via http://epub.sub.uni-hamburg.de/epub/volltexte/2023/151225/. Accessed 21 Sept 2023
Groß D (2017) Welt und Umwelt frühmesolithischer Jäger und Sammler. Mensch-Umwelt-Interaktion im Frühholozän in der nordmitteleuropäischen Tiefebene. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum 8. Ludwig, Kiel

Guedes J, Austermann J, Mitrovica JX (2016) Lost foraging opportunities for East Asian hunter-gatherers due to rising sea level since the last glacial maximum. Geoarchaeology 31(4):255–266. https://doi.org/10.1002/gea.21542
Hansson A, Boethius A, Hammarlund D et al (2019) Shoreline displacement, coastal environments and human subsistence in the Hanö Bay region during the Mesolithic. Quaternary 2:14. https://doi.org/10.3390/quat2010014
Harff J, Lampe R, Lemke W et al (2005) The Baltic Sea: A model ocean to study interrelations of geosphere, ecosphere, and anthroposphere in the coastal zone. J Coastal Res 21(3):441–446
Hartz S (1999) Die Steinartefakte des endmesolithischen Fundplatzes Grube-Rosenhof. Studien an Flintinventaren aus der Zeit der Neolithisierung in Schleswig-Holstein und Südskandinavien. Dissertation, Christian-Albrechts-Universität zu Kiel, 1995. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein 2. Wachholtz, Neumünster
Hartz S, Briel M (2020) Hunters and fishermen at the satruper moor: a late Mesolithic stratified site in Northern Germany. In: Zander A, Gehlen B (eds) From the early Preboreal to the Subboreal period—Current Mesolithic research in Europe. Studies in honour of Bernhard Gramsch. Mesolithic Edition 5. Kerpen-Loogh, Welt und Erde, pp 131–149
Hartz S, Lübke H (2006) New evidence for a chronostratigraphic division of the Ertebølle culture and the earliest funnel beaker culture on the Southern Mecklenburg Bay. After Ice Age SettlS, Subsist Soc Dev Mesolith Centl Eur 59–74
Hartz S, Jöns H, Lübke H et al (2014) Prehistoric settlements in the South-Western Baltic sea area and development of the regional stone age economy. Final Report of the Sincos-II-Subproject 4. Ber Rom-Ger Komm 92:77– 210.https://doi.org/10.5281/zenodo.260164
Häußler V (1995) Zwischen Recknitz und Salzhaff. Kreisverwaltung, Bad Doberan
Hede MU, Rasmussen P, Noe-Nygaard N et al (2010) Multiproxy evidence for terrestrial and aquatic ecosystem responses during the 8.2 ka cold event as recorded at Højby Sø, Denmark. Quat Res 73(3):485–496
Hoebe PW, Cohen KM, Busschers FS et al (2024) Early Holocene inundation of Doggerland and its impact on hunter-gatherers: An inundation model and dates-as-data approach. Quatern Int 694:26–50
Holling CS, Gunderson LH (2002) Resilience and adaptive cycles. In: Gunderson LH, Holling CS (eds) Panarchy. Island Press, Washington, D.C
Hussain ST, Floss H (2016) Streams as entanglement of nature and culture: European Upper Paleolithic river systems and their role as features of spatial organization. J Archaeol Method Theory 23(4):1162–1218. https://doi.org/10.1007/s10816-015-9263-x
Jensen TZT, Sjöström A, Fischer A et al (2020) An integrated analysis of Maglemose bone points reframes the Early Mesolithic of Southern Scandinavia. Sci Rep 10(1):17244. https://doi.org/10.1038/s41598-020-74258-8
Jöns H, Lübke H, Lüth F, Terberger T (2007) Prehistoric settlements and development of the regional economic area. Archaeological investigations along the Northeast-German Baltic Sea coast. Ber RGK 88:77–116
Jöns H, Lüth F, Mahlstedt S et al (2020) Germany: Submerged Sites in the South-Western Baltic Sea and the Wadden Sea. In: Bailey G, Galanidou N, Peeters H et al (eds) The archaeology of Europe's drowned landscapes 35. Springer International Publishing (Coastal Research Library), Cham, pp 95–123
Kaiser K, Lorenz S, Germer S et al (2012) Late Quaternary evolution of rivers, lakes and peatlands in northeast Germany reflecting past climatic and human impact—an overview. E&G Quat Sci J 61(2):103–132. https://doi.org/10.3285/eg.61.2.01
Kind CJ (1997) Die letzten Wildbeuter. Henauhof Nord II und das Endmesolithikum in Baden-Württemberg. Materialhefte zur Archäologie in Baden-Württemberg 39. Konrad Theiss, Stuttgart
Klassen L (2000) Frühes Kupfer im Norden. Untersuchungen zu Chronologie, Herkunft und Bedeutung der Kupferfunde der Nordgruppe der Trichterbecherkultur. Dissertation, Universität

Freiburg im Breisgrau, 1996. Jutland Archaeological Society publications 36. Aarhus University Press, Moesgård Museum, Århus, Højbjerg

Klassen L (2004) Jade und Kupfer. Untersuchungen zum Neolithisierungsprozess im westlichen Ostseeraum unter besonderer Berücksichtigung der Kulturentwicklung Europas 5500–3500 BC. Jutland Archaeological Society 47. Jutland Archaeological Society, Moesgård Museum, Århus

Klooß S, Lübke H, Mahlstedt S (2009) Der endmesolithische Fundplatz Timmendorf-Nordmole I. Unterwasserarchäologische Forschungen in der Wismarbucht. In: Müller U, Kleingärtner S, Huber F (ed) Zwischen Nord- und Ostsee 1997–2007: Zehn Jahre Arbeitsgruppe für maritime und limnische Archäologie (AMLA) in Schleswig-Holstein. Habelt, Bonn, pp 187–208

Klooß S (2015) Mit Einbaum und Paddel zum Fischfang. Holzartefakte von endmesolithischen und frühneolithischen Küstensiedlungen an der südwestlichen Ostseeküste. Untersuchungen und Materialien zur Steinzeit in Schleswig-Holstein und im Ostseeraum 6. Wachholtz, Neumünster

Kotula A, Terberger T, Jungklaus B et al (2023) The site groß fredenwalde, NE-Germany, and the Early Cemeteries of Northern Europe. Open Archaeol 9(1):20220348. https://doi.org/10.1515/opar-2022-0348

Krause-Kyora B, Makarewicz C, Evin A et al (2013) Use of domesticated pigs by Mesolithic hunter-gatherers in northwestern Europe. Nat Commun 4:2348. https://doi.org/10.1038/ncomms3348

Lübke H (2002a) Steinzeit in der Wismarbucht. Ein Überblick. NAU—Nachrichtenblatt Arbeitskreis Unterwasserarchäologie 9:75–88

Lübke H (2002b) Submarine Stone Age settlements as indicators of sea-level changes and the coastal evolution of the Wismar Bay area. Greifswalder Geographische Arbeiten 27:203–210

Lübke H (2006) Filling a gap. Five years of underwater archaeological investigations in submarine Stone Age sites in Wismar Bay, Germany. In: Hafner A, Niffeler U, Ruoff U (eds) Die neue Sicht: Unterwasserarchäologie und Geschichtsbild. Archäologie Schweiz, Basel

Lübke H, Schmölcke U (2010) Timmendorf-Nordmole III und der Neolithisierungsprozess an der südwestlichen Ostseeküste. NAU—Nachrichtenblatt ArbSkreis Unterwasser-Archäologie 16:13–24

Lübke H, Schmölcke U, Tauber F (2011) Mesolithic hunter-fishers in a changing world: a case study of submerged sites on the Jäckelberg, Wismar Bay, northeastern Germany. In: Benjamin J, Bonsall C, Pickard C et al (eds) Submerged prehistory. Oxbow Books, Oxford, pp 21–37

Lübke H, Rimkus T, Meadows J et al (2024) The chronology of T-shaped antler axe technology in northeastern Europe. Praehistorische Zeitschrift 99(1):63–84. https://doi.org/10.1515/pz-2023-2040

Mahlstedt S (2007) The stone artefacts of Timmendorf-Nordmole I. Ber Römisch-Ger Komm 88:189–204

Maier A, Zimmermann A (2017) Populations headed south? The Gravettian from a palaeodemographic point of view. Antiquity 91(357):573–588. https://doi.org/10.15184/aqy.2017.37

Manninen MA, Damlien H, Kleppe JI et al (2021) First encounters in the north: cultural diversity and gene flow in Early Mesolithic Scandinavia. Antiquity 95(380):310–328. https://doi.org/10.15184/aqy.2020.252

Mannino MA, Di Salvo R, Schimmenti V et al (2011) Upper Palaeolithic hunter-gatherer subsistence in Mediterranean coastal environments: an isotopic study of the diets of the earliest directly-dated humans from Sicily. J Archaeol Sci 38(11):3094–3100. https://doi.org/10.1016/j.jas.2011.07.009

Marchand G, Perrin T (2017) Why this revolution? Explaining the major technical shift in Southwestern Europe during the 7th millennium cal. Bc. Quat Int 428:73–85. https://doi.org/10.1016/j.quaint.2015.07.059

MathisonSlee M, Lade SJ, Barnes CD et al (2022) Fourteen propositions for resilience, fourteen years later. Ecology and Society 27(3). https://doi.org/10.5751/ES-13248-270308

Mithen S, Wicks K (2021) Population level models for testing hunter-gatherer resilience and settlement response to the combined impact of abrupt climatic events and sea level change: A case

study from the Holocene of northern Britain. Quatern Sci Rev 265:107027. https://doi.org/10.1016/j.quascirev.2021.107027
Nunn P (2021) Worlds in shadow. Submerged lands in science, memory and myth. Bloomsbury, London. Available via https://ebookcentral.proquest.com/lib/kxp/detail.action?docID=6675036. Accessed 10 Sept 2023
Perrin T, Dachy T, Guéret C et al (2020) Pressure knapping and the timing of innovation: New chrono-cultural data on prehistoric groups of the early Holocene in the Maghreb, Northwest Africa. Radiocarbon 62(2):e1–e51. https://doi.org/10.1017/RDC.2019.157
Posth C, Yu H, Ghalichi A et al (2023) Palaeogenomics of Upper Palaeolithic to Neolithic European hunter-gatherers. Nature 615(7950):117–126. https://doi.org/10.1038/s41586-023-05726-0
Povlsen K (2013) The introduction of ceramics in the Ertebølle culture. Dan J Archaeol 2(2):146–163. https://doi.org/10.1080/21662282.2013.904127
Price TD, Brown J (1985) Prehistoric hunter-gatherers. Academic Press, Burlington, The Emergence of Cultural Complexity
Redman CL, Kinzig, AP (2003) Resilience of past landscapes. Resilience theory, society, and the *Longue Durée*. Conserv Ecol 7(1). Available via http://www.jstor.org/stable/26271922
Rimkus T (2018) Kongemose flint technology in the East Baltic area. Some examples from Lithuanian stone age sites. Archaeologia Baltica 25
Ritchison B, Thompson V, Lulewicz I et al (2020) Climate change, resilience, and the Native American Fisher-hunter-gatherers of the late Holocene on the Georgia coast, USA. Quatern Int 584:82–92. https://doi.org/10.1016/j.quaint.2020.08.030
Rosen A, Rivera-Collazo I (2012) Climate change, adaptive cycles, and the persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant. PNAS 109:3640–3645. https://doi.org/10.1073/pnas.1113931109
Rosentau A, Klemann V, Bennike O et al (2021) A Holocene relative sea-level database for the Baltic sea. Quatern Sci Rev 266:107071. https://doi.org/10.1016/j.quascirev.2021.107071
Rowley-Conwy P, Zeder M (2014a) Mesolithic domestic pigs at Rosenhof – or wild boar? A critical re-appraisal of ancient DNA and geometric morphometrics. World Archaeol 46(5):813–824. https://doi.org/10.1080/00438243.2014.953704
Rowley-Conwy P, Zeder M (2014b) Wild Boar or Domestic Pigs? Response to Evin et al. World Archaeol 46(5):835–840. https://doi.org/10.1080/00438243.2014.953712
Schacht S (1983) Knochen- und Geweihgerate. Jahrb Bodendenkmalpfl Mecklenbg-Vorpommern 31:7–82
Schmölcke U (2008) Holocene environmental changes and the seal (Phocidae) fauna of the Baltic Sea: coming, going and staying. Mammal Rev 38(4):231–246. https://doi.org/10.1111/j.1365-2907.2008.00131.x
Schmölcke U, Ritchie K (2010) A new method in palaeoecology: fish community structure indicates environmental changes. Int J Earth Sci (Geolo-Gische Rundsch) 99(8):1763–1772. https://doi.org/10.1007/s00531-010-0524-3
Schmölcke U, Endtmann E, Klooss S et al (2006) Changes of sea level, landscape and culture: A review of the south-western Baltic area between 8800 and 4000BC. Palaeogeogr Palaeoclimatol Palaeoecol 240(3–4):423–438. https://doi.org/10.1016/j.palaeo.2006.02.009
Schulting RJ (2019) The success and failure of resilience in the European Mesolithic. In: Temple DH, Stojanowski CM (eds) Hunter-gatherer adaptation and resilience: A bioarchaeological perspective. Cambridge University Press, Cambridge, pp 65–84. Available via https://www.cambridge.org/core/product/0A72BDF02225BEB74F7344A919541792. Accessed 05 Aug 2023
Söderlind S (2018) A study of the mesolithic handle core technology in Schleswig-Holstein. Archäologische Inf 41:305–316. https://doi.org/10.11588/ai.2018.0.56949
Söderlind S (2024) The handle core concept. Lithic Technology and Knowledge Transmission in Mesolithic Northern Europe. ROOTS Studies 06. Sidestone Press Dissertations, Leiden. https://doi.org/10.59641/x0922aj
Solich M, Bradtmöller M (2017) Socioeconomic complexity and the resilience of hunter-gatherer societies. Quatern Int 446:109–127. https://doi.org/10.1016/j.quaint.2017.06.064

Sommer R, Pasold J, Schmölcke U (2008) Post-Glacial immigration of the harbour porpoise (Phocoena phocoena) into the Baltic Sea*. Boreas 37(3):458–464. https://doi.org/10.1111/j.1502-3885.2008.00034.x

Sørensen SA (2017) The Kongemose culture. Nordiske fortidsminder B27. The Royal Society of Northern Antiquaries, University Press of Southern Denmark, Copenhagen

Stattegger K, Leszczyōska K (2023) Rapid sea-level rise during the first phase of the Littorina transgression in the western Baltic Sea. Oceanologia 65(1):202–210. https://doi.org/10.1016/j.oceano.2022.05.001

Stratbücker J, Theuerkauf M, Mrotzek A et al (in press) Mittelsteinzeitliche Aktivitäten am Fundplatz Kobrow 8. Jahrbuch Bodendenkmalpflege Mecklenburg-Vorpommern

Terberger T, Burger J, Lüth F et al (2018) Step by step—the neolithisation of Northern Central Europe in the light of stable isotope analyses. J Archaeol Sci 99:66–86. https://doi.org/10.1016/j.jas.2018.08.004

Turck JA, Thompson VD (2016) Revisiting the resilience of Late Archaic hunter-gatherers along the Georgia coast. J Anthropol Archaeol 43:39–55. https://doi.org/10.1016/j.jaa.2016.05.006

Uthmeier T (2004) Micoquien, Aurignacien und Gravettien in Bayern. Eine regionale Studie zum Übergang vom Mittel- zum Jungpaläolithikum. Dissertation, Universität zu Köln, 1998. Archäologische Berichte 18. Habelt, Bonn

Walker B, Gunderson L, Kinzig A et al (2006) A handful of heuristics and some propositions for understanding resilience in social-ecological systems. Ecol Soc 11(1). https://doi.org/10.5751/ES-01530-110113

Weißmüller W (1995) Die Silexartefakte der unteren Schichten der Sesselfelsgrotte; Ein Beitrag zum Problem des Moustérien. (Habilitation, Erlangen; Nürnberg, 1992). Quartär-Bibliothek 6. Saarbrückener Druckerei und Verlag, Saarbrücken

Wenzel S (2012) Kern- und Scheibenbeile. In: Floss H (ed) Steinartefakte vom Altpaläolithikum bis in die Neuzeit. Kerns, Tübingen, pp 631–638

Wicks K, Mithen S (2014) The impact of the abrupt 8.2 ka cold event on the Mesolithic population of western Scotland: a Bayesian chronological analysis using 'activity events' as a population proxy. J Archaeol Sci 45:240–269. https://doi.org/10.1016/j.jas.2014.02.003

Wild M, Gehlen B, Street M (2021) Antler headdresses. Implications from a many-faceted study of an earliest Mesolithic phenomenon. Quartär 67:205–223

Wilkins J, Schoville BJ (2024) Did climate change make Homo sapiens innovative, and if yes, how? Debated perspectives on the African Pleistocene record. Quat Sci Adv 14:100179. https://doi.org/10.1016/j.qsa.2024.100179

Chapter 12
The Impact of the Storegga Tsunami (Ca. 6150 BCE) upon Mesolithic Site Distribution in Western and Central Norway

Håvard Kilhavn

Abstract The Mesolithic Storegga tsunami was the largest tsunami in the Northern Atlantic region recorded to date. In this chapter, the impact of the tsunami upon the chronological and spatial distribution of 1041 Mesolithic sites from Western and Central Norway is analysed. The main finding of the analysis is that the taphonomic consequences of the marine Tapes transgression have had such a profound impact upon the Mesolithic archaeological record of this region that it is difficult to draw conclusions about what impact the tsunami had upon Mesolithic site distribution. However, the lack of sites postdating the tsunami in an area especially badly hit by its waves may indicate that people avoided resettling in this area for some time after the event. This is the first time such a human response to the Storegga tsunami event has been potentially identified.

Keywords Prehistoric disasters · Natural hazards · Palaeotsunamis · Mesolithic Norway · Hunter-gatherers · Taphonomy

12.1 Introduction

One day in the late autumn or early winter between 8120 and 8175 (68.2% level) or 8070 and 8180 (95.4% level) cal BP, a submarine landslide at Storegga on the continental shelf off the north-west coast of Norway caused the largest tsunami in the Northern Atlantic region recorded during the Holocene, with run-up heights exceeding 20 m in some areas (Bondevik 2003:8–9; Bondevik et al. 2012; Bondevik et al. 1997a; Bondevik et al. 1998; Dawson et al. 1988; Dawson and Smith 2000; Løvholt et al. 2017; Svendsen 1985). The tsunami was undoubtedly a major geological event. What is less clear is what consequences it might have had for the Stone Age

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_12

population of coast-dwelling hunter-gatherers in the tsunami-affected areas (Nyland et al. 2021b).

The tsunami occurred in the Mesolithic period of the Northern European Stone Age at a time when people made a living from hunting, fishing, and gathering, and the shorelines were the most densely settled areas of Western Scandinavia and the British Isles (e.g. Bjerck 2008; Conneller 2022). Numerical modelling of the tsunami propagation and run-up has shown that among the coastal areas settled by people at the time, the north-west coast of Western and Central Norway was especially badly hit (Bondevik 1996; Bondevik et al. 2006, 2005, 2012, 1997a, 1997b; Bryn et al. 2005, 2003; Dawson et al. 2011, 2020; Dawson and Smith 2000; De Blasio et al. 2003; Gaffney et al. 2020; Gjevik et al. 1994; Glimsdal et al. 2013; Haflidason et al. 2005, 2004; Harbitz 1992; Hill et al. 2014; Løvholt et al. 2017, 2016). A new numerical modelling of the Storegga tsunami commissioned by the Life After the Storegga Tsunami (LAST) project[1] and developed by the Norwegian Geophysical Institute also highlights the huge regional differences in the magnitude of the tsunami along the Norwegian coast (Walker et al. 2024).

It is a simple hypothesis that the most disastrous consequences of a tsunami would be expected to occur in the areas with the greatest tsunami run-up heights. This hypothesis is consistent with research on modern tsunami events, where a general correlation between tsunami *magnitude* (the physical forces) and *intensity* (the potential for damage) is described (e.g. Boschetti and Ioualalen 2021, 827). Put bluntly: during a tsunami, a greater proportion of a population is generally more likely to be affected in areas hit by very big waves than in areas hit by smaller waves. However, the qualifying word "generally" is important to note here. As pointed out by Gerassimos Papadopoulos and Fumihiko Imamura (2001, 575), there is not always a positive correlation between tsunami magnitude and intensity:

"*For example, even the highest tsunami wave that attacks an uninhabited coastal region produces the lowest intensity. On the contrary, the tsunami intensity may reach a high degree in a vulnerable coastal region even with a moderate tsunami*."

If there was a positive correlation between tsunami magnitude and intensity, Western and Central Norway is the area where Mesolithic people most likely suffered the most severe consequences from the impact of the tsunami. Consequently, this could potentially be an area where it is reasonable to expect the impact of the tsunami to be visible in the archaeological record, in some way or another.

If, on the other hand, there is little evidence of disastrous consequences of the tsunami in this area, that also begs an explanation: is archaeological evidence of a disaster in this area lacking because, somewhat counterintuitively, the tsunami had no disastrous consequences? Or could it be that the state of preservation of the archaeological record and/or the methods used to analyse it make it difficult to "see" a disaster in the record? Indeed, what should we expect a tsunami disaster to look like in a rather fragmented and poorly preserved 8000-year-old archaeological record left behind by prehistoric hunter-gatherers?

[1] Norwegian Research Council project no. 302858.

In this chapter, I have chosen to approach these questions by using one of the most important and numerous categories of the Norwegian Mesolithic archaeological record: the coastal settlement sites. I have examined the chronological and spatial distribution of 1041 Mesolithic sites in Western and Central Norway, with the aim of identifying trends in relative site frequency and spatial site distribution before and after the tsunami event that might be a source of knowledge about the impact of the Storegga tsunami upon settlement site distribution, as well as about a changed perception of risk in a phase of adaptation and societal restructuring after the tsunami (Fig. 12.1). Is it possible to identify a drop in the relative frequency of sites after the tsunami event, and if so, might this indicate that the tsunami had demographic consequences? Also, do the archaeological data indicate that Mesolithic coastal dwellers altered their settlement location pattern after the tsunami event as a possible element of adaptation and societal restructuring? Most of the sites lack radiocarbon dates and have been dated using the method of shoreline dating (Simpson 2009). The results are used to discuss the potential impact of the tsunami upon Mesolithic settlements along these coastal shorelines.

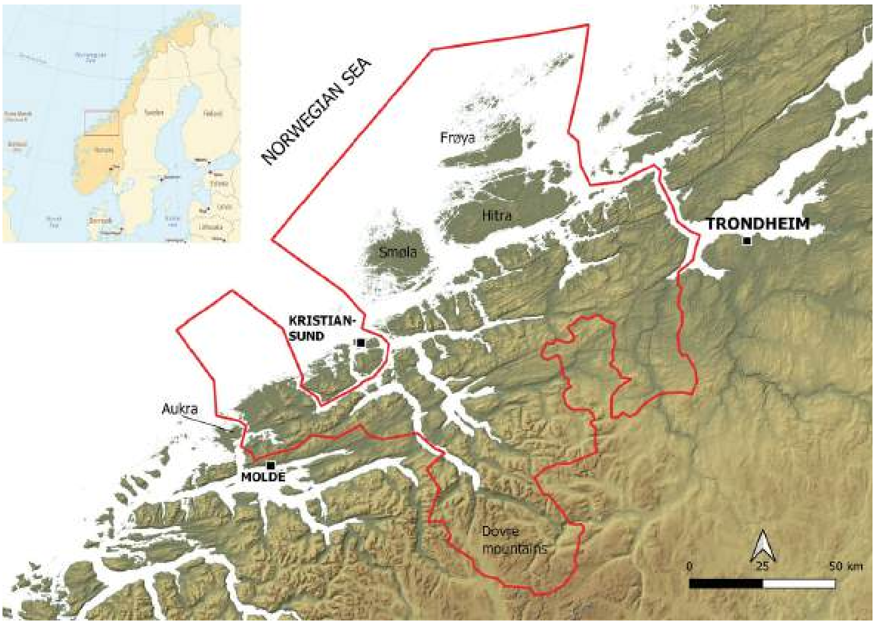

Fig. 12.1 The study area extends about 150 km along the coast south of the Trondheims fjord. The sites in Kristiansund, the only urban municipality in the region, have been omitted from the study area because there was not time to fully include the many sites here in the final analysis. However, a preliminary audit of the sites do not indicate that the overall trends in chronological and spatial site distribution here differs significantly from the rest of the study area

12.1.1 Concepts and Research History

In relation to a natural phenomenon like the Storegga tsunami, a highly complex interplay of environmental and social variables influences whether, and if so how, this phenomenon constitutes a natural hazard to people, how people may be vulnerable to this hazard, and how they perceive the risk of the hazard (e.g. Oliver-Smith 2002; Riede 2014). Both environmental factors and societal preconditions determine the impact of a particular natural hazard, the scale and scope of the impact, and whether the consequences of an event turn out to be disastrous. For example, the predominantly shore-bound settlement pattern of the Mesolithic population of Western and Central Norway must have been one of the socially produced risk factors that contributed to making these people especially vulnerable to a marine natural hazard like a tsunami. In the aftermath of a disaster, there may be a phase of recovery, including processes of mitigation, adaptation, and societal restructuring (e.g. Bavel et al. 2020, 2, Fig. 1.1; Singleton 2015).

The central concepts of "hazards", "vulnerability", "risk", and "disaster" have been developed in the context of research on contemporary natural hazards and disasters, e.g. for the UN (United Nations Office for Disaster Risk Reduction, 2015). However, while providing a theoretical framework for understanding the relationship between nature and culture in the context of extreme natural events like a tsunami, applying this framework in the interpretation of a specific archaeological record may be challenging. For example, Wisner et al. (2004:50) provide this definition of the concept of "disaster":

"*A disaster occurs when a significant number of vulnerable people experience a hazard and suffer severe damage and/or disruption of their livelihood system in such a way that recovery is unlikely without external aid. By 'recovery' we mean the psychological and physical recovery of the victims, and the replacement of physical resources and the social relations required to use them.*"

This definition provides a direction for exploring the potential consequences of the Storegga tsunami upon Mesolithic people. It would be interesting to assess whether a significant number of people suffered severe damage because of the tsunami, and whether they experienced disruption of their livelihood system. But how? For a palaeotsunami like the Storegga tsunami that happened more than 8000 years ago, most of the variables involved in describing the impact of the tsunami upon people are unknown or poorly understood. Even identifying quite basic facts about this potentially disastrous event and its consequences is no easy task. Thus, the main part of this chapter will be devoted to methodology. How can we assess archaeologically whether a significant number of people in Western and Central Norway suffered severe damage because of the tsunami, and whether they experienced disruption of their livelihood system?

The knowledge hitherto gained about the impact of the tsunami upon people as evidenced by the archaeological record is limited. In a recent review of the evidence of the impact of the tsunami, Nyland et al. (2021b) pointed out that:

"… *perceptions of the human impact of the Storegga tsunami have, to date, typically followed one of two lines of enquiry: either (1) inferring impact, sometimes implicitly, from the now sizeable database of geological deposits pertaining to the event from around the Scottish and Norwegian coasts relating to the event; or (2) identifying trends in palaeodemographic models of C14 dates that might relate to these changes.*"

Sedimentary deposits from the tsunami have only been identified at less than a handful of Mesolithic sites, and sometimes in the vicinity of such sites (Nyland et al. 2021b, 3–4; Figs. 12.2 and 12.3). However, determining synchroneity between the tsunami deposits and a settlement occupation phase is near impossible, because of the chronological uncertainty inherent in the methods of absolute dating of both sediments and sites. Instead, a positive correlation between tsunami magnitude and intensity is often implicitly taken for granted, and the disastrous impact of the tsunami, not only upon a particular site, but upon a region or a population in general, is inferred from geologically recorded tsunami run-up heights (e.g. Bjerck 2008, 68; Sharrocks and Hill 2024; Weninger et al. 2008).

Along another line of enquiry, Karen Wicks and Steve Mithen (2014), Clive Waddington and Karen Wicks (2017) and Mithen and Wicks (2021) have argued

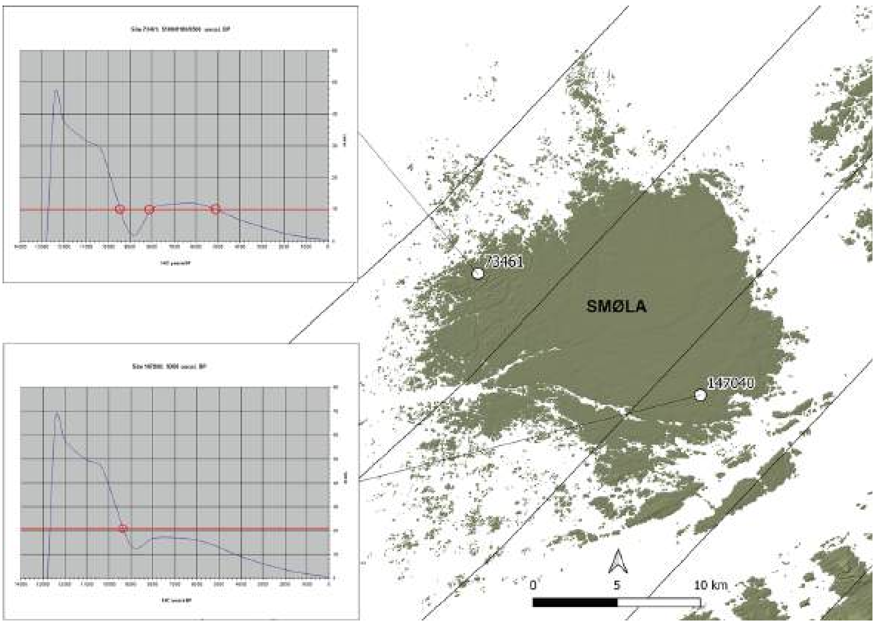

Fig. 12.2 Example of shoreline displacement diagram for two sites (ID 73461 and 147040) on the island Smøla. The transverse lines show the direction of the Tapes isobases (Creel et al. 2022). Isostatic uplift increases from the north-west to the south-east. The differences in isostatic uplift and its consequences for shoreline dating is illustrated in the shoreline displacement diagrams for the two Mesolithic sites. Site ID 73461 has three possible shoreline dates for the 10 masl. elevation, whereas site ID 147040 only has one possible date for the 21 masl. 3levation

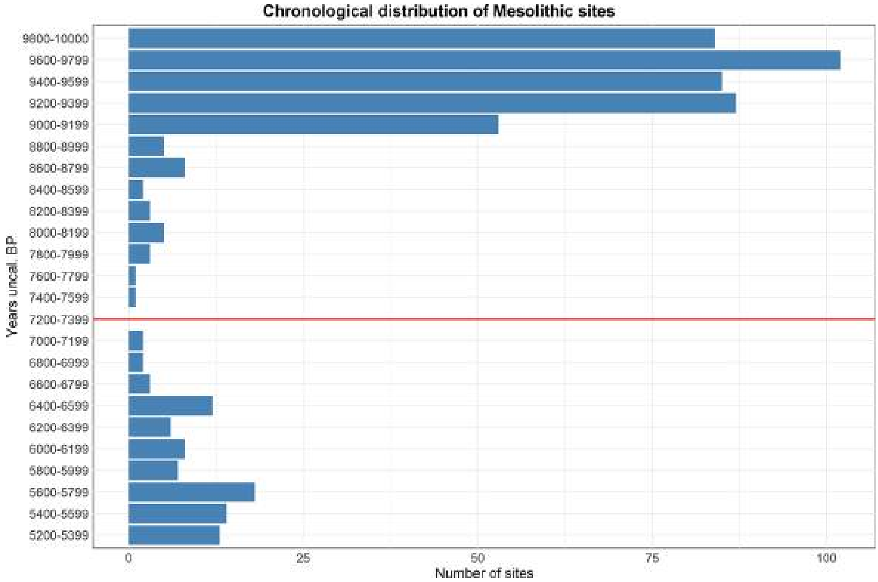

Fig. 12.3 Chronological distribution of sites in bins of 200 uncalibrated years BP. The red line marks the date of the Storegga tsunami

that the declining number of radiocarbon dates that they observe after 8200 cal BP in Northern Britain is causally linked to the tsunami, and that the tsunami caused a demographic collapse, a "wipeout", in parts of the British Isles. Preliminary results from applying the same method applied to a data set of Norwegian Mesolithic radiocarbon dates do not indicate such a clear drop in the number of radiocarbon dates (Kilhavn 2025, forthcoming).

While making palaeodemographic models of radiocarbon dates is one possible method of assessing whether a significant number of people suffered severe damage because of the tsunami, it is also a somewhat problematic method. The main sources of error in the method (intervening-, creation-, preservation-, and investigation biases) have already been pointed out in a seminal paper by John Rick (1987). As demonstrated by Martin Hinz (2020), the main problem of the method is not statistical conditions regarding issues like sample size and sensitivity, but rather:

"*… the often biased distribution caused by the production of the data in studies that almost never serve to produce a representative cross-section of dating in relation to the amount of material remains, but are usually carried out with specific different scientific objectives, as well as in the fact that often quite different deposition processes are treated equally*" (Hinz 2020, 250).

In addition to the general problems inherent in the method, there is also a specific representativity bias regarding the Mesolithic archaeological record in Western and Central Norway that makes it difficult to use radiocarbon dates as a demographic proxy for this time and area. This bias is caused by the early mid-Holocene marine

Tapes transgression. The transgression was caused by a global mean sea level rise that temporarily outpaced the falling relative sea level along the Norwegian coast caused by isostatic rebound (Creel et al. 2022). The transgression has had profound consequences for the preservation of parts of the Mesolithic archaeological record in this region (Bjerck 2008). In a palaeodemographic study of the Western Norwegian Stone Age, Bergsvik et al. (2021) concluded that the preservation bias caused by the Tapes transgression is too great for radiocarbon dates to be used as a reliable demographic proxy around the time of the Storegga tsunami. As will be discussed later in the chapter, this is also my conclusion.

12.2 Geographical and Cultural Background

12.2.1 Study Area and Tsunami Magnitude

The archaeological data chosen for this study consist of all recorded Mesolithic sites from 11 municipalities in Western and Central Norway: Aure, Gjemnes, Hustadvika, Smøla, Sunndal, Surnadal, Tingvoll (in Møre og Romsdal county), Frøya, Heim, Hitra, and Orkland (in Trøndelag county). The area roughly corresponds to the historical region of *Nordmøre*, as well as the outer part of the coast of *Trøndelag* south of the mouth of the Trondheim fjord. Geological observations from Bjugn on the northern side of the Trondheim fjord indicate a tsunami run-up of 6–8 m in that area, whereas observations from Sunnmøre immediately to the south of the area indicate a run-up of 10–11 m (Bondevik et al. 1997a). This is fairly consistent with the run-up values in open waters predicted by the aforementioned numerical modelling of the tsunami, but the authors point out that the geologically observed tsunami sediments most likely only give minimum run-up elevation values, and there would have been huge local differences in the run-up (Walker et al. 2024). The numerical model predicts a considerably larger tsunami run-up in some areas. The numerical model also shows that the tsunami would have submerged large portions of the low-lying strandflat between the mountains and the fjords on the mainland, as well as the more low-lying terrain on the large islands of Smøla, Hitra, and Frøya.

12.2.2 Geography, Mesolithic Chronology, and Archaeological Record

The study area features the whole range of landscapes typical for Western and Central Norway, from alpine regions with mountains, inland valleys, and deep fjords in the east and south, to the Atlantic coast with inlets, bays, and large and small islands in the west and north (Puschmann 2005). The climate in the Mesolithic varied from colder conditions in the Early Mesolithic to warmer conditions in the Late Mesolithic, but it has always been oceanic, with relatively mild winters, cool summers, and much precipitation. The Atlantic coast in this region is particularly rich in marine resources such as fish and marine mammals, and the northern part of the region in particular also has a large population of red deer (*Cervus elaphus*). While the range of marine species observable today is probably very similar to the range of species available in the Mesolithic, it is more uncertain whether red deer were as numerous then as now at the coast, because the coastal landscape was more forested (Bjerck et al. 2008, 72–74).

Hein Bjerck (2008) proposed a chronology for Mesolithic Norway, dividing the period into the Early (EM), Middle (MM), and Late Mesolithic (LM) periods, which are further subdivided into chronozones with a duration of 500 calendar years. The objective of this framework is to enable easier identification of cultural variability or similarities cutting across time and space, instead of using periods defined by typological developments (Bjerck et al. 1987, 41). In this chronological framework, the Storegga tsunami happened in the middle of the LM1 (7690–7110 uncal BP) (Table 12.1).

Human settlement in the area is attested throughout the Mesolithic. However, most known Mesolithic sites are unpublished surveyed sites and/or stray finds, and relatively few sites have been excavated. Larger surveys and excavations have been carried out in connection with the construction of the petroleum industry on Tjeldbergodden in Aure and on the southern part of Hitra (Berglund 2001; Søborg 1990). There have also been large-scale surveys in connection with the construction of wind farms on the islands of Frøya, Hitra, and Smøla. The most recent synthesis and chronology of the Mesolithic cultural development of the region is based upon the excavations of a total of 23 Mesolithic sites in Nyhamna, Aukra (Bjerck et al. 2008).

Throughout the Mesolithic, the overwhelming majority of known sites were related to the shifting shoreline (Bjerck et al. 2008, 550). People seem to have spent most of their time on the coast, hunting, fishing, and harvesting different marine resources. The close association between Mesolithic settlements and the gradually shifting shorelines is a general feature of the Norwegian Mesolithic, and a fundamental premise for using the relative dating of shorelines as a method for dating Mesolithic sites (Roalkvam 2023). It is also fundamental for understanding why the Storegga tsunami was a particularly potent hazard in this region, and how settlement location was a major factor in creating vulnerability and exposure to the tsunami.

While the main trends in Mesolithic settlement location are well known, less is known about how extended Mesolithic settlement systems in the region worked. Different models of logistical and residential mobility have been proposed (e.g. Bergsvik 2001; Boethius et al. 2020). The sparsity of organic remains makes it difficult to reconstruct the seasonal cycle of the settlement system based upon knowledge about subsistence. However, the few faunal assemblages that have been analysed show, unsurprisingly, a predominance of fish. Unspecified birds and mammals are also present in lower quantities. Shells and shellfish are generally lacking in the archaeological record, and it is unclear whether this is caused by poor preservation conditions or whether these resources held little importance for subsistence (Bjerck

2007; Åstveit 2008b, 584). What is clear, though, is that when engaging in subsistence activities, people seem to have spent most of their time at sea and at the coast, thus becoming particularly vulnerable to marine hazards.

In (lithic) technology, subsistence patterns, and settlement patterns, there is a large degree of continuity between the last part of the Middle Mesolithic and first part of the Late Mesolithic (Bergsvik et al. 2002, 288, fig. 274; Bjerck et al. 2008, 611–612; Olsen and Hjelle 1992). However, the taphonomic loss of Middle Mesolithic sites caused by the marine Tapes transgression in parts of the area has led to less data being available for that period, and is a serious obstacle for comparative analysis of Middle Mesolithic and Late Mesolithic sites and lithic assemblages (Åstveit 2008a, 571). The main chronologically significant formal lithic tools of the Early Mesolithic are flake adzes, tanged points, lanceolate microliths, and burins (Bjerck 2008, 74–78). Middle Mesolithic chronologically significant tools are adzes of basaltic rock, and polished and pecked chubby adzes. The Middle Mesolithic lithic flint industry is dominated by regular blades and microblades produced from multifacial, conical cores (Bjerck 2008, 78–79). Many of the Middle Mesolithic typological and technological traditions persisted throughout most of the Late Mesolithic. However, microliths are not known from this period, and transverse points were introduced towards the end of the Late Mesolithic. The lithic industry is dominated by the production of flint microblades from platform cores and bipolar cores. The transition to the Neolithic in Western Norway is marked by the discontinuation of the microblade industry and the introduction of cylindrical cores and tanged points (Bjerck 2008, 81–83).

12.3 Methods

12.3.1 Relative Site Frequency as a Proxy of Tsunami Impact

There are many potential reasons for the number of recorded Mesolithic settlement sites to vary over time, and any monocausal explanation of such variation is likely to be too simplistic. Several important forms of possible biases affect the chronological precision and representativity of the data (e.g. Berrey et al. 2015, 17). However, the relative frequency and chronological distribution of settlement sites across the subperiods of the Mesolithic is one of the aspects of the Mesolithic archaeological record that can be explored in some detail, and which potentially may be used as a proxy to assess whether a significant number of people suffered severe damage because of the tsunami, and whether they experienced disruption of their livelihood system.

The premise for using a chronological analysis of sites in this way is not that a marked reduction in the number of sites in the wake of the tsunami necessarily means that the tsunami killed a lot of people and caused a demographic crisis. However, if the tsunami really *did* cause a demographic crisis, it is hard to imagine that the relative frequency of sites would not be affected in some way. A drop in the relative frequency of sites could also be an indication of changes in the settlement pattern, the cause of which might be related to cultural changes in a post-tsunami phase of adaptation and societal restructuring. Finally, a change in the relative frequency of sites might be caused by the destructive impact of the tsunami upon the archaeological record. Thus, establishing facts about trends in relative frequency and chronological distribution of settlement sites before and after the tsunami has been one of the objectives of this study, as a point of departure for further discussion about potential causal relationships between the impact of the tsunami and the observed trends.

12.3.1.1 Sources of Bias and Error

When interpreting the results of the relative site frequency analysis, it is necessary to be aware of the main sources of bias and error that may influence the findings. The most important preservation bias and loss of sites because of the Tapes transgression has already been mentioned. It should also be noted that the same representativity biases apply to a data set with sites as to a radiocarbon data set used as a palaeodemographic proxy. In a comparative analysis of the summed radiocarbon probability distribution and site count data of shoreline-dated sites in the Oslo fjord area of Eastern Norway, Steinar Solheim and Per Persson (2018, 342) concluded that these two proxies showed similar chronological trends. Thus, counting sites is methodologically neither better nor worse than counting dates.

Perhaps the greatest advantage of using sites rather than radiocarbon dates as a demographic proxy is the potential large number of sites available for statistical analysis. There are a lot more Mesolithic sites than there are Mesolithic radiocarbon dates from the study area. The greatest disadvantage is that many of these sites are quite imprecisely dated. Mostly lacking organic remains and radiocarbon dates, the practically possible remaining dating methods are restricted to shoreline dating and typological dating–both rather blunt chronological tools for studying sudden change in the number and distribution of sites.

Typological dating is generally of little use, as most lithic object types were used for such long periods of time that they cannot be utilized to distinguish between sites predating and postdating the tsunami event other than with a chronological margin of several centuries, or even millennia, either way. As previously mentioned, there are some lithic objects that may be used to distinguish between the main Mesolithic periods, and typology has been used as a dating tool in the auditing of the site database, especially for excluding non-Mesolithic sites. However, the large degree of typological and technological continuity between the last part of the Middle Mesolithic and first part of the Late Mesolithic means that typology is of little use in distinguishing between these two periods. The production of microblades from conical flint cores that was introduced in MM1 is still present in LM1, when the tsunami happened (Damlien 2016). In the study area, this blade industry was only discontinued much later, after LM2, then giving way to the production of blades from bipolar flint cores (Åstveit 2008b, 580).

With regard to the chronological precision of shoreline dating, a recent comparative analysis of shoreline dates and radiocarbon dates from 67 Stone Age sites in Eastern Norway observed a very close chronological correlation between the two dating methods (Roalkvam 2023). Also, at Aukra, immediately to the south of the study area, Mesolithic radiocarbon samples have been shown to correspond very closely to the shoreline date for the sampling spot (Bjerck et al. 2008, 550, Fig. 5.3). These results are optimistic in terms of the chronological precision of the shoreline dating method. However, the Tapes transgression in Western and Central Norway makes shoreline dating more complicated here than in Eastern Norway. In Western Norway, a stretch of shoreline that became dry land in the Early Mesolithic could be submerged in the Middle Mesolithic, and then become dry land once more in the Late Mesolithic. Thus, a particular elevation above present-day sea level might have been shore-bound at several different points in time, all of which are possible shoreline dates for that elevation (Fig. 12.2).

In addition to the possibility of one site having more than one possible shoreline date, the time-averaged nature of the archaeological record must also be considered when counting sites for statistical analysis. One single site might represent a single phase of occupation or several such phases. It is generally very difficult to determine the minimum number of activity events at a site, and the period of time between these events (cfr. Åstveit and Tøssebro 2023).

12.3.1.2 Distinguishing Between Consequences of the Impact of the Tsunami upon People and upon the Conditions of Preservation

Even though the potential sources of error and biases regarding the relative frequency and chronological distribution of sites are considerable, it is a premise for this analysis that the large number of sites in the analysis is sufficient to reflect coarse, real past tendencies over time. Another premise is that if the impact of the tsunami had been severe, it would most likely have caused a reduction in the number of sites, even though it might be difficult to distinguish between such a reduction caused by a demographic crisis and a reduction caused by the taphonomic effect of the tsunami itself, washing away the archaeological record of older Mesolithic sites.

A simple hypothesis is suggested here about how it might be possible to distinguish between consequences of the impact of the tsunami upon people and its impact upon the conditions of preservation in the archaeological record: if the tsunami caused a demographic crisis and/or changes in the settlement system, which in turn caused a drop in the relative frequency of sites, the drop in the number of sites should only *postdate* the tsunami. If, on the other hand, a drop in the relative frequency of sites was caused by the eroding force of the tsunami, the period that *predates* the tsunami should be the one with fewer sites.

There is, of course, the possibility that the tsunami caused both outcomes. However, the potential causal mechanism between the impact of the tsunami and the observed site distribution remains the same: a drop in the number of sites older than (or contemporaneous with) the tsunami may be interpreted as an effect of the tsunami destroying sites, but the tsunami could not possibly destroy sites that are *younger* than the tsunami event. Therefore, a post-tsunami drop in site frequency is more likely to be caused either by a reduced number of people or a changed settlement system, or a combination of both.

12.3.2 Spatial Distribution of Sites as a Proxy of Landscape Use and Potential Societal Restructuring

Although there may be many causes of changes in geographical site distribution patterns, it is of interest to explore whether such changes can be identified in the wake of the Storegga tsunami. If there is a clear change in site distribution, the tsunami should at least be discussed as a potential cause (Nyland et al. 2021b, 11). A change in site distribution could indicate a change in the perception of risk in a phase of adaptation and social restructuring following a disastrous tsunami, as has been observed in other contexts (e.g. Fitzhugh 2012; Goff 2017; McFadgen 2007). To analyse the changes in site distribution over time, the Mesolithic sites in the study area were plotted in QGIS.

12.3.3 Data Analysis

A search in the national cultural heritage management database *Askeladden* for all sites in the study area that have been categorized as "Stone Age" and/or "Mesolithic" returned 1041 sites. Sites lacking geographical coordinates, numbering 108 in total, were excluded from further analysis. Fourteen rock art sites and one quartz quarry were also excluded in order to only keep possible settlement sites for the analysis. Duplicate sites that have been entered into the database, numbering 16 in total, were also excluded.

All the remaining 902 sites were then shoreline dated according to a method developed by David Simpson (2009). For each site, the relation to the younger Dryas isobase was recorded, and this information was then used to generate a shoreline displacement diagram for the site, in which the uncalibrated dating estimate was read.[2] This method of shoreline dating can only give rough dating estimates. Potential sources of error are the unknown full extent of sites, as well as the empirical and statistical uncertainty inherent in the shoreline displacement diagrams themselves. It is therefore important to note that the site dates given are tentative. Dates have been rounded off to the nearest 100 uncalibrated years. For sites with a possible *terminus ante quem* date given as an age range within a period rather than as a single year, the median year in the age range was recorded.

[2] For this reason uncalibrated dates have been used in the analysis.

Some sites have two or more possible shoreline dates. Where possible, typological dating of objects (typology described in Sect. 12.2.2) was used to determine on which of these dates the site was used. This does of course not exclude the possibility of a site also having several phases of use. Sites that are most likely Mesolithic, but which it is impossible to assign to one Mesolithic period or the other, or which most likely are mixed sites with two or more phases of use of different dates, a total of 139 sites, were excluded from the site count. However, these sites have been included in the spatial site distribution analysis as "Mixed/Uncertain" sites, to evaluate whether the omission of this large group of sites has significant consequences for overall spatial site distribution representativity. Also excluded were all the sites that turned out to most likely *not* be Mesolithic, a total of 229 sites. These sites were excluded because the recorded objects from the sites were not Mesolithic, and/or because the shoreline dating of the sites did not indicate a Mesolithic date.

The remaining 534 sites were then sorted chronologically. The chronological binning of sites is a compromise between obtaining a large enough sample within a period for a trend to be visible and the period within which it is reasonable to expect the consequences of the tsunami to be visible. There can be no single answer as to how long such a period should be. Bins of 200 years were chosen for the relative site frequency analysis, and the chronozones of 500 years were chosen for the spatial site distribution analysis.

12.4 Results

12.4.1 Relative Site Frequency and Chronological Distribution

The chronological distribution of the 534 shoreline-dated sites is presented in Fig. 12.3. There is a clear predominance of Early Mesolithic sites predating 9000 uncal BP, a total of 422 sites, which is 79% of all the sites that could be shoreline dated and assigned to a Mesolithic period. Only 25 sites (4.7%) were dated roughly to the Middle Mesolithic between 9000 and 7600 uncal. BP. Eighty-seven sites (16.3%) were dated roughly to the Late Mesolithic between 7600 and 5200 uncal BP. Noticeably, there is not a single shoreline-dated site between 7200 and 7400 uncal BP, with the Storegga tsunami event happening ca. 7300 uncal BP. In fact, there are no shoreline-dated sites at all between 7500 and 7000 uncal BP. Between 9000 and 7500 uncal BP there is no clear trendline, with a varying (small) number of sites until 7800 uncal BP, and then only two sites between 7800 and 7500 uncal BP. After 7000 uncal BP, the number of sites remains very low until 6600 uncal BP, increasing again towards the end of the Late Mesolithic, and especially from 5800 uncal BP onwards.

12.4.2 Spatial Site Distribution

The spatial site distribution for each Mesolithic chronozone is presented in Fig. 12.4. Early Mesolithic sites are found all along the coast, with a concentration on the outer coast and the islands. From EM1 to EM3 there seems to have been a great deal of continuity in the use of the landscape, although there are fewer EM3 sites in the southern part of the region than earlier in the Early Mesolithic. Even though the number of MM1 sites is much smaller, there is also continuity in site location between EM3 and MM1. Sites are present in the fjords, on the outer coast, and on the islands. In MM2 and MM3, the number of sites is very small, but there is still continuity in site location. Noticeably, the only two MM3 sites are to be found quite far to the north and east, at the mouth of the Trondheim fjord and in the Hemne fjord. The same is true for the only two LM1 sites, one at the mouth of the Trondheim fjord and the other on an island between the Ålvund fjord and the Stangvik fjord in the southern part of the region. In LM2, the site distribution is once again very similar to the situation in the Middle Mesolithic. In LM3 to LM5, the number of sites increases steadily, and there are also more sites in the south-western part of the region. Sites cluster on the islands and the outer coast, with a few sites also being present in the inner fjord regions.

Including the 139 chronologically mixed/uncertain sites does not substantially alter the main site distribution as described here. There is still a concentration of

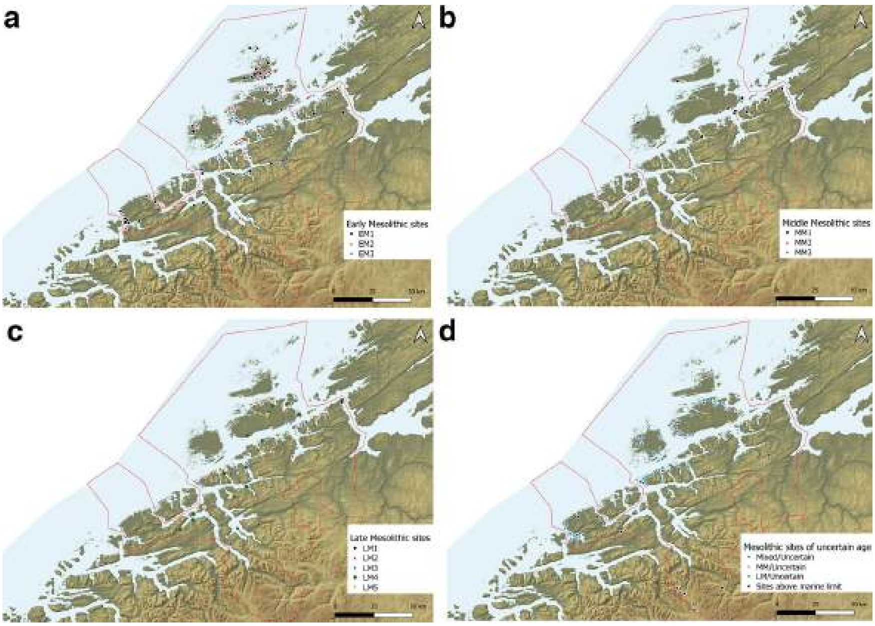

Fig. 12.4 **a** Early Mesolithic sites. **b** Middle Mesolithic sites. **c** Late Mesolithic sites. **d** Mesolithic sites of uncertain age and sites above the marine limit

sites on the outer coast and on the islands, and few sites in the inner fjord regions. However, if a lot of the mixed/uncertain sites in the south-western part of the region turn out to be Middle Mesolithic or Late Mesolithic sites, the apparent lack of such sites in this part of the study area is a false one.

Also, including the 24 Stone Age sites above the marine limit shows that there are sites present in the inner fjord area between the Sunndals fjord and the Dovre mountains. However, none of these sites have been dated either typologically or with radiocarbon, and it is not possible to determine their age before they have been archaeologically excavated.

12.5 Discussion

12.5.1 What Do the Changes in Relative Site Frequency and Spatial Distribution Represent?

There are marked differences in relative site frequency throughout the Mesolithic period in the study area. The sharpest observed drop in site frequency does not occur in the centuries immediately postdating the Storegga tsunami, but in the last part of the Early Mesolithic. However, the site lacuna between 7500 and 7000 uncal BP could possibly be causally linked to the tsunami event. Four explanations of the observed chronological and spatial trends are to be discussed here: demographic changes, preservation bias caused by the Tapes transgression, preservation bias caused by the Storegga tsunami, and cultural changes in settlement patterns in the wake of the tsunami.

12.5.1.1 Demographic Changes

The first question to be discussed is whether the observed trends may represent demographic changes. Do more/fewer sites mean more/fewer people? This necessitates making assumptions about both Mesolithic demographic patterns and mechanisms, and the relationship between population numbers and the number of sites. It is also necessary to evaluate the representativity of the data. Recently, Svein Nielsen (Nielsen et al. 2019, 2021, 2022) discussed demographic and economic variability in Southern Norway in the Late Mesolithic and the Neolithic periods based on a palaeodemographic model of a large number of radiocarbon dates. He claims that "the human population in Southern Norway grew steadily through the Mesolithic and until the onset of the Bronze Age with a long-term annual growth rate similar to prehistoric foragers in other parts of the globe" (Nielsen 2022, 4). If so, population numbers would be lowest in EM1, and then grow steadily throughout the rest of the Mesolithic, unless some interruption of the normal demographic growth rate occurred.

If relative site frequencies are to be used as a demographic proxy, the same logic must apply as when using radiocarbon dates as such a proxy: that more sites/dates means more human activity and more people (Shennan et al. 2013, 3). In this case, however, the empirical evidence is at odds with the hypothesis about a steady demographic growth throughout the Mesolithic, if the premise that more sites mean more people is correct. With more than 78% of the sites being Early Mesolithic and only 16% of the sites being Late Mesolithic, this would instead suggest that the Early Mesolithic population was larger than that of the Late Mesolithic. Also, the sudden drop in the number of sites between EM3 and MM1 would suggest some sort of demographic crisis occurring around that time.

The Early Mesolithic population, which was the pioneer population that first settled the Norwegian coast, was most likely a small one. Sites are usually small. They have been interpreted as being part of a settlement system of small, mobile social groups, organized in family-based residential units. In the Middle and Late Mesolithic, larger sites, larger dwelling structures, increased regional diversity in material culture, and increased social complexity may all be interpreted as indications of a growing population (Bjerck 2008, 103–104). A gradual demographic growth would be consistent with the demographic regime observed among living groups of hunter-gatherers (e.g. Pennington 2001). Estimates of Mesolithic demographic developments in Eastern Norway modelled from statistical probability distributions of radiocarbon dates indicate that there was a long-term, gradual demographic growth with fluctuations along the way after the initial pioneer settlement (Solheim 2020; Solheim and Persson 2018). The same pattern has been observed in Northern Fennoscandia (Jørgensen 2020; Tallavaara and Pesonen 2020), and also further south along the coast of Western Norway, although the statistically reliable data here only cover the Late Mesolithic (Bergsvik et al. 2021; Lundström 2023). Thus, that the Late Mesolithic population never reached the same population numbers as in the Early Mesolithic is no plausible demographic scenario. Other explanations for the huge discrepancy between Early Mesolithic site numbers and the number of Middle Mesolithic and Late Mesolithic sites must then be sought.

Perhaps the most obvious explanation is that the drop in the number of sites between EM3 and MM1 does *not* reflect a change in population numbers, but that other mechanisms are responsible for the creation of this pattern. It is well known that there was a declining number of sites towards the end of the Early Mesolithic and the transition to the Middle Mesolithic along the Norwegian coast, and that this, at least partly, was caused by a taphonomic loss of sites because of the marine Tapes transgression (Breivik 2014, 1485; Åstveit 2008a, 571).

However, it is unlikely that the Tapes transgression alone could be responsible for distorting the chronological distribution of sites to the extent shown in Fig. 12.3. At least, we would expect the number of Late Mesolithic sites postdating the Tapes transgression to outnumber the Early Mesolithic sites if the transgression was the only cause. In the study area, this seems not to be the situation. Cultural factors should therefore also be considered. Most likely, the Late Mesolithic population *was* larger than that of the Early Mesolithic, but the Late Mesolithic settlement pattern, for some reason, left behind fewer sites than that of the Early Mesolithic. This is also consistent with data from excavated sites at Aukra, where a tendency towards larger sites in the Late Mesolithic was observed, as well as thicker deposits on sites and dwellings, interpreted as indicating longer phases of use for each site (Åstveit 2008b, 576).This development may have begun as early as MM1, when the Atlantic current and oceanic conditions in the Mid-Preboreal stabilized, and glaciers retreated from the fjords. The outer coast became a zone of stable and high marine productivity, with good opportunities for subsistence fishing and other marine hunting and harvesting (Breivik 2014, 1485–1486).

It should also be noted that the drop in the number of sites from EM3 to MM1 happened at the same time as the introduction of pressure blade technology of eastern origin and the replacement of the Early Mesolithic technocomplex with a Middle Mesolithic one. Most likely, the new technology was introduced with population movement from the northern and eastern part of Fennoscandia southwards along the Norwegian coast (Manninen et al. 2021; Sørensen et al. 2013). This population movement should also be seen as a possible cause of the change in both site frequency and spatial distribution.

From this it should be clear that caution is needed when using the number of Mesolithic sites from the study area as a demographic proxy. When producing a palaeodemographic model based upon 703 radiocarbon dates of Mesolithic demographic developments further south in Western Norway, Bergsvik et al. (2021) also came to the conclusion that Early and Middle Mesolithic sites were severely affected by preservation bias, and argued that dates older than 6000 cal BC in that area are not a reliable demographic proxy. However, it could be argued that even though the number of Early Mesolithic sites seem not to be well suited for use as such a proxy, the number of Middle and Late Mesolithic sites *can* perhaps be used, as the ecological conditions, technocomplexes, and settlement patterns in these periods were more similar to each other than to those that prevailed in the very different Early Mesolithic period.

12.5.1.2 Preservation Bias Caused by the Tapes Transgression

A comparison between the chronological distribution of sites in the study area (Early Mesolithic sites excluded) and the chronological distribution of the radiocarbon dates from the excavations at Aukra, only 2 km to the south of the southernmost boundary of the study area, may serve as a point of departure for a discussion about the preservation bias caused by the Tapes transgression (Bjerck et al. 2008; 549, Fig. 5.2). At Aukra, no dates were obtained from MM2, and there were also very few dates from MM1. This lacuna is attributed to the taphonomic effect of the Tapes transgression (Bjerck et al. 2008, 459). From MM3 onwards, however, there is a steady increase in the number of radiocarbon dates until LM4 at Aukra. The trend for the sites in the study area is quite different. Here, the most marked change occurs earlier, between EM3 and MM1. There are some but not many sites from MM2 and MM3, and it is the time interval between 7500 and 7000 uncal BP, spanning most of LM1, that is lacking sites altogether. By contrast, there were 16 radiocarbon dates from LM1 at Aukra.

If there were no Tapes transgression, it would be tempting to interpret the lack of LM1 sites in the period 7500–7000 uncal BP as a consequence of the Storegga tsunami at 7300 uncal BP. The lack of sites predating the tsunami by a couple of centuries could conceivably be attributed to the tsunami as a taphonomic force, eroding and destroying older shore-bound sites. Waddington and Wicks (2017, 708) argue that the tsunami caused such a taphonomic loss of sites in North-East Britain, where a decrease in the number of sites can already be seen from 8600 cal BP. The lack of sites in the centuries after the tsunami could be interpreted in demographic terms as a landscape with a lot fewer people leaving remains behind, until population numbers again started growing. However, the Tapes transgression complicates the matter.

The amplitude of the Tapes transgression varied greatly along the Norwegian coast, with the amplitude gradually increasing with the distance from the area once covered by the Eurasian ice sheet complex, because of isostatic rebound (Creel et al. 2022, 21). In the study area, the amplitude of the transgression increases from the south-east towards the north-west (Fjeldskaar and Bondevik 2020, 8, Fig. 8). The transgression peaked at different times, and the peak was preceded in some places by a regression, which in places dipped below the present shore level. It is the shore-bound sites from this submerged period that might be lost, and, consequently, the preservation conditions and statistical representativity of sites decrease as the amplitude difference between the regression minimum and the transgression maximum increases (Bjerck 1986, Fig. 12.2). The chronological and spatial distribution of Mesolithic sites in the study area illustrates this quite clearly. All recorded MM3 and LM1 sites are located near the zero-transgression isobase, and the number of sites further away from this isobase increases with time, both before and after, the transgression maximum (Fig. 12.5).

The differences in the timing, duration, and amplitude of the Tapes transgression along the Norwegian coast have recently been summarized by Roger C. Creel et al. (2022). In the study area, the transgression peaked in LM1 around 6000 BC (7110 uncal BP), about two centuries after the Storegga tsunami (Creel et al. 2022, 13, Fig. 6). Along a linear gradient from the outer part of the Trondheim fjord south-east to the inner part of the Langfjord, there was no regression. Further north-west at Nordmøre, sites may have been submerged and destroyed by a regression between ca. 7000 and 6000 BC (7970–7110 uncal BP), i.e. MM3 and LM1 sites could have been affected. Even further from the area once covered by the Eurasian ice sheet complex, north-west of the island of Frøya, MM2, MM3, and LM1 sites may have been destroyed between ca. 7500 and 6000 BC (8400–7110 uncal BP). Near Aukra, in the north-eastern part of Sunnmøre, the same is true for the period between ca. 8500 and 5500 BC (9270–6560 uncal BP), with a regression minimum in MM2 around 7500 BC (8400 uncal BP). Here, the regression minimum dipped just below the present sea level.

The point of specifying the effect of the Tapes transgression in the study area in such detail is to point out that the chronological distribution of sites in Fig. 12.3

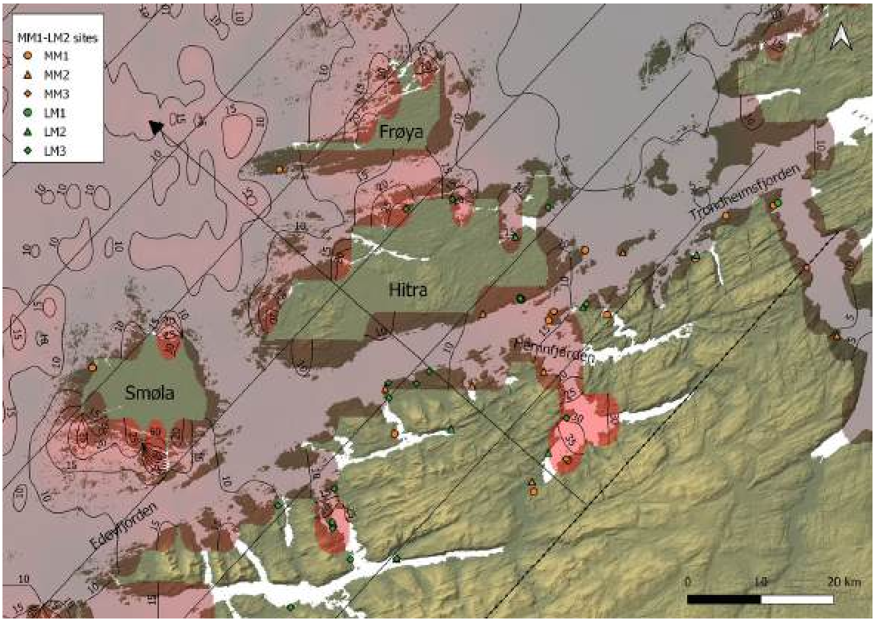

Fig. 12.5 Maximum tsunami run-up modelled by a numerical modelling of the Storegga tsunami in relation to middle and late Mesolithic sites and the tapes transgression isobases. The modelled run-up in meters is only a rough estimate and should not be read too literally. However, the model does indicate main differences of tsunami magnitude in different areas. The dotted line marks the limit of the area affected by the Tapes transgression. The arrow indicates the direction of increasing taphonomic loss of Mesolithic sites because of the transgression. Along the same isobase, the taphonomic effect of the transgression is roughly equal

correlates well with the expected taphonomic consequences of the transgression. The drop in site numbers from EM3 to MM1 coincides with the earliest onset of the transgression, and the site lacuna between 7500 and 7000 uncal BP coincides with the time just before the peak of the transgression in most of the area. Also, the increase in the number of sites around 6600 uncal BP coincides with the end of the transgression. These correlations are a strong indication of a causal link between the preservation bias caused by the Tapes transgression and the observed chronological and spatial distribution of sites.

12.5.1.3 Preservation Bias Caused by the Storegga Tsunami

There is one spatial pattern in the site distribution that cannot wholly be explained as a taphonomic consequence of the Tapes transgression, namely the lack of sites from MM1 to LM2 on the outer coast on the islands and mainland south of the Edøyfjord and the large island of Smøla. Throughout the Early Mesolithic, there were a lot of sites in this area, and there are also sites from LM4 and LM5. The Edøyfjord and the shallow waters south and south-west of Smøla were most likely rich fishing grounds throughout the Mesolithic, as they still are today. From a subsistence perspective, there is no reason for the lack of MM2–LM2 settlements. While the lack of MM3 and LM1 sites here may be explained by the Tapes transgression, the lack of sites from MM1–MM2, and LM2 cannot. In these periods, there are several sites along the same Tapes isobase further north, and there is no reason why the taphonomic loss of sites because of the transgression would be different along the same isobase.

As the number of both Middle and Late Mesolithic sites is small, it is possible that investigation bias is the cause of the lack of MM1–LM2 sites. They may be present, but not discovered. However, the area with a site lacuna in these periods correlates with an area with a larger-than-average tsunami run-up (Fig. 12.5). This could be an example of how the tsunami, as well as the Tapes transgression, might have been an eroding force, destroying older Mesolithic sites. The numerical model developed by the Norwegian Geotechnical Institute is the first to attempt to model the tsunami and its run-up across the complex topography of the coast of Western Norway in such detail that it is possible to discern between differences in tsunami run-up on a regional scale (Walker et al. 2024). The numerical model could possibly be used to correlate regions of different tsunami magnitude with different tsunami intensity, as evidenced by changes in the archaeological record. As argued above, the taphonomic effects of the Tapes transgression upon the archaeological record of this time and area generally makes such a correlation difficult. However, the MM2–LM2 site distribution lacuna south of Smøla does correlate with an area of great tsunami magnitude, whereas there is no reason why the site distribution here should be more severely affected by the Tapes transgression than comparable areas along the same isobase. This site distribution lacuna is therefore interpreted as a possible consequence of the tsunami–either by the tsunami as a taphonomic agent or as a proxy of cultural change in the wake of the tsunami, or as a combination of both.

12.5.2 Site Lacuna Possibly Caused by a Changed Perception of Risk

It is possible that the lack of LM1 and LM2 sites that postdate the tsunami in the area south of Smøla may be a culturally produced site distribution pattern, indicating that people for some time afterwards chose not to settle in an area especially badly hit by the tsunami. Cultural behaviour might also be the cause of the lack of LM1–LM2 sites in the Hemnfjord area. This was also an area with great tsunami magnitude. Here, only one LM2 site is recorded, even though several other LM2 sites are found more than 20 km to the north-west, in areas were the taphonomic effects of the Tapes transgression make it less likely that such sites are preserved.

A change in settlement pattern following a tsunami event has been observed in other parts of the world, notably in areas like New Zealand and the Kuril Islands in the Pacific Ocean (Fitzhugh 2012; Goff 2017; McFadgen 2007). When such a sudden change in a well-established settlement pattern occurs after a disastrous event like a tsunami, the change may be interpreted as an expression of a changed perception of risk among the Mesolithic inhabitants of the region, and as an indication of adaptation and societal restructuring in a phase of recovery. However, it is to be expected that such potential changes in site location preferences will be less visible in the archaeological record of the study area than a drop in the number of sites because of a demographic crisis. The predominantly marine subsistence pattern that continued throughout the rest of the Mesolithic would necessarily imply continued coastal settlement. Also, the steep terrain relief that characterizes much of the study area would be a geographical constraint, often limiting habitable surfaces to a small area between the sea and the mountains behind, causing clustering of sites in certain areas.

12.6 Conclusion

The aim of this paper has been to identify chronological and spatial trends in the Mesolithic settlement site record of Western and Central Norway that might be a source of knowledge about the impact of the Storegga tsunami upon settlement site distribution, as well as about a changed perception of risk in a phase of adaptation and societal restructuring after the tsunami (cf. Nyland, Chap. 7, Walker, Chap. 5).

One of the main findings of the site analysis is that the Middle and early Late Mesolithic relative site frequency is not a reliable demographic proxy because of the preservation bias caused by the Tapes transgression. While the general taphonomic consequences of the Tapes transgression are well known, this study is the first to use a large sample of sites to clearly demonstrate that relative site frequency cannot be used as a demographic proxy in the time and area in question (cfr. Bergsvik et al. 2021). Also, the most significant difference in relative site frequency does not occur around the time of the Storegga tsunami, but in the last part of the Early Mesolithic.

Another main finding is the observation of a correlation between areas with great tsunami magnitude and a lacuna of sites in these areas both predating and post-dating the tsunami by several hundred years. This correlation is interpreted as a possible combination of the taphonomic consequences of the tsunami and a changed perception of risk among the Mesolithic inhabitants of the area, who chose not to resettle the badly hit areas for some time after the event. Although possible human responses to the tsunami have been discussed before (e.g. Nyland et al. 2021a, 2021b; Weninger et al. 2008), this is the first time such a response to the Storegga tsunami has potentially been identified in the Mesolithic archaeological record.

Table 12.1 Mesolithic periods and chronozones (Bjerck 2008, Table 3.1)

Periods and chronozones			Cal. age BC		Duration (calendar years)		Uncal. age BP			Duration (14C-years)
Mesolithic	Early mesolithic	EM1	9500	9000	500	1500	10,020	9590	430	1120
		EM2	9000	8500	500		9590	9270	320	
		EM3	8500	8000	500		9270	8900	370	
	Middle mesolithic	MM1	8000	7500	500	1500	8900	8400	500	1210
		MM2	7500	7000	500		8400	7970	430	
		MM3	7000	6500	500		7970	7690	280	
	Late mesolithic	LM1	6500	6000	500	2500	7690	7110	580	2460
		LM2	6000	5500	500		7110	6560	550	
		LM3	5500	5000	500		6560	6090	470	
		LM4	5000	4500	500		6090	5680	410	
		LM5	4500	4000	500		5680	5230	450	

Acknowledgements This paper is funded by the Research Council of Norway, project 302858, and the Museum of Archaeology, University of Stavanger. The author would like to thank David Simpson (University of Bergen) for help and advice with shoreline dating of sites and Dr. Steven Gibbons (Norwegian Geotechnical Institute) for help with the numerical tsunami model.

References

Åstveit LI, Tøssebro C (2023) Sedentary people or short time events? high resolution radiocarbon chronology from a late Mesolithic dwelling site in Western Norway. J Archaeol Sci Rep 51:104178

Åstveit LI (2008a) Mellommesolittisk tid (mm) 8000–6500 bc. In: Bjerck HB, Åstveit LI, Meling T, Gundersen J, Jørgensen G, Normann S (eds) Ormen lange nyhamna-ntnu vitenskapsmuseets arkeologiske undersøkelser. Tapir Akademisk Forlag, Trondheim

Åstveit LI (2008b) Senmesolittisk tid (sm) 6500–4000 bc. In: Bjerck HB, Åstveit LI, Meling T, Gundersen J, Jørgensen G, Normann S (eds) Ormen lange nyhamna-ntnu vitenskapsmuseets arkeologiske undersøkelser. Tapir Akademisk Forlag, Trondheim

Bavel BJPV, Curtis DR, Dijkman J et al (2020) Disasters and history: the vulnerability and resilience of past societies. Cambridge University Press, Cambridge

Berglund B (2001). Gassprosjektet-Arkeologiske undersøkelser på Tjeldbergodden, Aure kommune, Møre og Romsdal fylke i forbindelse med bygging av metanolanlegg. Norges Teknisk-Vitenskapelige Universitet Vitenskapsmuseet. Rapport Arkeologisk Serie. Trondheim

Bergsvik KA, Senneset K, Hufthammer AK et al (2002) Arkeologiske undersøkelser ved Skatestraumen bind 1. Universitetet i Bergen, Bergen

Bergsvik KA, Darmark K, Hjelle KL et al (2021) Demographic developments in stone age coastal western Norway by proxy of radiocarbon dates, stray finds and palynological data. Quatern Sci Rev 259:106898

Bergsvik KA (2001) Sedentary and mobile hunterfishers in stone age western Norway. Arctic Anthropology: 2–26.

Berrey CA, Drennan RD, Peterson CE (2015) Regional settlement demography in archaeology. Eliot Werner Publications, New York
Bjerck HB (2007) Mesolithic coastal settlements and shell middens (?) in Norway. In: Milner N, Craig OE, Bailey GN (eds) Shell middens in Atlantic Europe. Oxbow Books, Oxford, pp 5–30
Bjerck HB, Østmo E, Imkkelsen E, Ska et al (1987) The Fosna-Nøstvet problem. A consideration of archaeological units and chronozones in the south Norwegian Mesolithic period. Nor Archaeol Rev 20(31):42
Bjerck, HB, Åstveit, LI, Meling T et al (2008). Ormen Lange Nyhamna-NTNU Vitenskapsmuseets arkeologiske undersøkelser. Trondheim, Tapir Akademisk Forlag
Bjerck, HB (1986) The Fosna-Nøstvet problem. A consideration of archaeological units and chronozones in the south Norwegian Mesolithic Period. Nor Archaeol Rev 19(2):103–122
Bjerck HB (2008) Norwegian mesolithic trends: a review. In: Bailey GN, Spikins P (eds) Mesolithic Europe. Cambridge, Cambridge University Press Cambridge
Boethius A, Bergsvik KA, Nilsson B (2020) Knowledge from the ancient sea–a long-term perspective of human impact on aquatic life in mesolithic scandinavia. The Holocene 30:632–645
Bondevik S (1996) The Storegga tsunami deposits in Western Norway and postglacial sea-level changes on Svalbard. University of Bergen, Bergen
Bondevik S (2003) Storegga tsunami sand in peat below the tapes beach ridge at Harøy, Western Norway, and its possible relation to an early stone age settlement. Boreas 32:476–483
Bondevik S, Svendsen JI, Mangerud J (1997b) Tsunami sedimentary facies deposited by the Storegga tsunami in shallow marine basins and coastal lakes, Western Norway. Sedimentol 44:1115–1131
Bondevik S, Løvholt F, Harbitz C, Mangerud J, Dawson A, Svendsen JI (2005) The Storegga slide tsunami—comparing field observations with numerical simulations. Marine Petroleum and Geology 22:195–209
Bondevik S, Stormo SK, Skjerdal G (2012) Green mosses date the Storegga tsunami to the chilliest decades of the 8.2 ka cold event. Quatern Sci Rev 45:1–6
Bondevik S, Svendsen JI, Johnsen G, Mangerud J, Kaland PE (1997a) The Storegga tsunami along the Norwegian coast, its age and run up. Boreas 26:29−53
Bondevik S, Svendsen JI, Angered J (1998) Distinction between the Storegga tsunami and the Holocene marine transgression in coastal basin deposits of western Norway. J Quat Sci 13:529−537
Bondevik S, Lovholt F, Harbitz C, Stormo S, Skjerdal G (2006) The Storegga slide tsunami-deposits, run-up heights and radiocarbon dating of the 8000-year-old tsunami in the North Atlantic. AGU fall meeting abstracts, OS34C-01
Boschetti L, Ioualalen M (2021) Integrated tsunami intensity scale based on maxima of Tsunami amplitude and induced current. Nat Hazards 105:815–839
Breivik HM (2014) Palaeo-Oceanographic development and human adaptive strategies in the Pleistocene-Holocene transition: a study from the Norwegian coast. Holocene 24:1478–1490
Bryn P, Solheim A, Berg K, Lien R, Forsberg C, Haflidason H, Ottesen D, Rise L (2003) The Storegga slide complex; repeated large scale sliding in response to climatic cyclicity. In: Locat J, Mienert J (eds) Submarine mass movements and their consequences advances in natural and technological hazards research. Kluwer Academic Publishers, Dordrecht, pp 215–222
Bryn P, Berg K, Forsberg CF, Solheim A, Kvalstad TJ (2005) Explaining the Storegga slide. Mar Pet Geol 22:11–19
Conneller C (2022) The Mesolithic in Britain: landscape and society in times of change. Routledge, London/New York
Creel RC, Austermann J, Khan NS, D'andrea WJ, Balascio N, Dyer B, Ashe E, Menke W (2022) Postglacial relative sea level change in Norway. Quatern Sci Rev 282:107422
Damlien H (2016) Between tradition and adaption. Long-term trajectories of lithic tool-making in South Norway during the postglacial colonization and its aftermath (c. 9500e7500 cal. Bc) (ph. D. Thesis). Faculty of Social Sciences, Museum of Archaeology, University of Stavanger.

Dawson S, Smith D (2000) The sedimentology of middle Holocene tsunami facies in Northern Sutherland, Scotland, UK. Mar Geol 170:69–79
Dawson AG, Long D, Smith D (1988) The Storegga slides: evidence from eastern Scotland for a possible tsunami. Mar Geol 82:271–276
Dawson A, Bondevik S, Teller J (2011) Relative timing of the Storegga submarine slide, methane release, and climate change during the 8.2 ka cold event. The Holocene 21:1167–1171
Dawson AG, Dawson S, Bondevik S, Costa PJ, Hill J, Stewart I (2020) Reconciling Storegga tsunami sedimentation patterns with modelled wave heights: a discussion from the Shetland Isles field laboratory. Sedimentol 67:1344–1353
De Blasio F, Issler D, Elverhøi A, Harbitz C, Ilstad T, Bryn P, Lien R, Løvholt F (2003) Dynamics, velocity and run-out of the giant storegga slide. In: Locat J, Mienert J (eds) Submarine mass movements and their consequences advances in natural and technological hazards research. Kluwer Academic Publishers, Dordrecht, pp 223–230
Fitzhugh B (2012) Hazards, impacts, and resilience among hunter-gatherers of the Kuril Islands. In: Cooper J, Sheets P (eds) Surviving sudden environmental change: answers from archaeology. University Press of Colorado, Boulder, pp 19–41
Fjeldskaar W, Bondevik S (2020) The early-mid holocene transgression (tapes) at the Norwegian coast–comparing observations with numerical modelling. Quatern Sci Rev 242:106435
Gaffney V, Fitch S, Bates M, Ware RL, Kinnaird T, Gearey B, Hill T, Telford R, Batt C, Stern B (2020) Multi-proxy characterisation of the Storegga tsunami and its impact on the early Holocene landscapes of the Southern North Sea. Geosciences 10:270
Gjevik B, Pedersen G, Dybesland E, Harbitz C (1994) Numerical simulations of tsunami waves: Preliminary results of the Storegga, the Gorringe bank and the Thera case studies. Preprint series. Mech Appl Math.http://urn.nb.no/URN:NBN:no-23418
Glimsdal S, Pedersen GK, Harbitz CB, Løvholt F (2013) Dispersion of tsunamis: does it really matter? Nat Hazard 13:1507–1526
Goff J (2017) Palaeotsunamis. Oxf Res Encycl Nat Hazard Sci
Haflidason H, Sejrup HP, Nygård A, Mienert J, Bryn P, Lien R, Forsberg CF, Berg K, Masson D (2004) The Storegga slide: architecture, geometry and slide development. Mar Geol 213:201–234
Haflidason H, Lien R, Sejrup HP, Forsberg CF, Bryn P (2005) The dating and morphometry of the Storegga slide. Mar Pet Geol 22:123–136
Harbitz CB (1992) Model simulations of tsunamis generated by the Storegga slides. Mar Geol 105:1–21
Hill J, Collins GS, Avdis A, Kramer SC, Piggott MD (2014) How does multiscale modelling and inclusion of realistic Palaeobathymetry affect numerical simulation of the Storegga slide tsunami? Ocean Model 83:11–25
Hinz M (2020) Sensitivity of radiocarbon sum calibration. J Comput Appl Archaeol 3:238–252
Jørgensen EK (2020) The Palaeodemographic and environmental dynamics of prehistoric arctic Norway: an overview of human-climate covariation. Quatern Int 549:36–51
Kilhavn H (2025, fortchoming) Palaeodemographic modelling and the human impact of the Mesolithic Storegga tsunami upon the hunter-fisher-gatherers of Southern Norway
Løvholt F, Pedersen G, Harbitz CB (2016) Tsunami-genesis due to retrogressive landslides on an inclined seabed. In: Lamarche G et al (eds) Submarine mass movements and their consequences: 7th International symposium advances in natural and technological hazards research. Springer, Cham, pp 569–578
Løvholt F, Bondevik S, Laberg JS, Kim J, Boylan N (2017) Some giant submarine landslides do not produce large tsunamis. Geophys Res Lett 44:8463–8472
Lundström V (2023) Living through changing climates: temperature and seasonality correlate with population fluctuations among holocene hunter-fisher-gatherers on the west coast of Norway. Holocene 33:1376–1388

Manninen MA, Damlien H, Kleppe JI, Knutsson K, Murashkin A, Niemi AR, Rosenvinge CS, Persson P (2021) First encounters in the north: cultural diversity and gene flow in early Mesolithic Scandinavia. Antiquity 95:310–328

Mcfadgen BG (2007) Hostile shores: Catastrophic events in prehistoric New Zealand and their impact on Maori coastal communities. Auckland University Press, Auckland, New Zealand

Mithen S, Wicks K (2021) Population level models for testing hunter-gatherer resilience and settlement response to the combined impact of abrupt climatic events and sea level change: a case study from the Holocene of northern Britain. Quat Sci Rev 265:107027

Nielsen SV (2021) A late Mesolithic forager dispersal caused pre-agricultural demographic transition in Norway. Oxf J Archaeol 40:153–175

Nielsen SV (2022) In the wake of farming. University of Oslo, Phd

Nielsen SV, Persson P, Solheim S (2019) De-Neolithisation in Southern Norway inferred from statistical modelling of radiocarbon dates. J Anthropol Archaeol 53:82–91

Nyland AJ, Walker J, Warren G (2021b) Evidence of the Storegga tsunami 8200 bp? An archaeological review of impact after a large-scale marine event in Mesolithic Northern Europe. Front Earth Sci 9:1–15

Nyland A, Warren G, Walker J (2021a) When the sea become a monster? The social impact of the Storegga tsunami, 8200 bp, on the Mesolithic of Northern Europe. In: EGU general assembly conference abstracts, EGU21–2008.

Oliver-Smith A (2002) Theorizing disasters: nature, power, and culture. In: Hoffman S, Oliver-Smith A (eds) Catastrophe and culture: the anthropology of disaster. Advanced Research Publications, Santa Fe, NM, Sch, pp 23–47

Olsen AB, Hjelle KL (1992) Kotedalen-en boplass gjennom 5000 år: fangstbosetning og tidlig jordbruk i vestnorsk steinalder: nye funn og nye perspektiver. Universitetet, Historisk Museum

Papadopoulos GA, Imamura FA (2001) Proposal for a new tsunami intensity scale. In: Proceedings of the International Tsunami Symposium 2001, Seattle, 7–10 August 2001. pp 569–577

Pennington R (2001) Hunter-gatherer demography. In: Panter-Brick C, Layton RH, Rowley-Conwy P, Rowley-Conwy P (eds) Hunter-gatherers: an interdisciplinary perspective. Cambridge University Press, Cambridge, pp 170–204

Puschmann O (2005) Nasjonalt referansesystem for landskap-beskrivelse av Norges 45 landskapsregioner. Nijos-Rapport.

United Nations Office for Disaster Risk Reduction. (2015). Sendai Framework for Disaster Risk Reduction 2015–2030. https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030

Rick JW (1987) Dates as data: an examination of the Peruvian preceramic radiocarbon record. Am Antiq 52:55–73

Riede F (2014) Towards a science of past disasters. Nat Hazards 71:335–362

Roalkvam I (2023) A simulation-based assessment of the relation between stone age sites and relative sea-level change along the Norwegian Skagerrak coast. Quatern Sci Rev 299:107880

Sharrocks PD, Hill H (2024) Evaluating the impact of the Storegga tsunami on Mesolithic communities in Northumberland. J Quat Sci 39:473–487

Shennan S, Downey SS, Timpson A, Edinborough K, Colledge S, Kerig T, Manning K, Thomas MG (2013) Regional population collapse followed initial agriculture booms in mid-holocene Europe. Nat Commun 4:1–8

Simpson D (2009) Automating the extrapolation of sea-level displacement curves: implications for Mesolithic research in Western Norway. In: Harris O (ed) Mesolithic horizons. Papers presented at the seventh international conference on the Mesolithic in Europe, Belfast 2005. Oxbow Books, Oxford

Singleton J (2015) Using the disaster cycle in economic and social history. In: Brown AT, Burn A, Doherty R (eds) Crises in economic and social history: a comparative perspective. Woodbridge, Boydell & Brewer. pp 53–78

Søborg HC (1990) Arkeologiske undersøkelser 1988 i forbindelse med planlagt ilandføring av gass fra haltenbanken. Universitetet i Trondheim-Vitenskapsmuseet

Solheim S, Persson P (2018) Early and mid-Holocene coastal settlement and demography in Southeastern Norway: comparing distribution of radiocarbon dates and shoreline-dated sites, 8500–2000 cal. Bce. J Archaeol Sci Rep 19:334–343

Solheim S (2020) Mesolithic coastal landscapes. Demography, settlement patterns and subsistence economy in Southeastern Norway. Coastal landscapes of the Mesolithic, human engagement with the coast from the Atlantic to the Baltic sea. Routledge, London, New York

Sørensen M, Rankama T, Kankaanpää J, Knutsson K, Knutsson H, Melvold S, Eriksen BV, Glørstad H (2013) The first eastern migrations of people and knowledge into scandinavia: evidence from studies of Mesolithic technology, 9th−8th millennium bc. Nor Archaeol Rev 46:19–56

Svendsen JI (1985) Strandforskyvning på sunnmøre. Bio-og litostratigrafiske undersøkelser på gurskøy, Leinøy og Bergsøy, Bergen Museum

Tallavaara M, Pesonen P (2020) Human ecodynamics in the north-west coast of Finland 10,000–2000 years ago. Quatern Int 549:26–35

Waddington C, Wicks K (2017) Resilience or wipe out? evaluating the convergent impacts of the 8.2 ka event and Storegga tsunami on the Mesolithic of Northeast Britain. J Archaeol Sci Rep 14:692–714

Walker J, Nyland AJ, Bergsvik KA, Kilhavn H, Gibbons SJ, Glimsdal S (2024) A multiproxy approach to understanding the impact of the Storegga tsunami upon Mesolithic hunter-fisher-gatherers across different regions of Western Norway. Quatern Sci Rev 324:108433

Weninger B, Schulting R, Bradtmöller M, Clare L, Collard M, Edinborough K, Hilpert J, Jöris O, Niekus MJ, Rholing E, Wagner B (2008) The catastrophic final flooding of Doggerland by the Storegga slide tsunami. Documenta Praehistorica 35:1–24

Wicks K, Mithen S (2014) The impact of the abrupt 8.2 ka cold event on the Mesolithic population of western Scotland: a Bayesian chronological analysis using 'activity events' as a population proxy. J Archaeol Sci 45:240–269

Wisner B, Blaikie P, Cannon T, Davis I (2004) At risk: natural hazards, people's vulnerability and disasters. Routledge, London

Chapter 13
Human Impacts of the 8.2 ka Event on Mesolithic Foragers in Western Denmark: A Model-Based Approach Inspired by "Radical" Disaster Risk Reduction Research

Felix Riede, Kathrine L. D. Andreasen, and Peter M. Yaworsky

Abstract The 8.2 ka event had a major but regionally variable climatic impact in the Northern Hemisphere. In Denmark, it impacted lakes and rivers, which were essential landscape features for contemporaneous foragers. There is also evidence for a marked increase in sand drift in the region. Around the same time as the 8.2 ka event, the Storegga tsunami affected the North Sea Basin. While there is considerable debate about the loss of lives and livelihoods associated with this event, we here explore whether the combination and convergence of these event-like environmental changes lead to changing land use amongst contemporaneous Maglemosian foragers in western Denmark. Placed in a theoretical framework derived from disaster risk reduction research, we focus on sites in a small part of River Gudenå catchment but also draw on regional-scale proxies of population processes. In combining these lines of evidence, we explore the possibility of a reorientation from inland to coast and from networks reaching westwards towards networks with an eastern orientation. The time of the 8.2 ka event broadly coincides with the transition from the Early Mesolithic Maglemose culture to the Middle Mesolithic Kongemose culture, raising the question of whether the environmental upheavals around this time are causally implicated.

Keywords Mesolithic · Climate · Risk management · Disaster · 8.2 ka BP event

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_13

13.1 Introduction

Climate change, extreme environmental events, and disasters make for alluring causal narratives of culture change—of human impacts—in the present as much as in the past (Pomeroy 2008). Seeking causes for the virtues or otherwise of certain social groups, cultures, or even hominin species in their natural environment has a long intellectual pedigree, often with unsavoury connotations of moral judgement and environmental determinism (Livingstone 1991, 2012). Environmental determinism can take different forms, each subtly different: Some give strong priority to natural forces, where any form of impact is directly proportional to the magnitude or severity of the stressor. In the contemporary world, many see impacts rooted in dimensions of socio-economy where more "developed" societies are mostly seen as more resilient; commonly, the degree to which some societies rather than others had historically achieved greater degrees of "development" (mostly in the sense of industrialization) is then often also seen as related to environmental factors (see discussions in Wisner et al. 2004). Different forms of environmental determinism can also readily be found in archaeological scenarios of how climate change affected past societies, especially at the interface between academia and the public (e.g. Diamond 2005; Weiss 2017; Cline 2021).

In the spirit of the original usage of the term "apocalypse" as a critical turn of events in a stage play, disaster narratives make for excellent stories. Critiques of such narratives that let the environment determine the course of events are not new either. Entire volumes have been published that take issue with specific scenarios of societal collapse in the face of climatic pressures (McAnany and Yoffee 2010; Middleton 2017), rejecting, relativizing, or nuancing such visions of past calamities (cf. Middleton 2024). This chapter seeks a different path, one that combines behavioural ecological theory (see Codding and Bird 2015) with models derived from disaster risk resilience. Rather than arguing against the causal role of climate and extreme events in societal change, this chapter combines Wisner et al.'s (2004) Pressure-and-Release Model (PAR) for disaster impacts with multi-proxy archaeological data to suggest that the combined and multifaceted impacts of the 8.2 ka BP event (Alley and Ágústsdóttir 2005; Rohling and Pälike 2005) and the 8.15 ka BP Storegga tsunami (Bondevik et al. 1997a, b, 2003) that occurred at around the same time in the North Atlantic may have had downstream effects on contemporaneous Mesolithic societies in Western Denmark that were mediated through behavioural responses of mobility, social networks, cultural transmission dynamics, and resource use. Using site counts, the summed probability distributions of calibrated radiocarbon dates, and changes in the archaeological record more broadly, we suggest that this compound cascade of events (cf. Cutter 2018; Zscheischler et al. 2018) aggravated an ongoing demographic downturn, which eventually led to behavioural changes that could be interpreted as resilience in the sense of selective pressures acting on a variable repertoire of socio-ecological habits and options. This analysis points us to the vulnerability of Mesolithic populations in the ninth millennium BP, arguably reveals the impact of the environmental pressures that occurred at this time, and flags up how resilience can be captured as an emergent feature of behavioural change in domains related to mobility, social structure, and economy. Ultimately, we suggest that the cascading impacts of the 8.2 ka event and the Storegga tsunami may be implicated, albeit indirectly and certainly not exclusively, in the transition from the Early Mesolithic Maglemosian to the Middle Mesolithic Kongemose culture.

13.2 Natural Disasters, the Radical Critique, and Human Behavioural Ecology

Our knowledge of past climate and environments has increased dramatically in recent decades, including ever more precise dating of both events and processes. Stimulated by these advances and backed by the epistemic power of the natural sciences (cf. Heymann et al. 2017), many studies have considered the impacts of past climate change on contemporaneous communities (see Jacobson 2022 for a recent review). Many of these studies take the shape of what in disaster risk reduction research has become known as the "dominant" approach that foregrounds the physical aspects of natural disasters. Humans tend to be viewed as responding passively to such stressors, either individually or as societal collectives. In contrast, the "radical" critique, which emerged in the early 1980s, maintains that "the 'natural' and the 'human' are…so inextricably bound together in almost all disaster situations, especially when viewed in an enlarged time and space framework, that disasters cannot be understood to be 'natural' in any straightforward way" (Wisner et al. 2004, 9) where a disaster is defined as a "serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity" (https://www.undrr.org/terminology/disaster). Notable in the context of this chapter, the cover image of Wisner and colleagues' landmark "At Risk" volume is one version of Katsushika Hokusai's (1760–1849) haunting image "The Great Wave off Kanagawa". While the great wave itself dominates the image, a close inspection reveals numerous aspects that allude to the threat and terror of multiple environmental stressors—volcanic eruptions, storms, tsunamis—and their interactions with human technologies and societies.

The Pressure-and-Release model is at the heart of the approach outlined by Wisner et al. (2004). Nested within this model is the Access Model, which presents the vulnerability of individuals, households, communities, and society as a whole centre stage (Fig. 13.1). Rooted in materialist (Marxist) theory, this vulnerability is seen as a product of historical, economic/ecological, and political circumstances at the time of the disaster, and it is particularly related to the material and social capital that can be mobilized at different levels of society to weather the pressures exerted by the environment. Workers operating within this framework are keenly aware of how socially grounded inequalities in the accumulation and distribution of such capital condition vulnerability and response options. Extreme environmental events are hence never considered causal in isolation, with impactful catastrophes only ever

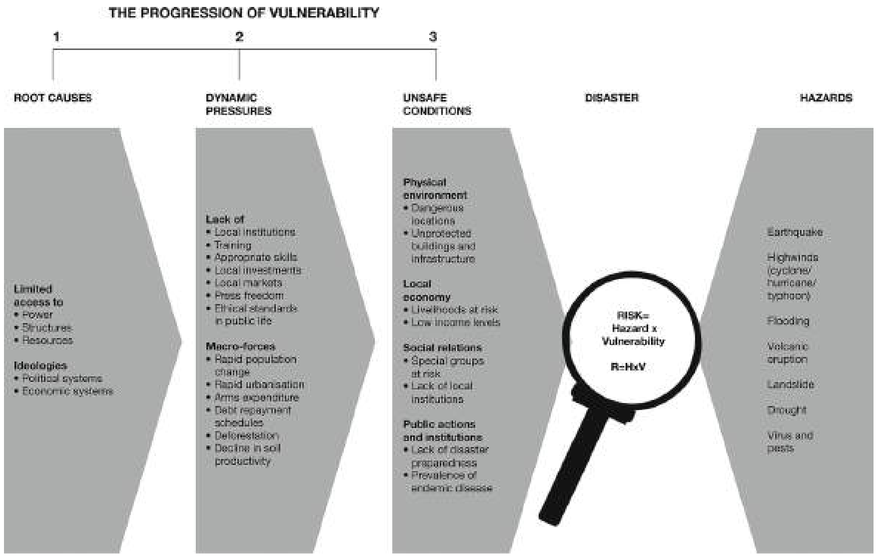

Fig. 13.1 Pressure-and-release model of Wisner et al. (2004). Originally designed to assist in analysing contemporary disaster scenarios, it highlights societal and behavioural aspects (vulnerability, V) in addition to the pressure exerted by external forcing mechanism (hazards, H), which together put given communities at risk (R). Additionally, the notion of a "progression of vulnerability" highlights the historical origins of vulnerability, the root causes of which often need to be sought in periods long before the occurrence of a given hazard

emerging at "the interface between an extreme physical event and a vulnerable human population" (Susman et al. 1983, 264).

For decades now, "radical" disaster scientists with backgrounds in anthropology, geography, and sociology have challenged the "tacit assumption of an unexamined normality" (Hewitt 1995, 232) said to prevail prior to a disaster and have sounded "an explicit call for the study of human agency in disaster research" (Oliver-Smith 1986, 24). Such sentiments reflect parallel developments in archaeology, where post-processual theory has, however, generally turned away from environmental concerns. Yet, "[t]he field of natural hazards is peculiarly adapted to a human ecological approach, for the simple reason that environmental extremes are powerful enough to exert a strong and consistent influence upon social and cultural systems, if not also on physiological ones" (Alexander 2000, 55).

Access to resources, mobility, and social organization are also all topics commonly addressed by research within human behavioural ecology (Borgerhoff Mulder and Schacht 2012; Codding and Bird 2015; Koster et al. 2024), and especially so in regard to hunter-gatherers (e.g. Winterhalder 2001; Bird and O'Connell 2006; Morgan 2008, 2012; Moritz et al. 2020; Jazwa et al. 2019; Smith and Codding 2021). In contrast to the largely inductive approaches in disaster science, human behavioural ecology (HBE) provides theory and methods for devising and testing explicit hypotheses. While this chapter cannot provide a full exploration of how HBE may profitably interact with disaster risk management, we build here on earlier attempts (Layton and Rowley-Conwy 2013; Brewer and Riede 2018) to combine such seemingly disparate stances as Marxism—and with it, disaster risk reduction research—and cultural evolutionary theory/human behavioural ecology. In doing so, we explore how established approaches to past risk management may be articulated with HBE in the context of the prehistoric extreme environmental events that occurred around 8200 years ago.

13.2.1 Really Bad Year Economics—Risk Management Under Extreme Environmental Events

Both disaster scientists and archaeologists have long been thinking about how human societies respond to environmental pressures. Disaster scientists, beginning with White (1974), broadly divided societies into post-industrial, industrial, and pre-industrial (Table 13.1). Pre-industrial societies are extremely diverse, however, and the term covers a wide range of different socio-ecological constellations. This is all the more true when the societies of the past are also included in this tally (cf. Panter-Brick et al. 2001; Kelly 2013; Finlayson and Warren 2017). Despite this evident syn- and diachronic diversity, Halstead and O'Shea (1989), in their volume titled "Bad Year Economics", were able to demonstrate that the fundamental risk management strategies at the disposal of such pre-industrial societies can be grouped into a quartet of vital behavioural measures:

- Resource diversification/intensification.
- Food storage.
- Exchange.
- Mobility.

The compilation of ethnographic and archaeological case studies provided by Halstead and O'Shea (1989) illustrated powerfully the situated specificity of responses to risk. Foragers, for example, chiefly respond via increases to, and changes in, mobility and through activating their social networks (Minc and Smith 1989; Whallon 2006; Strawhacker et al. 2020). Additionally, foragers are expected to expand their dietary breadth to include a wider range, but also lower-ranked food resources as their preferred, high-rank resources become scarce. Pastoralists commonly mix mobility responses with greater investments in storage and by shifting resource investments from, for instance, cattle to sheep and goats (Legge 1989). Farmers, in contrast, tend to prioritize responses that do not involve long-range mobility, as land, and with it their landesque capital, can often not be abandoned for long periods of time. That said, even within the broad category of farmers, many different mobility regimes may buffer against environmental risks (e.g. Goland 1993; Heitz et al. 2021). For farming societies, risk analyses have primarily focused on pre-harvest investment strategies that affect variance in agricultural yield. Strategies

Table 13.1 Pre-industrial and industrial responses to natural hazards, modified from White (1974) and Chester et al. (2012). It remains unclear what characterizes the response pattern of post-industrial societies

Response types and characteristics		
	Pre-industrial	Industrial
Adjustment range	Wide	Restricted
Actors	Individuals, households, small groups	Authorities, authority-coordinated groups
Relation to nature	Harmonization with	Technological control over
Capital investment	Low	High
Spatial variability in responses	High	Low
Response flexibility	High	Low
Loss perception	Perceived as inevitable	Losses should be reduced by government action; technology, science, and development as responses
Time depth	Deep, often with traditional ecological knowledge and disaster memory	Shallow, often with little knowledge of environmental risks and responses

attributed to a preference for risk aversion include field scattering as well as crop and animal diversification, all of which can decrease the variance of economic output, and thus the probability of starvation (see Yaworsky 2021).

Key to understanding the differential investment in these risk-buffering mechanisms are (i) their investment costs, (ii) their temporal and spatial efficacy, and (iii) their demographic implications (Table 13.2). In regard to hunter-gatherers, it is well understood that the spatial and temporal rhythms of resource availability structure mobility and also social organization, including exchange networks (Whallon 2006; Kelly 2007): the more variable vital resources are in space and time, the greater the mobility that is expected (Dyson-Hudson and Smith 1978). Food storage is limited in most forager societies (Hayden 2020), and the opportunities for resource diversification and intensification depend strongly on the affordances of specific environments. High-latitude environs, for instance, may allow for at least seasonal specialization and intensification, yet their limited ecological richness commonly precludes diversification. In lower-latitude environs, the reverse pattern commonly holds true. The relative investment in these buffering mechanisms relates to their perceived costs and benefits vis-à-vis the specific resources in question, making them amenable to HBE modelling and interpretation. In the following, we review the nature of environmental stressors that occurred in the centuries up to 8.2 ka BP and how their impacts may be traceable in the archaeological record. The observed changes are then interpreted in light of behavioural ecological theory and disaster risk reduction models.

Table 13.2 Ranked risk-buffering mechanisms, their costs, efficacy, and societal effects. Failure of these risk management strategies may result in social unrest and violence

Risk management strategy	Efficacy in			
	Time	Space	Investment cost	Societal effects
Resource diversification/ intensification	++	−−	+	May result in resource depression
Food storage	−−−	−−−	++	May catalyse inequality
Exchange	++	+++	−−−	Can lead to dependencies
Mobility	+++	+++	−−−	Limits or depresses population density

13.3 The 8.2 ka Event and the Storegga Tsunami in Southern Scandinavia

Backed by scores of proxy records, the 8.2 ka event is now widely recognized as an episode of rapid climate change caused by a substantial meltwater influx into the North Atlantic (Wiersma and Renssen 2006), perhaps coupled with reduced solar activity at this time (Bond et al. 2001) and extensive iceberg discharge (Wiersma and Jongma 2010). The resulting cooling preferentially affected the Northern Hemisphere, albeit in various ways (cooling, drying, wetting; see Morrill et al. 2013). The limited sensitivity of many mid-latitude proxy systems to the winter and spring cooling that appears to have dominated at this time makes it challenging to detect the event's full extent and severity (Seppä et al. 2007). In Southern Scandinavia, palaeoecological proxy records clearly indicate impacts on hydrology and on vegetation as recorded at, for instance, Lake Højby on Sealand (Hede et al. 2010) and Lake Sarup on Funen (Bjerring et al. 2013), accompanied by a marked increase in sand drift in Western Denmark (Dalsgaard and Vad Odgaard 2001). Notably, much like many proxy records elsewhere (see Wiersma and Renssen 2006), the evidence from Denmark indicates an onset of cooler and stormier conditions well before 8.2 ka BP, i.e. from as early as 8.5 ka BP. Although at present limited to just a few high-resolution proxy studies, the evidence from Lake Højby in Eastern Denmark suggests both a marked increase in precipitation beginning at around 8.5 ka BP and depressed summer temperatures that affected trees. In this context, Hede et al. (2010) demonstrate that the impact on tree reproduction was especially pronounced for hazel, by far the most economically vital tree species at this time. The data from Lake Højby are also suggestive of increased particulate matter input through erosion from the immediate or wide catchment due to increased wind speeds.

The human impacts of the 8.2 ka event have been widely studied in recent years (cf. Manninen 2014), from the Mediterranean in the south (e.g. Weninger et al. 2006; Biehl and Nieuwenhuyse 2016) through the British Isles (Wicks and Mithen 2014) to the very north of Europe (Manninen et al. 2018), and from Iberia in the west (Fernández-López de Pablo et al. 2019) to Russia in the east (Schulting et al.

2022), as well as in the Levant. The bulk of these studies appear to support some form of demographic impact on contemporaneous forager and early farmer communities, most commonly reflected in proxy data such as decreased site counts and troughs in the summed probability distributions of calibrated radiocarbon dates. These demographic downturns may have been caused by the general cooling—forager demography is, after all, broadly driven by temperature (Tallavaara and Seppä 2012; Ordonez and Riede 2022; Yaworsky et al. 2023)—and the speed of climate change at this time, which in turn may have led to cascading ecosystem effects on, for instance, plant phenology. That said, demographic impacts are not seen across all regions, and their extent and our ability to capture it are fiercely debated (Schulting 2018; Griffiths and Robinson 2018; Warren 2020; Van Maldegem et al. 2021; Chapple et al. 2022). In fact, some refugial regions may indeed have experienced demographic growth at this time, albeit notably due to immigration rather than autochthonal growth under favourable environmental conditions (García-Escárzaga et al. 2022). It is clear, therefore, that the nature and extent of human impacts of the 8.2 ka event cannot be assumed but need to be interrogated on and across variable scales. With reference to the PAR model presented above, it is equally clear that a climatic alteration by itself cannot be marshalled as the sole motor of either human impact or cultural change in its wake.

An additional non-climatic factor that may have further stressed at least some forager populations at this time may be the Storegga tsunami. Generated by a gargantuan submarine landslide off the west coast of Norway (Bondevik et al. 1997a; Atakan and Ojeda 2005), a large tsunami affected the North Sea Basin. The extent, wave height, and run-up of this correspondingly massive wave have been particularly well documented in Norway (Bondevik et al. 1997a, 2003; Bondevik 2003; Blankholm 2020) and the British mainland (Smith et al. 2004; Bateman et al. 2021) as well as intermediate islands (Grauert et al. 2001; Bondevik et al. 2005). Arguments have been made that this extreme event led to a final inundation of whatever was left of the once-dry North Sea landmass (Weninger et al. 2008)—Coles' (1998) Doggerland—but the extent of this terminal drowning has recently been questioned (Walker et al. 2020). The evidence from the eastern side of the North Sea Basin indicating that the tsunami waves reached what today are the Danish shorelines comes from the very north and very south of the Jutland peninsula, as well as from the northern coast of what today is the island of Zealand (Noe-Nygaard et al. 2005; Fruergaard et al. 2015).

It remains challenging to estimate the extent of Mesolithic occupation on Doggerland. While concerted efforts in the Dutch and British sectors in particular have produced robust evidence of later Mesolithic land use in these nearshore areas (Peeters and Momber 2014), finds from earlier in the Holocene and from the more northerly reaches of Doggerland remain scarce (cf. Bjerck 1995; Coles 1998). Mesolithic amber carvings and other organic objects do wash up on contemporary North Sea shores but are rarely datable or dated. One exception is an antler flaking tool (Fig. 13.2) retrieved from the Dogger Bank dated to (AAR-3046 = 8020 ± 110 bp) 9270–8590 cal BP (2s) when calibrated with IntCal20 (Reimer et al. 2020). Predating the onset of initial cooling around 8400 BP, this object does indicate human presence on the northern hills of Doggerland prior to the Storegga tsunami. In terms of human impacts, it has been argued that modern-day Scotland was affected by a combination of this tsunami and the cooling of the 8.2 ka event (Waddington and Wicks 2017; Mithen and Wicks 2021) but there may have been considerable diversity and variation in the intensity of the hazard and its attendant impacts (Nyland et al. 2021). From elsewhere in the world, it is known that tsunamis can have major impacts on small populations in particular and that they can play important roles in political processes and in land use decisions (e.g. McFadgen 2007; Begét et al. 2008; Lavigne et al. 2021). Against this mosaic of cultural geography, regional ecologies, and tsunami impacts, we can now turn to evidence from Denmark.

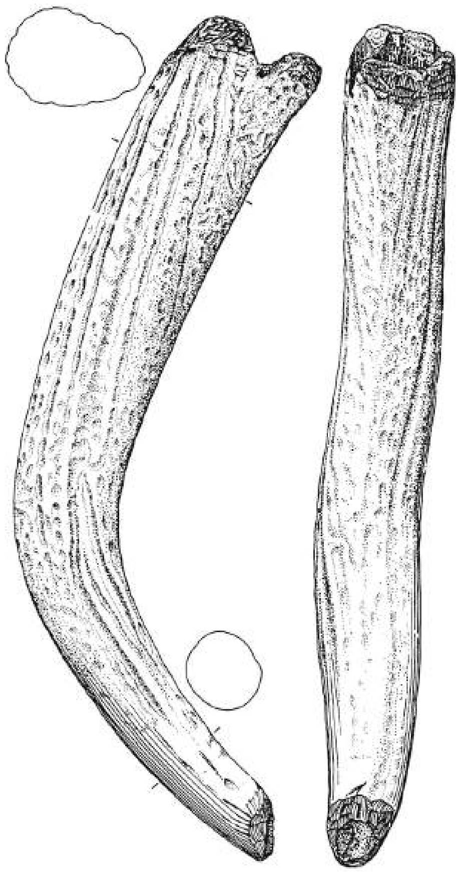

Fig. 13.2 The antler flaking tool from Dogger Bank (Andersen 2005). Drawing by Orla Svendsen

13.4 Palaeodemographic and Material Culture Change During the Ninth Millennium BP in Denmark

Following the lead of the many studies that have investigated palaeodemographic and cultural changes around the ninth millennium BP, we have used here both the summed probability frequency distributions of calibrated radiocarbon dates and site counts as proxies for potentially climate-driven modulations in human populations (e.g. Rick 2007; Tallavaara and Seppä 2012; Wicks and Mithen 2014; Jørgensen 2020; Crema 2022). We do so at a national level using data sourced from the Danish sites and monuments register (https://www.kulturarv.dk/ffreg; see Christoffersen 1992; Hansen 1992) and available radiocarbon dates. In addition, and following a preliminary consideration by Rysgaard et al. (2016), we also examine microregional settlement dynamics in Western Denmark (Central Jutland) in order to elucidate the pace of impact and potential root causes of vulnerability that reach back to the centuries prior to both the 8.2 ka event and the Storegga tsunami. Finally, we synoptically use available archaeological data to discuss how societies changed in the wake of these compound events, and how this may reflect an eventual resilient response.

The approximate relative chronological sensitivity of Mesolithic microliths and lithic technology, respectively, has long been established for Denmark (Brinch Petersen 1966; Petersen 1984; Sørensen 2006, 2007). Traditional interpretations of this sequence—progressing broadly from simple backed or single-edged points to triangles of various geometries in the Early Mesolithic/Maglemosian (phases 0 to 5) to trapezes in the Middle Mesolithic/Kongemosian and on to transverse arrowheads in the Late Mesolithic/Ertebølle culture—highlight continuity across cultural boundaries; recent palaeogenomic data likewise suggest continuity (Allentoft et al. 2024). Recent foci on technological attributes (Sørensen et al. 2013) and osseous barbed points (Jensen et al. 2020) do suggest a greater degree of punctuation in this sequence. The latter analysis indicates a marked change in the design of organic technologies in the Maglemosian, as well as indicating a disappearance of the barbed point design characteristic of this culture at around 8.2 ka BP. These Early Mesolithic barbed points fashioned out of one piece of bone were being replaced by points made up of an osseous core and lithic insets (cf. Manninen et al. 2021). The transition from the Maglemosian to the Kongemosian is traditionally dated to 8400 BP. Using site count data from the Danish sites and monuments register, an overall difference between the former and the latter is evident (Fig. 13.3a). Further querying these data by chronological subphases additionally indicates a population decline at the transition from the Early Mesolithic Maglemosian to the Middle Mesolithic Kongemosian (Fig. 13.3b). The granularity of these register data is low, however, and interpretations based on these site counts alone need to be approached with due caution.

Drawing on the now well-established "dates-as-data" approach, we complement site counts here with summed probability frequency distributions of calibrated radiocarbon dates as an additional palaeodemographic proxy (see French et al. 2021). The available radiocarbon dates ($n = 485$) for the chronological bracket 11 to 6 ka are

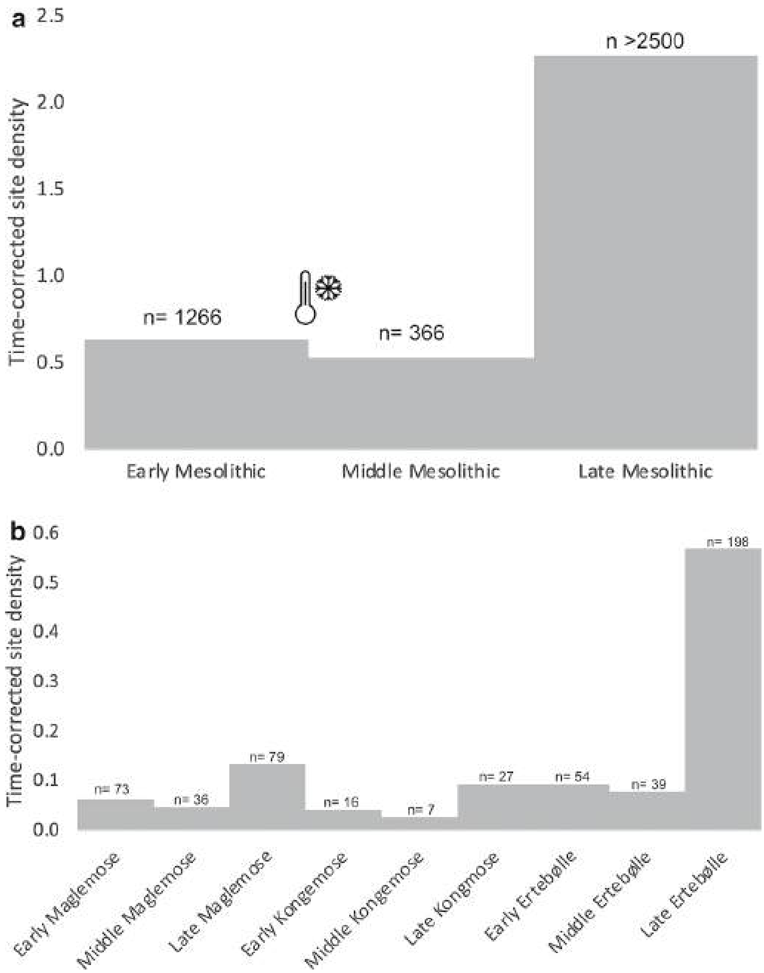

Fig. 13.3 **a** The number of Mesolithic sites in Denmark classified to the Maglemosian (11–8.4 ka BP), Kongemosian (8.4–7.4 ka BP), and Ertebølle culture (7.4–5.95 ka BP), respectively. **b** The same data divided by chronological subphases. The counts are given relative to the length of each phase or subphase. Note that only between 12 and 15% of all sites recorded as "Mesolithic" in the Danish sites and monuments register are assigned to a subphase

drawn from the P3KC14 database (Bird et al. 2022). After removing duplicate observations, we calibrate the radiocarbon dates using the rcarbon package and generate a summed probability distribution with a 200-year bin window (Bevan et al. 2022). We juxtapose the summed probability distributions of these calibrated dates with temperature proxy data from Greenland (Alley 2004) indicative of hemispheric changes in weather systems (Fig. 13.4). Note that the 8.2 ka BP event here also began around 8.45 ka BP, reaching its nadir around 8.2 ka BP before warming resumed. The effect

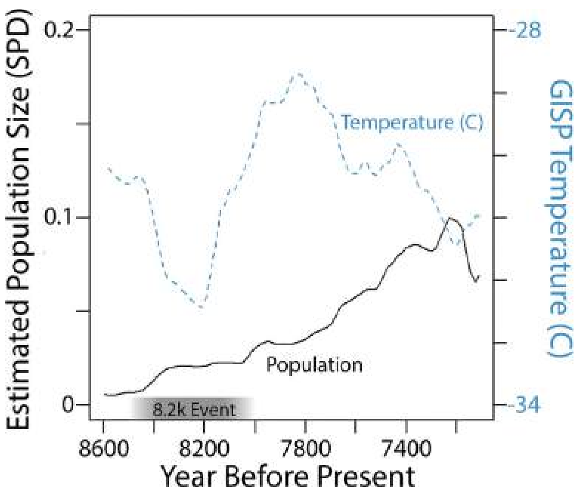

Fig. 13.4 Palaeodemographic proxy (summed probability distribution) shown in black and the GISP2 temperature proxy estimates (Stuiver et al. 1995) shown in blue from 8.6 to 7.1 ka

on the estimated population size in Denmark appears to be a slowing of the population growth rate during this time beginning around 8.3 ka BP. Population growth rates did not return to pre-8.3 ka BP rates until after conditions had improved around several hundred years later (~8000 BP).

Both the site count and radiocarbon data sets also record a shift of settlement intensity towards Eastern Denmark around 8.2 ka BP (Fig. 13.5). While taphonomic biases might make Middle Mesolithic sites both hard to find and hard to identify in Western Denmark (cf. Andersen and Sterum 1971), the scarcity of Late Maglemosian and Kongemosian sites in Jutland has long been noted (Hartz 1985; Nielsen 2006). This dearth of sites and the associated shift in settlement pattern from Western to Eastern Denmark and the inland to the coast come into focus at the level of microregional "contextual areas" (cf. Richter et al. 2012). A detailed analysis of the microliths from several locales in Central Jutland (Sølund–SIM 127-2014; Sølyst–SIM 135-2014; Bjørnholt IV–SIM 114-2012; Sørkelvej–SIM 5142/SIM 111-2012; Papirtårnet–SIM 5170; Dværgebakke III–HEM 2983) indicates a decline in human activity levels towards the end of the Maglemosian in this particular part of the Gudenå catchment (Fig. 13.6). All these sites were closely tied to inland waterbodies, which served as key landscape features both economically and socially (cf. Hussain and Floss 2016). If the evidence from palaeoecological records elsewhere in Denmark (e.g. at Lake Højby on Sealand or Lake Sarup on Funen) can be taken as representative, the waterways experienced major disturbances beginning around 8400 BP or even slightly before. Exactly how these climatic changes may have translated into ecosystem service reductions relevant for contemporaneous foragers remains unclear. The relative chronology for the human occupation in this microregion does indicate a population decline during the ninth millennium BP (Table 13.3). Surface scatters and sites with Kongemosian material culture are not absent from this area, nor from the Jutland peninsula on the whole (cf. Hartz 1985; Sindbæk 2006),

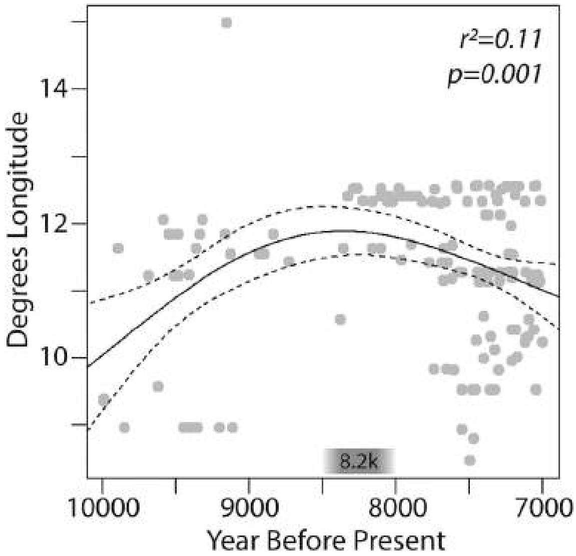

Fig. 13.5 Generalized additive model (Wood 2017) that plots the geographic coordinates in relation to their calibrated age using the same dataset as in Fig. 13.4. A significant ($p = 0.001$, $r^2 = 0.11$) shift towards the east in the centuries around the 8.2 ka event is apparent, followed by a reappearance of sites several centuries later

Fig. 13.6 **a** Denmark as shown on historical ordinance maps made between 1842 and 1899. **b** The microregion of the middle Gudenå catchment in Central Jutland. © The Danish Agency for Data Supply and Infrastructure

yet the extent and nature of human presence and the relations to Eastern Denmark are rather diffuse and remain difficult to assess (Sørensen et al. 2018).

13.5 Cultural Responses to the 8.2 ka Event/Storegga Tsunami Compound Event

It is unlikely that even the combined impacts of the 8.2 ka event and the Storegga tsunami—severe as they may have been in their own rights—led to a sudden and complete collapse of Mesolithic populations in Denmark. It is much more likely,

Table 13.3 Occupation phase chronology for the Gudenå River system in Central Jutland based on diagnostic microliths. Actual sites postdating 8400 BP are not registered in this area; note also that the small number of microliths recovered at some of these sites indicates a moderate level of activity and hence likely also small groups

			Maglemosian phases					
Sites	**Register code**	$n_{microliths}$	***0***	***1***	***2***	***3***	***4***	***5***
	Approximate subphase ages (ka BP)		**10.7–10**	**…–9.6**	**…–9.1**	**…–8.9**	**…–8.8**	**…–8.4**
Dværgebakke III	HEM 2983	27						
Bjørnholt IV	SIM 114-2012	5						
Sørkelvej	SIM 5142 & 111-2014	21						
Papirtårnet	SIM 5170	48						
Sølyst	SIM 135-2014	239						
Sølund	SIM 127-2014	306						
Occupation count			5	6	4	3	3	2

in our view, and better supported by the data presented here, that a loss of land, a decline in resources, and perhaps a rupture of contemporaneous social networks together led to a population shift, a decline, and—eventually—downstream material culture change (cf. Manninen et al. 2023). None of the palaeodemographic proxies deployed here indicate complete breaks, nor does the archaeological evidence support such a view. The chronological proximity of the 8.2 ka event—especially if its effects are extended to 8400 BP—and the Storegga tsunami with the transition from Early to Middle Mesolithic is striking, however. Working ethnographically, Dyer (2002) developed a model for cascading impacts of contiguous and cascading stressors that erode communities' ability to tolerate and rebound.

In terms of vulnerability, a population in decline may have been more sensitive to additional reductions in environmental productivity but also to external influences. The main inland resources used by Early Mesolithic foragers (cf. Blankholm 1992; Groß 2017) may have been preferentially affected by the 8.2 ka event impacts. Behavioural ecological theory would suggest increased mobility and a broadening of diet as a response to adversity; interestingly, the Middle Mesolithic does represent an extension of the resource base to include a wider range of species, and especially a greater focus on coastal and marine resources (Sørensen 2007; Gron and Robson 2016; Robson and Ritchie 2019). Thus, the transition from the Maglemose to the Kongemose culture may be seen as an extended "moment of crisis" (cf. Tipping et al. 2012)—the culmination of a series of pressures generated in the preceding centuries. By the same token, Kongemosian economy may represent an evolved resilient response to these earlier pressures. Similarly, Kongemosian social networks—essential in safeguarding forager resilience (Whallon 2006)—come into focus through the presence of exotic fauna (Petersen 1990) and other evidence of an increasing reach of social networks postdating the Maglemosian (Klassen 2004; Gronenborn 2010). These changes appear, however, to have gone hand in hand with an overall reduction of mobility reflected in the contraction of the Kongemosian "contextual area" that no longer included, for instance, Northern Poland. Whether networks actually became smaller or larger—or whether network structure changed independently of network extent—is for future research to evaluate.

With due caution, these shifts in settlement pattern and land use, in economy, and in technology may be interpreted as behavioural responses to risk according to the scheme outlined in Table 13.1 with mobility—as expected for hunter-gatherers—constituting the initial response, followed by economic diversification and adjustments in social network connectivity. Storage remains difficult to capture in Danish Mesolithic archaeology. There is robust evidence of hazelnut roasting (Holst 2010) and fish fermentation (Boethius 2016) in the Maglemosian but less so in later phases; hazelnuts do remain ubiquitous, and there is much later evidence of smoking (Jensen and Møbjerg 2007). Whether this is due to an actual decline in storage technologies or a lack of targeted investigations also remains for future research to address. In terms of the Pressure-and-Release Model, the "root causes" and "dynamic processes" that may have interacted with the more immediate impacts of the combined hazards generated by rapid cooling and the great wave point our attention to the fragility of Early Mesolithic social networks, a lack of (traditional ecological) knowledge regarding tsunamis, and perhaps the relevance of wider macroregional demographic fluctuations at this time (Fig. 13.7). The model draws attention away from bombastic single-cause explanations in which either the 8.2 ka event or the Storegga tsunami alone, or even in interaction, mechanistically forced some culture change. Instead, it guides us to examine the prelude and context of these periods of socio-ecological reorganization.

13.6 The Progression of Resilience in the Mesolithic of Southern Scandinavia

This chapter has applied an approach that combines models derived from disaster risk reduction research with behavioural ecological thinking about human decision-making and has applied this conceptual amalgam to the transition from the Early to Middle Mesolithic in Denmark. Inspired by Wisner et al.'s (2004) notion of a "progression of vulnerability", we have attempted to elucidate the historical origins of Maglemosian vulnerability, the root causes of which relate to their particular societal and material culture constellations at least as much as to the magnitude and speed of the combined stress generated by the 8.2 ka event cooling and the Storegga tsunami. In the period following these compound events, population growth appears to have stalled in Denmark, possibly as a result of both the environmental deterioration and

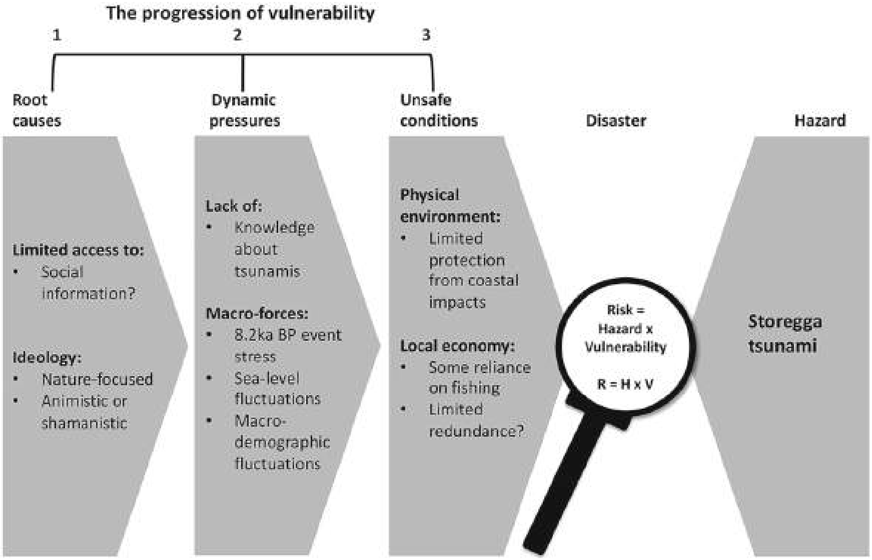

Fig. 13.7 Pressure-and-release model applied to the interaction between late Maglemosian communities in Denmark, the 8.2 ka event, and the Storegga tsunami

the specific response mechanism—mobility, with its demographic implications—taken into use at the time. We see a likely decline in human activity in areas such as Central Jutland, where sites attributed to the Kongemosian are both rare and different from those in Eastern Denmark (Sørensen et al. 2018). Somewhat later, additional risk management strategies (e.g. economic adjustments towards considerably more marine resource use) were also applied by these communities, alongside a changed material culture repertoire. These changes can most likely not be understood in isolation from much larger, transregional processes of culture change that occurred in Europe at this time, but they also hint at a "progression of resilience"—an unfolding of risk management strategies that evolved in response to compound and cascading pressures—that has a temporal dimension much like its counterpart vulnerability.

While some have alluded to the possibility of significant demographic fluctuations in the Mesolithic of Denmark (Price 1999), cultural change across these millennia has traditionally been interpreted as steady and continuous. This strong continuity paradigm (cf. Davey and Innes 2002) coupled with a lack of chronological precision has perhaps been blinding research to just how marked the changes that occurred both at the interfaces between cultural periods and within them may have been. As in other parts of prehistory (cf. Reynolds and Riede 2019), the very definition of these Mesolithic cultural periods (Friman 1996) may in itself be an analytical hurdle rather than help in addressing questions of vulnerability, response, and resilience. We must, in general, reject the determinist idea of "natural" disasters where the environmental stressor alone determines all impacts and outcomes (cf. Chmutina and von Meding 2019); we must not, however, in the same breath reject the idea that climatic and environmental change and extreme events had no impact on past populations, including those of Mesolithic Denmark. The current culture-historical framework for the Mesolithic in this region was put in place long before the conceptual revolutions of processual and post-processual archaeology, long before the emergence of modern climate science and its refinement of Holocene variability, and long before the emergence of computer-aided methods for capturing large-scale patterns in material culture. Hence, approaching the Mesolithic through the lens of human behavioural ecology and disaster risk reduction—and with new analytical methods that align with these theoretical frameworks—may prove productive in not only asking novel questions but also finding possible answers to these.

A better understanding of the environmental upheavals around the 8.2 ka event in Denmark and a higher chronological resolution for the transitions from Maglemosian to Kongemosian constitute obvious and desirable research priorities. Such work would usefully flesh out the environmental hazard component of understanding Mesolithic vulnerability. In addition, future work would also need to specifically address changes in material culture that reflect the available risk management options. In doing so, we would be able to bring both the vulnerability and the resilience of these communities into sharper focus.

The notion of resilience offers a salient but also conceptually slippery point of contact between archaeology and contemporary concerns (Redman 2005; Bradtmöller et al. 2017; Jacobson 2022; Løvschal 2022). We present here an approach to capturing past resilience that is theoretically motivated and heeds the empirical limitations of the archaeological record. In this context, the risk management strategies defined by Halstead and O'Shea (1989) and their attendant archaeological proxies should make this approach readily case-transferable, even between ethnographic and archaeological settings. At the same time, the synoptic interpretation offered here is necessarily preliminary given the data at hand. The notion of vulnerability and the PAR model point backwards in time from the event horizon of 8.2 ka BP while the companion notion of resilience points forward towards responses enacted thereafter; future research targeted at these different domains of risk management is set to reveal important new insights into the socio-ecological dynamics of Mesolithic societies in Denmark. At present, many regions of the world are undergoing rapid hydrological changes, some of which may herald irreversible tipping points and additional cascading impacts on essential ecosystem services (Reichstein et al. 2021; Willcock et al. 2023). Understanding the vulnerability and resilience of these ancient foragers in the context of such "socio-hydrology" (see Sivapalan et al. 2014) may not directly allow us to become more resilient ourselves. Yet, it would provide a salient and evidence-based point of contact between the natural and social sciences (Allen et al. 2022) for weaving the sorts of narratives that also contribute to both greater climate literacy and climate action (Kerr et al. 2022).

Acknowledgments We thank the reviewers for their constructive comments and Astrid Nyland for inviting us to the original and very stimulating "Under Pressure" conference.

References

Alexander DE (2000) Confronting catastrophe. Oxford University Press, Oxford
Allen K, Riede F, Gouramanis C et al (2022) Coupled insights from the palaeoenvironmental, historical and archaeological archives to support social-ecological resilience and the sustainable development goals. Environ Res Lett 17:055011. https://doi.org/10.1088/1748-9326/ac6967
Allentoft ME, Sikora M, Fischer A et al (2024) 100 Ancient genomes show repeated population turnovers in Neolithic Denmark. Nature 625:329–337. https://doi.org/10.1038/s41586-023-06862-3
Alley RB (2004) NOAA/WDS Paleoclimatology—GISP2—temperature reconstruction and accumulation data. NOAA National Centers for Environmental Information. https://doi.org/10.25921/36sb-3355. Accessed 01 Dec 2024
Alley RB, Ágústsdóttir AM (2005) The 8k event: cause and consequences of a major Holocene abrupt climate change. Quatern Sci Rev 24:1123–1149
Andersen SH (2005) En glittestok fra Dogger Banke i Nordsøen. Kuml 54:9–16. https://doi.org/10.7146/kuml.v54i54.97309
Andersen SH, Sterum N (1971) Gudenåkulturen. Holstebro Museums årsskrift 1970–1971:14–32
Atakan K, Ojeda A (2005) Stress transfer in the Storegga area, offshore mid-Norway. Mar Pet Geol 22:161–170. https://doi.org/10.1016/j.marpetgeo.2004.10.005
Bateman MD, Kinnaird TC, Hill J et al (2021) Detailing the impact of the Storegga Tsunami at Montrose, Scotland. Boreas 50:1059–1078. https://doi.org/10.1111/bor.12532
Begét J, Gardner C, Davis K (2008) Volcanic tsunamis and prehistoric cultural transitions in Cook Inlet, Alaska. J Volcanol Geotherm Res 176:377–386
Bevan A, Crema ER, Bocinsky RK et al (2022) Rcarbon: calibration and analysis of radiocarbon dates. https://CRAN.R-project.org/package=rcarbon. Accessed 01 Dec 2024
Biehl PF, Nieuwenhuyse OP (eds) (2016) Climate and cultural change in prehistoric Europe and the near East. State University of New York Press, Albany, NY
Bird DW, O'Connell JF (2006) Behavioural ecology and archaeology. J Anthropol Res 14:143–188
Bird D, Miranda L, Vander Linden M et al (2022) P3k14c, a synthetic global database of archaeological radiocarbon dates. Sci Data 9:27. https://doi.org/10.1038/s41597-022-01118-7
Bjerck HB (1995) The North Sea continent and the pioneer settlement of Norway. In: Fischer A (ed) Man and sea in the Mesolithic. Oxbow, Oxford, pp 131–144
Bjerring R, Olsen J, Jeppesen E et al (2013) Climate-driven changes in water level: a decadal scale multi-proxy study recording the 8.2-ka event and ecosystem responses in Lake Sarup (Denmark). J Paleolimnol 49:267–285. https://doi.org/10.1007/s10933-012-9673-7
Blankholm HP (2020) In the wake of the wake. An investigation of the impact of the Storegga tsunami on the human settlement of inner Varangerfjord, northern Norway. Quatern Int 549:65–73. https://doi.org/10.1016/j.quaint.2018.05.050
Blankholm HP (1992) On the track of a prehistoric economy. Maglemosian Subsistence in Early Postglacial South Scandinavia. Aarhus University Press, Århus
Boethius A (2016) Something rotten in Scandinavia: the world's earliest evidence of fermentation. J Archaeol Sci 66:169–180. https://doi.org/10.1016/j.jas.2016.01.008
Bond G, Kromer B, Beer J et al (2001) Persistent solar influence on North Atlantic climate during the Holocene. Science 294:2130–2136. https://doi.org/10.1126/science.1065680
Bondevik S (2003) Storegga tsunami sand in peat below the Tapes beach ridge at Harøy, Western Norway, and its possible relation to an early Stone Age settlement. Boreas 32:476–483. https://doi.org/10.1111/j.1502-3885.2003.tb01229.x
Bondevik S, Inge Svendsen J, Mangerud JAN (1997a) Tsunami sedimentary facies deposited by the Storegga tsunami in shallow marine basins and coastal lakes, western Norway. Sedimentology 44:1115–1131
Bondevik S, Svendsen JI, Johnsen G et al (1997b) The Storegga tsunami along the Norwegian coast, its age and run up. Boreas 26:29–53. https://doi.org/10.1111/j.1502-3885.1997.tb00649.x

Bondevik S, Mangerud J, Dawson S et al (2003) Record-breaking height for 8000-year-old Tsunami in the North Atlantic. Eos 84:289–300
Bondevik S, Mangerud J, Dawson S et al (2005) Evidence for three North Sea tsunamis at the Shetland Islands between 8000 and 1500 years ago. Quatern Sci Rev 24:1757–1775. https://doi.org/10.1016/j.quascirev.2004.10.018
Borgerhoff Mulder M, Schacht R (2012) Human behavioural ecology. Wiley Online Library: Encyclopedia of life sciences. https://doi.org/10.1002/9780470015902.a0003671.pub2
Bradtmöller M, Grimm SB, Riel-Salvatore J (2017) Resilience theory in archaeological practice—an annotated review. Quatern Int 446:3–16. https://doi.org/10.1016/j.quaint.2016.10.002
Brewer J, Riede F (2018) Cultural heritage and climate adaptation: a cultural evolutionary perspective for the Anthropocene. World Archaeol 50:554–569. https://doi.org/10.1080/00438243.2018.1527246
Brinch Petersen E (1966) Klosterlund-Sønder Hadsund-Bøllund. Les trois principaux du malémosien ancien en Jutland essai de typologie et de chronologie. Acta Archaeologica 37:77–185
Chapple RM, McLaughlin TR, Warren G (2022) "...Where they pass their unenterprising existence...": change over time in the Mesolithic of Ireland as shown in radiocarbon-dated activity. Proc R Irish Acad Archaeol Cult Hist Lit 122:1–38. https://doi.org/10.1353/ria.2022.0011
Chester DK, Duncan AM, Sangster H (2012) Human responses to eruptions of Etna (Sicily) during the late-pre-industrial era and their implications for present-day disaster planning. J Volcanol Geotherm Res 225–226:65–80. https://doi.org/10.1016/j.jvolgeores.2012.02.017
Chmutina K, von Meding J (2019) A dilemma of language: "natural disasters" in academic literature. Int J Disast Risk Sci 10:283–292. https://doi.org/10.1007/s13753-019-00232-2
Christoffersen J (1992) The Danish national record of sites and monuments, DKC. In: Larsen CU (ed) Sites & monuments. National Archaeological Records. Nationalmuseet, Copenhagen, pp 7–21
Cline EH (2021) 1177 B.C.: the year civilization collapsed, Revised and expanded edition. Princeton University Press, Princeton, NJ
Codding BF, Bird DW (2015) Behavioral ecology and the future of archaeological science. J Archaeol Sci 56:9–20. https://doi.org/10.1016/j.jas.2015.02.027
Coles BJ (1998) Doggerland: a speculative survey. Proc Prehist Soc 64:45–81
Crema ER (2022) Statistical inference of prehistoric demography from frequency distributions of radiocarbon dates: a review and a guide for the perplexed. J Archaeol Method Theory 29:1387–1418. https://doi.org/10.1007/s10816-022-09559-5
Cutter SL (2018) Compound, cascading, or complex disasters: what's in a name? Environ Sci Policy Sustain Dev 60:16–25. https://doi.org/10.1080/00139157.2018.1517518
Dalsgaard K, Vad Odgaard B (2001) Dating sequences of buried horizons of podzols developed in wind-blown sand at Ulfborg, Western Jutland. Quatern Int 78:53–60. https://doi.org/10.1016/S1040-6182(00)00115-4
Davey PJ, Innes JJ (2002) Innovation, continuity and insular development in the Isle of Man. In: Waldren WH, Ensenyat JA (eds) World islands in prehistory. In: International insular investigations V Deia international conference in prehistory. Oxbow, Oxford, pp 44–56
Diamond JM (2005) Collapse. How societies choose to fail or survive. Penguin Books, London
Dyer CL (2002) Punctuated entropy as culture-induced change: the case of the *Exxon Valdez* oil spill. In: Hoffman SM, Oliver-Smith A (eds) Catastrophe & culture: the anthropology of disaster. School of American Research Press, Santa Fe, NM, pp 159–185
Dyson-Hudson R, Smith EA (1978) Human territoriality: an ecological reassessment. Am Anthropol 80:21–41. https://doi.org/10.2307/673509
Fernández-López de Pablo J, Gutiérrez-Roig M, Gómez-Puche M et al (2019) Palaeodemographic modelling supports a population bottleneck during the Pleistocene-Holocene transition in Iberia. Nat Commun 10:1872. https://doi.org/10.1038/s41467-019-09833-3
Finlayson B, Warren GM (eds) (2017) Diversity of hunter-gatherer pasts. Oxbow Books, Oxford

French JC, Riris P, Fernandéz-López de Pablo J et al (2021) A manifesto for palaeodemography in the twenty-first century. Philos Trans R Soc B Biol Sci 376:20190707. https://doi.org/10.1098/rstb.2019.0707
Friman B (1996) Does the Kongemose culture exist? About the concept of culture. Archaeologia Polona 34:143–163
Fruergaard M, Piasecki S, Johannessen PN et al (2015) Tsunami propagation over a wide, shallow continental shelf caused by the Storegga slide, southeastern North Sea, Denmark. Geology 43:1047–1050.https://doi.org/10.1130/G37151.1
García-Escárzaga A, Gutiérrez-Zugasti I, Marín-Arroyo AB et al (2022) Human forager response to abrupt climate change at 8.2 ka on the Atlantic coast of Europe. Sci Rep 12:6481. https://doi.org/10.1038/s41598-022-10135-w
Goland C (1993) Field scattering as agricultural risk management: a case study from Cuyo Cuyo, Department of Puno, Peru. Mount Res Dev 13:317–338. https://doi.org/10.2307/3673760
Grauert M, Björck S, Bondevik S (2001) Storegga tsunami deposits in a coastal lake on Suðuroy, the Faroe Islands. Boreas 30:263–271
Griffiths S, Robinson E (2018) The 8.2 ka BP Holocene climate change event and human population resilience in northwest Atlantic Europe. Quatern Int 465:251–257. https://doi.org/10.1016/j.quaint.2017.10.017
Gron KJ, Robson HK (2016) The Ertebølle Zooarchaeological dataset from Southern Scandinavia. Open Quatern 2:1. https://doi.org/10.5334/oq.15
Gronenborn D (2010) Fernkontakte aus dem nördlichen Europa während der Bandkeramischen Kultur. In: Suteková J, Pavúk J, Kalábková P et al (eds) PANTA RHEI. Studies in chronology and cultural development of South-Eastern and Central Europe in earlier prehistory presented to Juraj Pavúk on the occasion of his 75. Birthday. Comenius University, Bratislava, pp 561–574
Groß D (2017) Welt und Umwelt frühmesolithischer Jäger und Sammler. Mensch-Umwelt-Interaktion im Frühholozän in der nordmitteleuropäischen Tiefebene. Ludwig, Kiel
Halstead P, O'Shea J (eds) (1989) Bad year economics. Cultural responses to risk and uncertainty. Cambridge University Press, Cambridge
Hansen HJ (1992) Content, use and perspectives of DKC, the Danish national record of sites and monuments. In: Larsen CU (ed) Sites & monuments. National Archaeological Records. Nationalmuseet, Copenhagen, pp 23–47
Hartz S (1985) Kongemose-Kultur in Schleswig-Holstein. Offa 42:35–56
Hayden B (2020) Archaeological pitfalls of storage. Curr Anthropol 61:763–793. https://doi.org/10.1086/712087
Hede MU, Rasmussen P, Noe-Nygaard N et al (2010) Multiproxy evidence for terrestrial and aquatic ecosystem responses during the 8.2 ka cold event as recorded at Højby Sø, Denmark. Quatern Res 73:485–496.https://doi.org/10.1016/j.yqres.2009.12.002
Heitz C, Hinz M, Laabs J et al (2021) Mobility as resilience capacity in northern Alpine Neolithic settlement communities. Archaeol Rev Cambridge 36:75–106
Hewitt K (1995) Studying disaster: a review of the main conceptual tools. Int J Mass Emerg Disast 13:231–240
Heymann M, Gramelsberger G, Mahony M (eds) (2017) Cultures of prediction in atmospheric and climate science: epistemic and cultural shifts in computer-based modelling and simulation. Routledge, Abingdon
Holst D (2010) Hazelnut economy of early Holocene hunter–gatherers: a case study from Mesolithic Duvensee, northern Germany. J Archaeol Sci 37:2871–2880. https://doi.org/10.1016/j.jas.2010.06.028
Hussain ST, Floss H (2016) Streams as entanglement of nature and culture: European Upper Paleolithic River systems and their role as features of spatial organization. J Archaeol Method Theory 23:1162–1218. https://doi.org/10.1007/s10816-015-9263-x
Jacobson MJ (2022) Archaeological evidence for community resilience and sustainability: a bibliometric and quantitative review. Sustainability 14(24):16591. https://doi.org/10.3390/su142416591

Jazwa CS, Kennett DJ, Winterhalder B et al (2019) Territoriality and the rise of despotic social organization on western Santa Rosa Island, California. Quatern Int 518:41–56. https://doi.org/10.1016/j.quaint.2017.11.009
Jensen HJ, Møbjerg T (2007) Et røgeri fra ældre stenalder ved Bølling Sø? Midtjyske Fortællinger 2007:51–62
Jensen TZT, Sjöström A, Fischer A et al (2020) An integrated analysis of Maglemose bone points reframes the Early Mesolithic of Southern Scandinavia. Sci Rep 10:17244. https://doi.org/10.1038/s41598-020-74258-8
Jørgensen EK (2020) The palaeodemographic and environmental dynamics of prehistoric Arctic Norway: an overview of human-climate covariation. Quatern Int 549:36–51. https://doi.org/10.1016/j.quaint.2018.05.014
Kelly RL (2007) The foraging spectrum: diversity in hunter-gatherer lifeways. Percheron Press, Clinton Corners, NY
Kelly RL (2013) The lifeways of hunter-gatherers: the foraging spectrum. Cambridge University Press
Kerr S, Krogh U, Riede F (2022) Experimental participatory methodology brings local pasts to contemporary climate action. Clim Action 1:5. https://doi.org/10.1007/s44168-022-00006-5
Klassen L (2004) Jade und Kupfer: Untersuchungen zum Neolithisierungsprozess im westlichen Ostseeraum unter besonderer Berücksichtigung der Kulturentwicklung Europas 5500-3500 BC. Jysk Arkæologisk Selskab, Højbjerg
Koster J, Scelza B, Shenk MK (eds) (2024) Human behavioral ecology. Cambridge University Press, Cambridge
Lavigne F, Morin J, Wassmer P et al (2021) Bridging legends and science: field evidence of a large tsunami that affected the Kingdom of Tonga in the 15th century. Front Earth Sci 9:748755. https://doi.org/10.3389/feart.2021.748755
Layton RH, Rowley-Conwy PA (2013) Wild things in the north? Hunter-gatherers and the tyranny of the colonial perspective. Anthropologie 51:213–230
Legge K (1989) Changing responses to drought among the Wodaabe of Niger. In: Halstead P, O'Shea J (eds) Bad year economics. Cultural responses to risk and uncertainty. Cambridge University Press, Cambridge, pp 81–86
Livingstone DN (1991) The moral discourse of climate: historical considerations on race, place and virtue. J Hist Geogr 17:413
Livingstone DN (2012) Changing climate, human evolution, and the revival of environmental determinism. Bull Hist Med 86:564–595. https://doi.org/10.1353/bhm.2012.0071
Løvschal M (2022) Retranslating resilience theory in archaeology. Annu Rev Anthropol 51:195–211. https://doi.org/10.1146/annurev-anthro-041320-011705
Van Maldegem E, Vandendriessche H, Verhegge J et al (2021) Population collapse or human resilience in response to the 9.3 and 8.2 ka cooling events: a multi-proxy analysis of Mesolithic occupation in the Scheldt basin (Belgium). J Anthropol Archaeol 64:101348. https://doi.org/10.1016/j.jaa.2021.101348
Manninen M (2014) Culture, behaviour, and the 8200 cal BP cold event. Organisational change and culture-environment dynamics in Late Mesolithic northern Fennoscandia. Archaeological Society of Finland, Helsinki
Manninen MA, Tallavaara M, Seppä H (2018) Human responses to early Holocene climate variability in eastern Fennoscandia. Quatern Int 465:287–297. https://doi.org/10.1016/j.quaint.2017.08.043
Manninen MA, Asheichyk V, Jonuks T et al (2021) Using radiocarbon dates and tool design principles to assess the role of composite slotted bone tool technology at the intersection of adaptation and culture-history. J Archaeol Method Theory 28:845–870. https://doi.org/10.1007/s10816-021-09517-7
Manninen MA, Fossum G, Ekholm T et al (2023) Early postglacial hunter-gatherers show environmentally driven "false logistic" growth in a low productivity environment. J Anthropol Archaeol 70:101497. https://doi.org/10.1016/j.jaa.2023.101497

McAnany PA, Yoffee N (eds) (2010) Questioning collapse: human resilience, ecological vulnerability & the aftermath of empire. Cambridge University Press, Cambridge
McFadgen B (2007) Hostile shores: catastrophic events in prehistoric New Zealand and their impact on Maori coastal communities. Auckland University Press, Auckland
Middleton GD (2017) Understanding collapse. Ancient history and modern myths. Cambridge University Press, Cambridge
Middleton GD (2024) Collapse studies in archaeology from 2012 to 2023. J Archaeol Res. https://doi.org/10.1007/s10814-024-09196-4
Minc LD, Smith KP (1989) The spirit of survival. In: Halstead P, O'Shea J (eds) Bad year economics: cultural responses to risk and uncertainty. Cambridge University Press, Cambridge, pp 8–39
Mithen S, Wicks K (2021) Population level models for testing hunter-gatherer resilience and settlement response to the combined impact of abrupt climatic events and sea level change: a case study from the Holocene of northern Britain. Quatern Sci Rev 265:107027. https://doi.org/10.1016/j.quascirev.2021.107027
Morgan C (2008) Reconstructing prehistoric hunter–gatherer foraging radii: a case study from California's southern Sierra Nevada. J Archaeol Sci 35:247–258. https://doi.org/10.1016/j.jas.2007.02.025
Morgan C (2012) Modeling modes of hunter-gatherer food storage. Am Antiq 77:714–736. https://doi.org/10.7183/0002-7316.77.4.714
Moritz M, Scaggs S, Shapiro C, Hinkelman S (2020) Comparative study of territoriality across forager societies. Hum Ecol 48(2):225–234. https://doi.org/10.1007/s10745-020-00141-9
Morrill C, Anderson DM, Bauer BA et al (2013) Proxy benchmarks for intercomparison of 8.2 ka simulations. Clim Past 9:423–432. https://doi.org/10.5194/cp-9-423-2013
Nielsen LB (2006) Jysk Maglemosekultur - den manglende brik i puslespillet. In: Eriksen BV (ed) Stenalderstudier. Tidligt mesolitiske jægere og samlere i Sydskandinavien. Jysk Arkæologisk Selskab, Højbjerg, pp 197–212
Noe-Nygaard N, Nielsen L, Hede SU (2005) En tsunami i Danmark? Geoviden 2005:16–19
Nyland AJ, Walker J, Warren G (2021) Evidence of the Storegga Tsunami 8200 BP? An archaeological review of impact after a large-scale marine event in Mesolithic Northern Europe. Front Earth Sci 9:767460. https://doi.org/10.3389/feart.2021.767460
Oliver-Smith A (1986) Disaster context and causation: an overview of changing perspectives in disaster research. In: Oliver-Smith A (ed) Natural disasters and cultural responses. College of William and Mary, Williamsburg, VA, pp 1–35
Ordonez A, Riede F (2022) Changes in limiting factors for forager population dynamics in Europe across the last glacial-interglacial transition. Nat Commun 13:5140. https://doi.org/10.1038/s41467-022-32750-x
Panter-Brick C, Layton RH, Rowley-Conwy P (2001) Hunter-gatherers: an interdisciplinary perspective. Cambridge University Press, Cambridge
Peeters JHM, Momber G (2014) The southern North Sea and the human occupation of northwest Europe after the Last Glacial Maximum. Neth J Geosci 93:55–70. https://doi.org/10.1017/njg.2014.3
Petersen PV (1984) Chronological and regional variation in the Late Mesolithic of Eastern Denmark. J Danish Archaeol 3:7–18
Petersen PV (1990) Eksotiske faunarester i Kongemose- og Ertebølletid – resultat af udveksling? Hikuin 16:17–30
Pomeroy AJ (2008) Then it was destroyed by the volcano. The ancient world in film and on television. Duckworth, London
Price TD (1999) Human population in Europe during the Mesolithic. In: Kersting T, Pratsch S (eds) Cziesla E. Den Bogen spannen...Festschrift für Bernhard Gramsch. Beier & Beran, Weissbach, pp 185–195
Redman CL (2005) Resilience theory in archaeology. Am Anthropol 107:70–77. https://doi.org/10.2307/3567674

Reichstein M, Riede F, Frank D (2021) More floods, fires and cyclones—plan for domino effects on sustainability goals. Nature 592:347–349. https://doi.org/10.1038/d41586-021-00927-x
Reimer PJ, Austin WEN, Bard E et al (2020) The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 62:725–757. https://doi.org/10.1017/RDC.2020.41
Reynolds N, Riede F (2019) House of cards: cultural taxonomy and the study of the European Upper Palaeolithic. Antiquity 93:1350–1358. https://doi.org/10.15184/aqy.2019.49
Richter J, Hauck T, Vogelsang R et al (2012) "Contextual areas" of early Homo sapiens and their significance for human dispersal from Africa into Eurasia between 200 ka and 70 ka. Quatern Int 274:5–24. https://doi.org/10.1016/j.quaint.2012.04.017
Rick J (2007) Dates as data: an examination of the Peruvian ceramic radiocarbon record. Am Antiq 52:55–73
Robson HK, Ritchie K (2019) The Early Mesolithic fisheries of southern Scandinavia. In: Groß D, Lübke H, Meadows J et al (eds) Working at the sharp end at Hohen Viecheln: from bone and antler to Early Mesolithic life in Northern Europe. Wachholtz, Kiel, pp 289–303
Rohling EJ, Pälike H (2005) Centennial-scale climate cooling with a sudden cold event around 8,200 years ago. Nature 434:975–979
Rysgaard K, Fredsgaard K, Riede F (2016) Mesolitiske bosættelser ved Gudenåsystemets søer og åer. Kuml 2016:55–80. https://doi.org/10.7146/kuml.v65i65.24829
Schulting RJ (2018) The success and failure of resilience in the European Mesolithic. In: Temple DH, Stojanowski CM (eds) Hunter-gatherer adaptation and resilience: a bioarchaeological perspective. Cambridge University Press, Cambridge, pp 65–84
Schulting RJ, Mannermaa K, Tarasov PE et al (2022) Radiocarbon dating from Yuzhniy Oleniy Ostrov cemetery reveals complex human responses to socio-ecological stress during the 8.2 ka cooling event. Nat Ecol Evol 6:155–162. https://doi.org/10.1038/s41559-021-01628-4
Seppä H, Birks HJB, Giesecke T et al (2007) Spatial structure of the 8200 cal yr BP event in northern Europe. Clim Past 3:225–236
Sindbæk SM (2006) Dalhus. En Kongemoseboplads ved Storåen og spørgsmålet om den mesolitiske indlandsbebyggelse i Jylland. In: Eriksen BV (ed) Stenalderstudier. Tidligt mesolitiske jægere og samlere i Sydskandinavien. Jysk Arkæologisk Selskab, Højbjerg, pp 213–240
Sivapalan M, Konar M, Srinivasan V et al (2014) Socio-hydrology: use-inspired water sustainability science for the Anthropocene. Earth's Future 2:225–230. https://doi.org/10.1002/2013EF000164
Smith EA, Codding BF (2021) Ecological variation and institutionalized inequality in hunter-gatherer societies. PNAS 118:e2016134118. https://doi.org/10.1073/pnas.2016134118
Smith DE, Shi S, Cullingford RA et al (2004) The Holocene Storegga Slide tsunami in the United Kingdom. Quatern Sci Rev 23:2291–2321
Sørensen M (2006) Teknologiske traditioner i Maglemosekulturen. En diakron analyse af maglemosekulturens flækkeindustri. In: Eriksen BV (ed) Stenalderstudier. Tidligt mesolitiske jægere og samlere i Sydskandinavien. Jysk Arkæologisk Selskab, Højbjerg, pp 19–77
Sørensen M (2018) Early Mesolithic regional mobility and social organization: evidence from lithic blade technology and Microlithic production in Southern Scandinavia. In: Knutsson K, Knutsson H, Apel J et al (eds) Technology of early settlement in Northern Europe. Equinox Publishing, Sheffield, pp 173–201
Sørensen SA (2007) The Kongemose culture. Syddansk Universitetsforlag, Odense
Sørensen M, Rankama T, Kankaanpää J et al (2013) The first eastern migrations of people and knowledge into Scandinavia: evidence from studies of mesolithic technology, 9th-8th millennium BC. Norweg Archaeol Rev 46:19–56. https://doi.org/10.1080/00293652.2013.770416
Strawhacker C, Snitker G, Peeples MA et al (2020) A landscape perspective on climate-driven risks to food security: exploring the relationship between climate and social transformation in the prehispanic U.S. Southwest. Am Antiq 85:427–451. https://doi.org/10.1017/aaq.2020.35

Stuiver M, Grootes PM, Braziunas TF (1995) The GISP2 δ18O climate record of the past 16,500 years and the role of the sun, ocean, and volcanoes. Quatern Res 44:341–354. https://doi.org/10.1006/qres.1995.1079

Susman P, O'Keefe P, Wisner B (1983) Global disasters, a radical interpretation. In: Hewitt K (ed) Interpretations of calamity. Allen & Unwin, London, pp 263–283

Tallavaara M, Seppä H (2012) Did the mid-Holocene environmental changes cause the boom and bust of hunter-gatherer population size in eastern Fennoscandia? Holocene 22:215–225. https://doi.org/10.1177/0959683611414937

Tipping R, Bradley R, Sanders J et al (2012) Moments of crisis: climate change in Scottish prehistory. Proc Soc Antiq Scotl 142:9–25

Waddington C, Wicks K (2017) Resilience or wipe out? Evaluating the convergent impacts of the 8.2 ka event and Storegga tsunami on the Mesolithic of northeast Britain. J Archaeol Sci Rep 14:692–714. https://doi.org/10.1016/j.jasrep.2017.04.015

Walker J, Gaffney V, Fitch S et al (2020) A great wave: the Storegga tsunami and the end of Doggerland? Antiquity 94:1409–1425. https://doi.org/10.15184/aqy.2020.49

Warren G (2020) Climate change and hunter gatherers in Ireland: problems, potentials and pressing research questions. Proc R Irish Acad Archaeol Cult Hist Lit 120C:1–22. https://doi.org/10.3318/priac.2020.120.01

Weiss H (2017) Megadrought and collapse: from early agriculture to Angkor. Oxford University Press, Oxford

Weninger B, Alram-Stern E, Bauer E et al (2006) Climate forcing due to the 8200 cal yr BP event observed at Early Neolithic sites in the eastern Mediterranean. Quatern Res 66:401–420

Weninger B, Schulting R, Bradtmöller M et al (2008) The catastrophic final flooding of Doggerland by the Storegga Slide tsunami. Documenta Praehistorica 35:1–24

Whallon R (2006) Social networks and information: non-"utilitarian" mobility among hunter-gatherers. J Anthropol Archaeol 25:259–270

White GF (1974) Natural hazards research: concepts, methods and policy implications. In: White GF (ed) Natural hazards: local, national, global. Oxford University Press, Oxford, pp 3–16

Wicks K, Mithen SJ (2014) The impact of the abrupt 8.2 ka cold event on the Mesolithic population of western Scotland: a Bayesian chronological analysis using 'activity events' as a population proxy. J Archaeol Sci 45:240–269. https://doi.org/10.1016/j.jas.2014.02.003

Wiersma AP, Jongma JI (2010) A role for icebergs in the 8.2 ka climate event. Clim Dyn 35:535–549. https://doi.org/10.1007/s00382-009-0645-1

Wiersma AP, Renssen H (2006) Model–data comparison for the 8.2 ka BP event: confirmation of a forcing mechanism by catastrophic drainage of Laurentide Lakes. Quatern Sci Rev 25:63–88. https://doi.org/10.1016/j.quascirev.2005.07.009

Willcock S, Cooper GS, Addy J et al (2023) Earlier collapse of Anthropocene ecosystems driven by multiple faster and noisier drivers. Nat Sustain 6:1331–1342. https://doi.org/10.1038/s41893-023-01157-x

Winterhalder B (2001) The behavioural ecology of hunter-gatherers. In: Panter-Brick C, Layton RH, Rowley-Conwy P (eds) Hunter-gatherers: an interdisciplinary perspective. Cambridge University Press, Cambridge, pp 12–38

Wisner B, Blaikie P, Cannon T et al (2004) At risk. Natural hazards, people's vulnerability and disasters, 2nd edn. Routledge, London

Wood SN (2017) Generalized additive models: an introduction with R, 2nd edn. Chapman and Hall/CRC, Boca Raton

Yaworsky PM, Hussain ST, Riede F (2023) Climate-driven habitat shifts of high-ranked prey species structure Late Upper Paleolithic hunting. Sci Rep 13:4238. https://doi.org/10.1038/s41598-023-31085-x

Yaworsky PM (2021) Prehistoric land use in the grand staircase-Escalante National Monument and West Tavaputs Plateau, Utah. Dissertation, University of Utah

Zscheischler J, Westra S, van den Hurk BJJM et al (2018) Future climate risk from compound events. Nat Clim Change 8:469–477. https://doi.org/10.1038/s41558-018-0156-3

Chapter 14
Hidden Hazards and the Long-Term Robusticity of Foraging Societies in the Levantine Epipalaeolithic (25–12 ka)

Aaron Jonas Stutz

Abstract This chapter considers radiocarbon-date evidence of demographic dynamics in the Epipalaeolithic of the Levant, ca. 25,000–12,000 cal BP. The calibration analysis results reveal a millennial-scale trend, stretching over nearly 9000 years. It involves significant long-term average demographic expansion followed by deceleration. This development is gradual, rather than abrupt. It does not appear to have been significantly affected by climatic fluctuations. This main finding highlights the robusticity of hunter-gatherer adaptability, even in the face of sporadic, otherwise archaeologically invisible, short-term hazards that inevitably impacted fertility, mortality, and migration over decadal and centennial time frames. By the end of the Last Glacial Maximum (LGM, ca. 22–19,000 cal BP), regional human cultural systems had evolved significant resilience to natural perturbations, but something else may also have emerged. Resilient cultural institutions and built environments already in place at that time constituted social networks that stretched across strong gradients in biomass productivity. Over the long run, cultural adaptations and self-organizing demographic responses to spatial gradients in ecological productivity interacted, supporting adaptive social responses to perturbations. Increases in resource-extraction efficiency raised, in turn, culturally mediated demographic carrying capacity. Elucidating this emergent feature of coupled human–environment systems is key for understanding the root causes of long-term human demographic dynamics and environmental impacts.

Keywords Levantine Epipalaeolithic · Radiocarbon calibration analysis · Palaeodemography · Niche construction · Biocultural adaptation · Culturally mediated carrying capacity

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_14

14.1 Introduction

The Epipalaeolithic period of the Levant, dated to ca. 25–12,000 cal BP (Goring-Morris and Belfer-Cohen 2017), set the stage for hallmark Neolithic transformations in the early Holocene, involving the emergence of food storage, domestication, agriculture, herding, village life, and private property (Bar-Yosef 1998; Belfer-Cohen and Bar-Yosef 2002; Bowles and Choi 2013; Belfer-Cohen and Goring-Morris 2014; Wright 2014; Grosman and Munro 2017). Material technologies that first appeared or substantially developed during the Epipalaeolithic period include durable residential architecture; long-distance raw material transport; well-defined ritual installations and places, often involving memorialization of the dead; and compound implements and heavy-duty groundstone equipment focused on targeting or processing small game, fish, and plant foods (Bar-Yosef and Belfer-Cohen 1989; Belfer-Cohen 1995; Stiner and Munro 2002; Munro and Grosman 2010; Maher et al. 2011b, 2021; Edwards 2012; Yeshurun et al. 2014a; Rosenberg and Nadel 2014; Grosman and Munro 2016, 2017; Nadel 2017; Friesem et al. 2019; Richter et al. 2019; Belfer-Cohen and Goring-Morris 2020; Rosenberg et al. 2021). In this time frame, specialized foraging and residential mobility strategies took hold in semi-arid and arid zones (Stutz 2025). At the same time, some Late Epipalaeolithic (ca. 15–12,000 cal BP) hamlets in the Mediterranean vegetation zone were occupied year-round (Yeshurun et al. 2014b; Weissbrod et al. 2017; Rivals et al. 2020). In the final millennium of the Epipalaeolithic, grinding slabs and mortars were more widely used for processing seeds (Dubreuil 2004; Nørskov Pedersen et al. 2016; Eitam 2019). Silica polish on Late Epipalaeolithic sickle blades points towards the increasing economic and dietary importance of storable starchy seeds (Anderson 1999). It seems unavoidable, indeed, to characterize the Levantine Epipalaeolithic as a prelude to neolithization. From this perspective, a major challenge for research on Levantine prehistory persists. We aim to explain how and why Epipalaeolithic developments established the conditions for Neolithic domestication, agriculture, and village life. Yet, we must avoid falling into the trap of teleological or oversimplified prime-mover explanations.

With this concern in focus, two conceptual threads in ongoing research on neolithization are identified—niche construction theory (Kuijt and Prentiss 2009; Asouti and Kabukcu 2014; Asouti et al. 2015; Ramsey 2023) and resilience/panarchy theory (Rosen and Rivera-Collazo 2012). In this chapter, these threads are integrated with recent work on largely archaeologically invisible population fluctuations that necessarily tempered long-term hunter-gatherer demographic dynamics (Hamilton and Walker 2018; Gurven and Davison 2019). The general human adaptive system is anchored by a uniquely derived life history strategy, with a relatively long juvenile stage and extended post-reproductive longevity for both sexes. Associated with a technological, omnivorous, extractive, and intensively social niche (Stutz 2020a, b), the human adaptive system evolved in the Pleistocene to involve societies with at least three overlapping, culturally organized generations (Hill et al. 2009; Stutz 2009; Davison and Gurven 2022; Paige and Perreault 2022). Fluctuations in fertility and mortality (Milner and Boldsen 2023) shape decadal and centennial trends in population growth, density, and age structure, contributing to intergenerational inheritance integral to biocultural adaptation-niche construction dynamics. While niche construction research has emphasized the importance of ecological inheritance and patch engineering (Odling-Smee et al. 2003; Mohlenhoff and Codding 2017; Ramsey 2023), the inheritance of demographic conditions has received limited explicit attention. In combination with Panarchy theory's broad conceptual approach to ecosystem cycles in connectivity and organization (Gunderson and Holling 2001; Rosen and Rivera-Collazo 2012; Bradtmöller et al. 2017; Solich and Bradtmöller 2017), niche construction theory has the potential to advance our understanding of how human societies have recurrently evolved strategies for increasing rates of energy extraction, thereby raising demographic carrying capacity (Stutz 2020b; Freeman et al. 2023).

This presentation utilizes a novel analysis of summed calibrated radiocarbon date probability density distributions—based on 321 published ^{14}C dates, drawn from 71 buried, often stratified, archaeological units, covering 59 Levantine sites with associated Epipalaeolithic material culture. This study of Levantine Epipalaeolithic population dynamics supports an exploration of how cultural institutions and culturally mediated carrying capacity co-evolved. A key question is whether we can begin to identify temporal, spatial, and population scales at which adaptive cycles unfolded in coupled systems encompassing cultural institutions, human demographic regimes, and broader ecosystems in the final millennia of the Pleistocene.

14.2 Background

Recent theoretical work in anthropological demography has reinvigorated the topic of prehistoric population dynamics, seeking to elucidate plausible micro-evolutionary mechanisms that spanned transitions from predominantly foraging economies to agricultural ones (Richerson et al. 2001, 2009; Freeman et al. 2023). These approaches have built on now classic interdisciplinary debates—spanning human demography, economic history, and anthropology—about the relationship between population growth, intensification of labour, and innovation in non-industrial agricultural systems (Boserup 1965; Lee 1986; Wood 1998). These discussions have brought into focus complex systemic feedback among cultural institutions, population growth rate, population size, and the adoption of organizational and technological innovations. Both absolute population size and its rate of change influence, often quite directly, human impact on the wider ecosystem, in terms of matter and energy extraction. Yet, these same factors also influence the potential for adaptability. All living members of the population represent mouths to feed. At the same time, the population constitutes potentially productive, cooperative social resources, but it also includes potentially conflicting factions. Along with complementary, arguably hallmark research on stochastic population fluctuations in prehistory (Hamilton and Walker 2018; Gurven and Davison 2019), the recent work in anthropological demography offers a key opportunity for theoretically integrating human population dynamics into niche-construction and adaptive-cycle approaches. This chapter's presentation centres, therefore, on a demographic model of millennial-scale feedback between niche construction and biocultural adaptation. The aim is to re-evaluate the complex evolutionary processes that linked change in Epipalaeolithic social technologies to the subsequent Neolithic period.

For Pleistocene and early Holocene foragers, we are only beginning to understand the long-term evolution of cultural institutions that mediated the rates at which communities extracted energy and nutrients from their prevailing ecosystems. In general, in a given small-scale non-industrial cultural system, the community is expected to extract edible biomass at roughly an optimal population size and territorial extent (Wood 1998; Winterhalder et al. 2015; Puleston and Winterhalder 2019; Stutz 2020b; Freeman et al. 2023). Here, cultural institutions shape and mediate social relationships, the organization of labour, ownership or distribution of food, and management of common-pool resources. The compounding nature of population growth means that, when a group colonizes a new territory, re-occupies an abandoned area, or begins recovering from a significant demographic downturn, increase will follow a nonlinear trajectory, first accelerating and then decelerating towards the prevailing saturation level mediated by socially constitutive institutions. At this jointly ecologically and culturally dependent carrying capacity, the community risks overexploiting prey populations or degrading ecosystem services (Freeman et al. 2023). However, in the Late Pleistocene and Holocene time frames, cultural systems have adapted, again and again, to a marginally declining elasticity of resource-extraction rates. Communities have adopted innovative technologies and cultural institutions, which facilitated higher energy-extraction rates, feeding, in turn, higher population densities (Bocquet-Appel and Bar-Yosef 2008; Barton et al. 2011; Shennan et al. 2013; Stutz 2014; Tallavaara et al. 2015; Stutz et al. 2021; Freeman et al. 2021; Milner and Boldsen 2023).

Figure 14.1 builds on the graphical approach presented in Lee (1986) and further considered in Wood (1998), illustrating how adaptation in cultural institutions can support expanded elasticity of aggregate energy extraction, with respect to population size around the equilibrium population size. The result can sustainably raise culturally mediated carrying capacity, indicated by the shift from P_1 to P_2 in Fig. 14.1. These points represent the respective group sizes at which surplus above metabolic maintenance requirements is maximized (Lee 1986). As discussed in Stutz (2020b), the social management of surplus calories above physiological maintenance requirements constitutes an important domain of biopolitics, even in small-scale societies, where resources may be allocated to group rituals, visiting and gift exchange, conflict resolution, handling of serious social transgressions, and other domains of practice that culturally reproduce the prevailing system of energy extraction. Figure 14.1 also graphically implies that repeated population overshoots, resulting significant caloric shortfalls, can plausibly lead to a communal shift towards lower-productivity cultural institutions. This, in turn, opens up the possibility of long-term adaptive cycles between lower- and higher-productivity systems.

However, the importance of population overshoots and resulting demographic declines opens up a further area of inquiry, with far-reaching implications for understanding the long-term co-evolution of cultural institutions and carrying capacity.

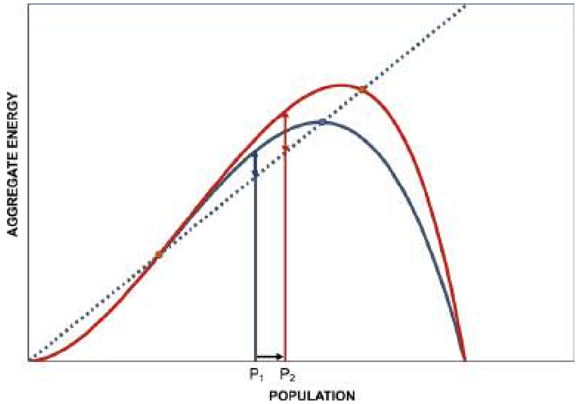

Fig. 14.1 Model of culturally mediated increase in carrying capacity, involving increased positive elasticity of energy extraction relative to population size. Solid lines: lower (blue) and higher (red) productivity systems for energy extraction. Dotted line: aggregate energy required for physiological maintenance at population size P. Population levels P_1 and P_2 illustrate the productivity-related increase in culturally mediated carrying capacity at maximum energy extraction above physiological maintenance requirements

Gurven and Davison's (2019) simulation study, which utilizes data on age-specific mortality and fertility rates from a range of ethnographically documented foraging societies, finds that significant Malthusian downturns—occurring stochastically at decadal or centennial scales in small-scale communities—must have checked prehistoric hunter-gatherer populations over centennial and millennial time frames (see also Hamilton and Walker 2018). Central to this conclusion is the fact that, under a range of ethnographically observed conditions, mobile hunter-gatherers have sufficiently high fertility and low mortality to support strongly positive population growth, the compounding effects of which would be unsustainable after only a few generations (Hill and Hurtado 1996; Richerson et al. 2001, 2009; Hill et al. 2007; Gurven and Kaplan 2007; Hamilton et al. 2007).

Extending the findings reported in Gurven and Davison (2019), it may be emphasized that unpredictably occurring demographic downturns would have varied in frequency and intensity across spatial gradients in biomass productivity. Together with subsequent recovery periods, Malthusian crashes would have driven irregular but recurrent cycles in population growth rates in zones of higher ecological productivity, such as the Mediterranean vegetation zone and Jordan Valley. In a conceptually related article, I present a detailed analysis and discussion of spatial gradients in ecological productivity; their impacts on associated gradients in culturally mediated carrying capacity; and the nonlinear effects on the frequency and depth of sporadic population crashes (Stutz 2024). In general, across demographic scales—and in a wide range of historical circumstances—the population growth rate in human communities is systemically negatively coupled to the risks that innovation poses for average well-being (Rogers 1994). As cultural institutions supporting robust long-distance delayed-reciprocity relationships emerged in the Upper Palaeolithic period (Whallon 1989, 2006), widespread social networks would have better buffered against localized, sporadic, but inevitable demographic downturns. However, they would only have reduced their intensity and, by extension, the risk of local extinction. It may be emphasized, then, that periods of localized population growth—constituting recoveries from unavoidable demographic crashes—would have been coupled with higher discounting of future returns on embodied and social capital. Thus, episodes of localized population growth would have entailed greater potential for efficiency-raising innovations to emerge and take hold in cultural systems. This argument is mainly based on Rogers' (1994) formal mathematical treatment of the evolution of time preference. Fitzhugh (2001) provides a conceptually similar treatment of risk-taking and invention in human demographic cycles.

With recurrent demographic recessions occurring unpredictably, every few generations in local forager communities, it is fundamentally expected that experiences of nutritional stress, raised mortality, higher mobility, territorial abandonment, and shifting land tenure from higher- to lower-productivity zones (e.g., from lowland valleys to highlands or from wetter to semi-arid vegetation zones) would have commonly been represented by culturally conserved tropes. These would have been taught and conveyed in myths, rituals, and oft-repeated glosses on meaningful place names, on indications of extreme deviations in weather and food resource availability, and on starvation foods (Colson 1979; Minc 1986).

Very roughly, based on Gurven and Davison's (2019) analysis, we would expect that, throughout the Levant, several hundred localized Malthusian downturns in group size, reaching a depth of least 20–25%, occurred over the course of the Epipalaeolithic (ca. 13 millennia). The vast majority of dated buried Epipalaeolithic sites were settled, likely repeatedly reoccupied, and eventually abandoned over relatively brief intervals. We have few archaeological cases tracing localized or regional demographic recessions or abandonment (but see Yeshurun et al. 2025). An exception may be reflected in the relatively high frequency of linear enamel hypoplasias (i.e. dental developmental defects caused by early childhood stress) in the Late Natufian (ca. 13–12,000 cal BP) cemetery at Nahal Oren (Bocquentin 2003). Demographic modelling results indicate that population downturns (often referred to as "Malthusian crashes") were important past phenomena, shaping cultural practice, expression, and knowledge. At longer time frames, complex population fluctuations and geographic shifts in mobility and land tenure would have driven cycles in future discounting, in turn structuring patterns of innovation and cultural adaptation in carrying capacity (Stutz 2024).

The model presented in this chapter, then, focuses on stochastic demographic fluctuations. A region such as the Levant is ecologically defined by strong and persistent geographic gradients in biomass productivity, the structure of which is explored in the companion article, focused on mapping temperature and annual net-primary-productivity (NPP) data from MODIS satellite measurements (Stutz 2024).

Spatially varying biomass availability would have been coupled to varying risks of localized human demographic fluctuations. The predicted cycles of localized demographic downturns and recoveries—likely more conspicuous in higher-productivity zones—are expected to have shaped selective pressures on those cultural institutions that simultaneously mediated carrying capacity and structured resilience in the face of social and environmental hazards across the Levant as a whole. As summarized in detail in Fig. 14.2 and Table 14.1, the model predicts that cooler periods, characterized by reduced biomass-productivity differentials between wetter and drier habitat zones, would have entailed dampened demographic fluctuations, along with smaller-amplitude cycles in the potential for carrying-capacity-raising innovations. In contrast, warmer periods, usually involving higher differentials in biomass productivity between wetter and drier zones, would have featured more frequent demographic cycles in the more humid zones. At the same time, with interstadial climates generally forcing shorter demographic cycles in wetter zones, more arid areas would have had relatively limited edible biomass availability to support surges in land tenure during cycle downturns. Warm periods, then, would have involved a complex pattern of raised demographic volatility; higher potential for the adoption of innovations during recovery phases; higher coupled potential for raised, culturally mediated carrying capacity; and risk for social responses to localized Malthusian demographic "recessions" to trigger compounding interactions among resource overexploitation, social instability, reduced fertility, and climbing mortality.

This model contextualizes Gurven and Davison's (2019) analysis of population fluctuations as necessary drivers of centennial-scale near-zero population growth ("near ZPG"), at once within a broader complex-systems theoretical perspective and an empirical archaeological and palaeoenvironmental focus on the Levantine Epipalaeolithic. Ecological productivity gradients, then, would have tended to force geographic variation in fertility rates, carrying capacity, and risks of Malthusian downturns, in turn, driving local cycles—at centennial or millennial scales—in future discounting. This framework complements recent theoretical approaches to prehistoric population fluctuations, such as Freeman et al.'s (2023) adaptive trade-off model. The model presented in this chapter, explored in greater theoretical depth in Stutz (2024), identifies a systemic tendency for innovation—with a coupled adaptive rise in culturally mediated carrying capacity—during periods of demographic recovery, especially in zones of higher biomass productivity.

14.3 Materials and Methods

In order to begin evaluating this new future-discounting-cycle model of long-term biocultural adaptation and niche construction of carrying capacity, this section turns to the calibration probability density distribution (PDD) analysis of available Levantine Epipalaeolithic radiocarbon dates. In using summed radiocarbon calibration PDDs, this study employs radiocarbon data as a proxy for relative population footprint over time (Blockley et al. 2006; Shennan and Edinborough 2007; Surovell et al. 2009; Kelly et al. 2013; Contreras and Meadows 2014; Crema et al. 2017; Freeman et al. 2018; Fernández-López de Pablo et al. 2019; Palmisano et al. 2019; Riris et al. 2024). Two statistical hypotheses are evaluated in light of the published data.

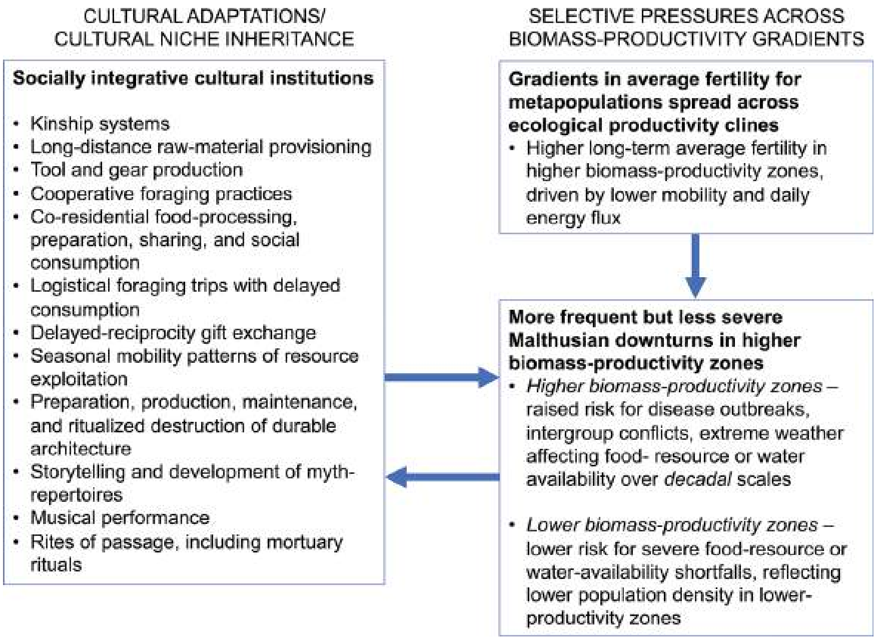

Fig. 14.2 Relationships among adaptations in cultural institutions and cultural niche (left-hand system), spatially varying demographic rates and demographic fluctuations (lower right), and spatial ecological productivity gradients (upper right). Along with seasonality, the latter force spatial differences in available edible biomass (Zhu et al. 2021). In turn, these ecological constraints are expected to force differences in the frequency and amplitude of population fluctuations. Finally, variable population fluctuations affect and are mediated by cultural adaptations

First, the calibration analysis considers whether the Levantine Epipalaeolithic time frame encompassed a significant long-term rise in human population, and along with it, maximum culturally mediated carrying capacity. This hypothesis is relevant for considering the model prediction of a long-term tendency towards rising culturally mediated carrying capacity, and it is tested through examining a smoothed standardized calibration PDD for the Levantine Epipalaeolithic, as a whole, with millennial-scale binned probabilities cautiously corrected for taphonomic site (Surovell et al. 2009; Bluhm and Surovell 2019). If the statistical test, described below, clearly meets criteria for rejecting the null hypothesis of no change in long-term maximum carrying capacity, then the inference of demographic growth will be supported. Changes in settlement size and within-settlement density may also mean that radiocarbon PDD signals capture the direction of demographic growth, although they may not have a constant proportional relationship to past census size (Downey et al. 2014; Jacobsson 2019; Birch-Chapman and Jenkins 2019).

Second, the calibration analysis considers the hypothesis that shorter-term Malthusian downturns and subsequent recoveries are preserved in the Epipalaeolithic radiocarbon record. This hypothesis has a bearing on how thoroughly we

Table 14.1 Schematic description of niche construction-biocultural adaptation dynamics across biomass-productivity clines

Climate-linked long-term fluctuations
• When cooler conditions prevailed:
– Climate-forced reduction in biomass productivity in relatively wetter zones
– Climate-forced reduction in biomass-productivity differential between wetter and more arid zones, driven by lower evaporation and precipitation differential
– *Reduced differential in culturally mediated population carrying capacity, between higher- and lower-productivity zones*
– *Increased relative importance of wetlands as resource patches*
– *Increased social connectivity and mobility across productivity gradients*
• When warmer conditions prevailed:
– Climate-forced increase in biomass productivity in relatively wetter zones
– Climate-forced increase in biomass-productivity differential between wetter and more arid zones, driven by higher evaporation and precipitation differential
– *Higher population carrying capacity in wetter, more ecologically productive zones*
– *More frequent stochastic demographic fluctuations in higher biomass-productivity zones, forcing more frequent disruptions to social networks, dispersals to lower-productivity zones, and cycles in risk-taking/innovation*

may test the carrying-capacity-increase model presented above, in light of currently available data. The test is carried out by simulating an arbitrarily large number of random radiocarbon dates (in this case, over 30,000 dates), represented in (taphonomically uncorrected) proportion to the best-fit polynomial curve that captures the central tendency of the millennially smoothed Levantine Epipalaeolithic radiocarbon calibration PDD. This simulated radiocarbon dataset models what we would expect if the available archaeological record was representative of a gradual population history, lacking shorter-scale demographic fluctuations. A random resampling approach (repeatedly drawing a number of simulated radiocarbon dates equal to the number of stratigraphically discrete units included in the study sample) will allow us to identify those fluctuations in the observed radiocarbon calibration PDD that likely are artefacts of the INTCAL 2020 calibration curve itself, discriminating them from observed PDD fluctuations likely representing past centennial- or decadal-scale demographic cycles.

14.3.1 The Archaeological Sample of Radiocarbon Dates

This analysis draws on published radiocarbon dates on wood charcoal, carbonized seeds, and bone collagen from buried archaeological contexts associated with Epipalaeolithic material culture in the Levant, generally marked by the proliferation of microlith manufacturing practices (Belfer-Cohen and Goring-Morris 2020;

Abadi et al. 2024). The Epipalaeolithic period is taken to begin with assemblages assigned to the Late Ahmarian/Masraqan technocomplex, with the earliest dates stretching back to ca. 25,000 cal BP (Goring-Morris and Belfer-Cohen 2017; Belfer-Cohen and Goring-Morris 2020). Later named "technocomplexes" in the Levantine Epipalaeolithic are listed here from a taxonomic "splitter's" perspective. They may be grouped roughly chronologically into a tripartite subdivision, although, as discussed below, some technocomplexes have associated radiocarbon dates that transgress any neat temporal classification, suggesting a more complex, as-yet incompletely understood history of cultural reproduction, negotiation, and change in material-culture style (Maher et al. 2012; Goring-Morris and Belfer-Cohen 2017; Abadi et al. 2024). Early Epipalaeolithic technocomplexes include the Nebekian, Qalkan, Jilatian, Kharanan, Kebaran, and Nizzanan. Middle Epipalaeolithic technocomplexes include Geometric Kebaran, Mushabian, and Early Ramonian. Late Epipaeolithic technocomplexes include late and final Ramonian, Early Natufian, Late/Final Natufian, and Harifian. Some technocomplexes are locally geographically restricted, while others—such as the Kebaran, Geometric Kebaran, and Late Natufian—have wide Levantine distributions (Belfer-Cohen and Goring-Morris 2020; Stutz 2025). Overall, the Epipalaeolithic period spans roughly 25–12,000 cal BP.

The radiocarbon dataset expands on previous reviews and summaries of Late Pleistocene ^{14}C dates from the region (Goring-Morris 1987; Bar-Yosef and Kra 1994; Aurenche et al. 2001; Goring-Morris and Belfer-Cohen 2003a; Blockley and Pinhasi 2011; Maher et al. 2011a; Grosman 2013; Stutz 2025). Building on Grosman's important review of Natufian radiocarbon dates (2013) and Maher et al.'s (2011a) study of Epipalaeolithic and Pre-Pottery Neolithic chronology, this chapter also covers published dates from Ain Qasiyeh, Ein Qashish South, el-Wad Cave and Terrace, Dederiyeh Cave, Jordan River Dureijat, Kharaneh IV, Nahal Ein Gev II, Rakefet Cave, Shubayqa 1, and Uyun el-Hammam (Maher et al. 2011b; Weinstein-Evron et al. 2012, 2018; Richter et al. 2013, 2017; Grosman et al. 2016; Yaroshevich et al. 2016; Caracuta et al. 2016a; Nishiaki et al. 2017; Barzilai et al. 2017; Sharon et al. 2020; Belli et al. 2023). At the time of publication, the current study has not been updated with newly published dates in Abadi et al. (2024).

In screening the available dates, this study aimed to be as inclusive as possible, seeking to capture chronological signals of human activity depositionally associated with Epipalaeolithic material culture. Thus, dates from likely intrusive or mixed units were often included. Individual outlying assays were removed from the analysis only if they fell more than 2000 radiocarbon years outside the range of the remaining available dates for the technocomplex associated with it. While scrubbing outliers far older or younger than other contexts associated with a given technocomplex, this screening approach is nevertheless looser than some previous analyses, including those seeking to assess intrasite sequences and their relevance for measuring settlement density and duration of occupation (Blockley and Pinhasi 2011; Benz et al. 2012; Wicks et al. 2016; Jacobsson 2019; Birch-Chapman and Jenkins 2019). Again, the aim of this study is to look at the overall radiocarbon calibration signature of human settlement activity across the Epipalaeolithic span. For this reason, except for clear outliers, along with older assays on bone collagen and some conventional assays with very large standard errors or known problems with laboratory procedures (Blockley et al. 2006; Jacobsson 2019) all published dates from stratigraphically defined, technocomplex-associated units were included. While most of the 59 sites studied have a single component, many have successive stratified units that may be associated with different Epipalaeolithic technocomplexes. A total of 71 technocomplex-associated components had at least one radiocarbon date. Altogether, 321 dates were included in the analysis. A decision was made to represent the Natufian occupation of Abu Hureyra (Moore et al. 2000) by stratigraphically associated dates on bone collagen, in order to avoid uncertainty over post-depositional movement of charred seeds, including those from overlying, much later Pre-Pottery Neolithic deposits. A list of published radiocarbon dates, as of 2023, from buried Epipalaeolithic archaeological contexts in the Levant is included in the online project dataset.

14.3.2 Radiocarbon Date Calibration and Standardized Probability Density Distributions

Each of the 321 radiocarbon dates was calibrated in Excel, using the INTCAL 2020 atmospheric Northern Hemisphere calibration curve (Reimer et al. 2020). The calibration data were imported into Excel from the data file available in the Calib (rev. 8) software package (Stuiver and Reimer 1993). These data were interpolated with a cubic spline function (Jenkins 2009), producing an annually resolved calibration curve, spanning 0 BP (1950 CE) to 55,000 BP. Yearly relative probabilities were calculated according to Bronk Ramsey (1998), with the area under the curve from 0 to 55,000 BP standardized to one. The calibration PDD for each date was thus approximated by 55,000 chronologically ordered rectangles of width one year.

Because the database includes both single-component sites with one date and recently excavated sites with as many as 29 assays (el-Wad Terrace's Early Natufian component), each of the 71 stratigraphically discrete units was represented by a summed and standardized radiocarbon calibration PDD. This decision was essential. It avoids producing a Levantine summed calibration PDD distorted by recent research history, overrepresenting a relatively small handful of sites. The summed "PDD of PDDs" combining the 71 archaeological units was again standardized to area 1 between 0 and 55,000 BP, and the resulting probabilities were binned into 15 ordered 1000-year sets, from 25,000 to 10,000 BP. This interval encompassed 99.6% of the "PDD of PDDs" for the Levantine Epipalaeolithic dataset. The 1000-year probabilities were corrected for time-dependent likelihood of taphonomic loss, according to the equation for open-air sites in Surovell et al. (2009). For purposes of further analysis, the 25–10,000 BP PDD, divided into corrected millennial bins, was standardized to encompass an area of one.

14.3.3 Statistical Methods

A polynomial curve was fitted to the probabilities associated with the bins, using the millennial midpoint as the date (in years BP) for each bin. The best-fit polynomial function was determined by adding exponential terms to the time-before-present variable, up to the last order that significantly increased the R^2 value for fit to the observed data, according to the F-statistic (McDonald 2014). In order to account for possible temporal autocorrelation, the significance of the best-fit polynomial function was evaluated with the Mantel test for multiple regression (Smouse et al. 1986), modified from this author's previously published Mantel test procedure in Excel (Stutz et al. 2009). Excel VBA code and data, along with the full study data set and calibration calculations with the INTCAL 2020 curve, are provided in the online project dataset.

The best-fit polynomial equation—which represents a smoothed, taphonomically corrected PDD for the Epipalaeolithic time frame—was used, along with the annual INTCAL 2020 ATM Northern Hemisphere calibration curve, to generate a large number of random radiocarbon dates. By reversing the taphonomic correction, this procedure produced radiocarbon dates in direct proportion to the polynomial function's probabilities across the 25–10,000 BP interval. The error terms for the simulated radiocarbon dates were randomly chosen on a normal distribution, based on the mean and standard deviation of the standard errors for the 321 ^{14}C dates included in the study. Together, the simulated dates were used to determine the expected Levantine Epipalaeolithic PDD for a continuous, smooth demographic history, without any short-term fluctuations. Confidence intervals for the smoothed PDD were estimated by repeatedly randomly sampling—with replacement—71 dates from the simulated data set. The resampling procedure was carried out 1000 times in Excel (Excel VBA code and macro-procedure output included in the supplementary online materials). The 95% confidence bands around the median values allow identification of unusually large deviations in the observed Levantine Epipalaeolithic calibration PDD, signalling fluctuations that are significantly unlikely to be artefacts of the INTCAL 2020 ATM calibration curve.

14.4 Results

The calibration analysis yielded unambiguous support for the first hypothesis, that over the course of the Epipalaeolithic, there was a long-term trend of a rising human population footprint in the Levant. This finding indicates that hunter-gatherer communities recurrently raised culturally mediated carrying capacity in the region. Figure 14.3 shows the observed summed and standardized calibration PDD for the 71 Epipalaeolithic archaeological units in the study. While the annually resolved Levantine data exhibit substantial fluctuations, especially coinciding with the Late Natufian time frame, the best-fit curve for the millennially binned probability density values show an increasing population footprint over millennial timescales (Fig. 14.4). It is outside the scope of this paper to evaluate whether the abrupt drop-off in probability density at the end of the Epipalaeolithic marks a brief population decline. Alternatively, this may be a truncation effect of including only data on Epipalaeolithic contexts; the hypothesis must also bear in mind that the right-hand fall-off in probability density values marks a complex—and still poorly understood—shift to Pre-Pottery Neolithic A material culture (Blockley and Pinhasi 2011; Finlayson et al. 2011a; Wicks et al. 2016), in which case, the Epipalaeolithic-PPNA transition likely began in the centuries prior to the Pleistocene-Holocene transition (Bar-Yosef 2009).

Figure 14.4 illustrates both the uncorrected and the taphonomically corrected binned values, along with the curve for the best-fit fourth-degree polynomial function for the corrected values. The coefficient of multiple determination, R^2, was calculated based on the pairwise distance matrices used in the Mantel test procedure. The R^2 value for the fourth-degree polynomial model is 0.784. With 100,000 random permutations of the 15×15 pairwise distance matrix for the millennially binned and taphonomically corrected probability density values, the associated p-value for the fourth-degree polynomial model is 0.001 (in the run for this publication, 106 random permutations gave equal or higher R^2-values, compared to observed). The sigmoid shape of the millennially smoothed trend suggests that a bioculturally evolutionary dynamic, involving a recurrent carrying-capacity increase and long-term average population growth, took hold in the Early Epipalaeolithic time frame, accelerating

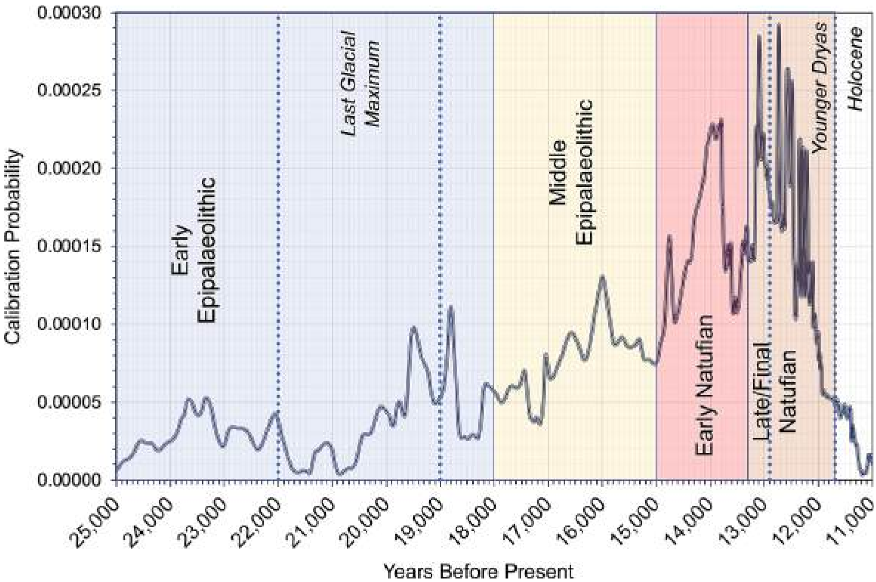

Fig. 14.3 Standardized probability density values for combined 71 calibration PDDs analysed in the study, with major Epipalaeolithic and palaeoclimatic chronological markers shown

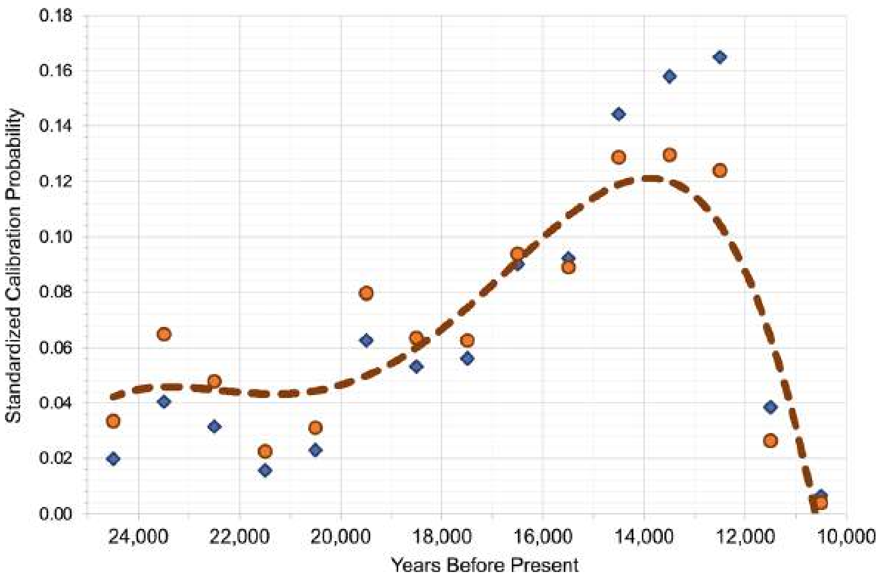

Fig. 14.4 Uncorrected (blue diamonds) and taphonomically corrected (orange circles) probability density values for 1000-year bins. Dashed line: best-fit fourth-degree polynomial function for taphonomically corrected PD values ($R^2 = 0.78$)

into the Middle Epipalaeolithic phase, only to decelerate in the Late Epipalaeolithic phase (see Figs. 14.3 and 14.4).

The results generally do not support the second hypothesis, that significant decadal or centennial demographic fluctuations may be resolved in the available radiocarbon data. Figure 14.5 illustrates that the fluctuations in the observed Levantine Epipalaeolithic calibration PDD (compound line) are substantially larger than the artefacts of the calibration curve alone. The latter (solid line) are made visible from the summed standardized calibration PDD for the radiocarbon dates simulated in proportion to the millennially smoothed model PDD. Yet, the bootstrapping procedure, repeatedly randomly resampling with replacement 71 simulated dates, yielded 95% confidence intervals that almost entirely encompassed these observed fluctuations. Figure 14.6 provides a graphical argument for why the null hypothesis, that the observed PDD fluctuations are independent of past human–environment system dynamics, cannot be rejected. The observed PDD reflects instead random effects of site preservation and discovery. Analysis of ethnographically documented hunter-gatherer age-specific mortality and fertility patterns indicates that past populations must have undergone repeated, irregular boom-bust demographic cycles (Hamilton and Walker 2018; Gurven and Davison 2019). Such dynamics are not currently resolvable in the available Levantine record.

The significantly high probability density value of 12,476 BP (see Fig. 14.6) is consistent with the interpretation that the Late Natufian population reached a peak roughly four centuries after the relatively cool and dry onset of the Younger Dryas

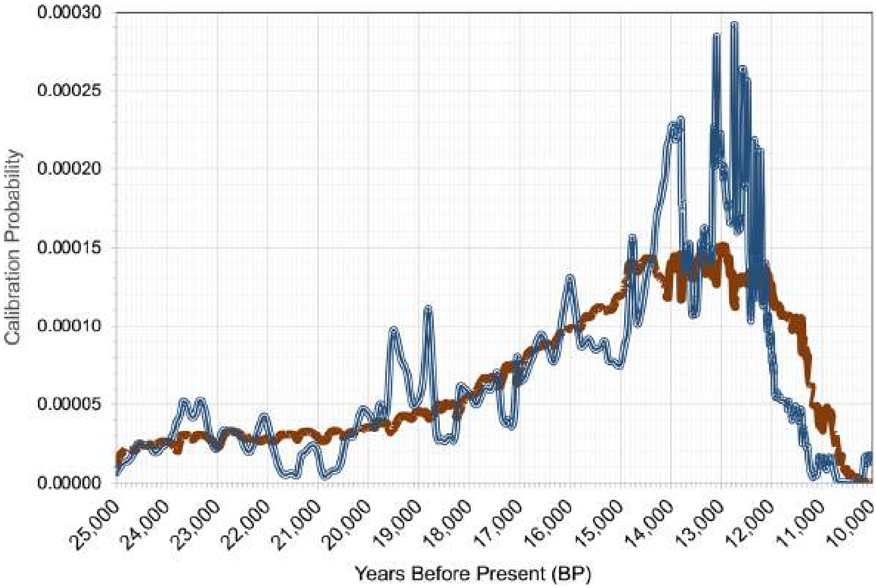

Fig. 14.5 Observed and simulated summed and standardized radiocarbon calibration probability density distributions. Compound line: calibration PDD for observed data. Solid line: calibration PDD for 34,282 radiocarbon dates representative of the best-fit fourth-degree polynomial function

period, only to decline somewhat afterwards. However, the decline in probability density after 12,476 BP may alternatively be explained by an as-yet poorly documented shift in intra-settlement density and geographic settlement distribution across the Levant. The tail end of the analysis time frame is marked by significantly high probability density values after 10,182 BP. Inspection of individual radiocarbon dates and within-site-component calibration PDDs (see online project dataset) reveals that, in this analysis, the conservatively inclusive criteria significantly affected Jordan River Dureijat's Late Natufian chronological span (Sharon et al. 2020). Indeed, at many sites, a number of charred seeds and wood-charcoal fragments from later periods have ended up being associated with older in situ material culture (Finlayson et al. 2011a). With only one annual point and a limited tail of the observed Levantine Epipalaeolithic calibration PDD falling outside the 95% confidence interval, the overwhelming statistical indication is that we cannot reject the null hypothesis of random sampling effects.

If we had adopted different screening criteria for published radiocarbon dates, the details would certainly have varied for the Levantine summed radiocarbon calibration PDD (see Figs. 14.3, 14.5, and 14.6). This source criticism issue is briefly addressed in the following discussion section, as it encompasses questions of taphonomy and the built environment as niche construction, especially in the Epipalaeolithic-Neolithic transition in the Northern Levant (Bar-Yosef 2009). Here, it is noted that Pre-Pottery Neolithic A-associated radiocarbon dates have not been included in this study because

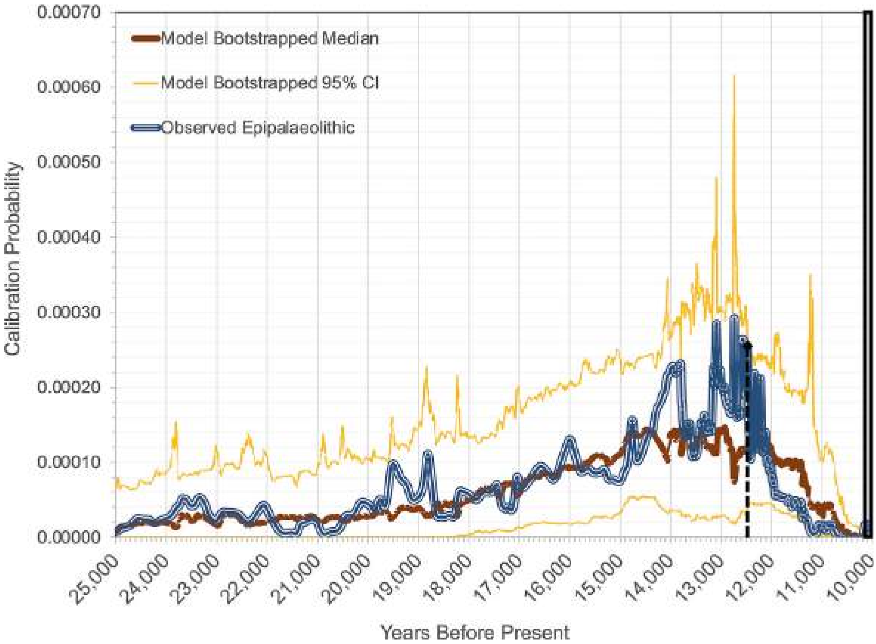

Fig. 14.6 Observed summed standardized calibration PDD for the Levantine Epipalaeolithic (compound line), viewed with the bootstrapped median, 68%, and 95% confidence intervals for 71 randomly resampled radiocarbon dates, drawn from the simulated millennially smoothed data set. Dashed-line marker: the year 12,476 cal BP has a statistically significantly high probability density. Solid rectangle marker: the right-hand tail, after 10,182 cal BP, has a statistically high probability density

PPNA settlement sites are often much larger than the most extensive Natufian hamlet sites (Bar-Yosef and Belfer-Cohen 1991; Bar-Yosef 1998), entailing a range of challenges for weighing the relationship between radiocarbon dates, site components, and population, so that Neolithic data may be reliably compared with Epipalaeolithic sources (Benz et al. 2012; Wicks et al. 2016; Jacobsson 2019; Birch-Chapman and Jenkins 2019).

14.5 Discussion

Overall, support for Hypothesis 1 is empirically robust, indicating a long-term, likely nonlinear rise in culturally mediated carrying capacity in the Levantine Epipalaeolithic time frame. However, the available radiocarbon data set does not offer support for Hypothesis 2, in that it cannot be massaged to reveal shorter-term probability density fluctuations that could be interpreted as demographic boom-bust cycles (see supplementary online materials for further details). This discussion considers implications for the proposed future-discounting-cycle model of long-term biocultural adaptation and niche construction of carrying capacity.

It may not be surprising that the region's centennially averaged census size was larger when its inhabitants were producing Natufian material culture than when earlier generations of foragers made Masraqan, Nebekian, or Kebaran retouched bladelets (cf. Goring-Morris and Belfer-Cohen 2017; Abadi et al. 2024). The radiocarbon calibration data are indeed concordant with archaeozoological data for the same time frame, indicating that human populations had a dramatically rising impact on key animal prey populations in the Southern Levant's Mediterranean vegetation zone (Stiner and Munro 2002; Munro 2004; Stutz et al. 2009; Munro et al. 2018). Data on artefact density relative to deposit volume is further consistent with the long-term rising population footprint in the Epipalaeolithic archaeological record (Bar-Yosef and Belfer-Cohen 1991; Hardy-Smith and Edwards 2004; Edwards 2012). Moreover, although the Early and Late/Final Natufian technocomplexes are associated with limited evidence of regular food storage (Boyd 2006), the emergence of sedentary hamlets with durable architecture points toward a relatively high Natufian population density. Some Natufian and Harifian (ca. 15–12,000 cal BP) arid-zone camps incorporated durable residential architecture (Goring-Morris 1987; Henry 1989; Goring-Morris et al. 1999; Goring-Morris and Belfer-Cohen 2003b, 2008, 2019; Finlayson et al. 2011a; Richter et al. 2017, 2019; Belfer-Cohen and Goring-Morris 2020), reflecting socially structured, stable land tenure associated with expected seasonal reoccupation. It is likely that, viewed across biomass-productivity clines (Stutz 2024, 2025), Epipalaeolithic innovations in the organization of cooperative foraging, logistical mobility, and co-residence—which are materially manifested in archaeological traces of hunting gear, architectural structures, plant food processing technology, and ritual deposits, including feasting and mortuary features—led to significantly reduced per capita territorial requirements.

The millennial-scale increase in culturally mediated carrying capacity appears to have followed a trend that took off between 20 and 19,000 cal BP, toward the end of the Last Glacial Maximum (see Figs. 14.3, 14.4, and 14.5). This pattern of carrying-capacity increase either plateaued or decelerated after 13,000 cal BP, transgressing the onset of the Younger Dryas climatic reversal, which involved cooler temperatures and reduced precipitation for roughly 1200 years (Bar-Matthews et al. 1999). The correction for taphonomic loss of open-air sites (Surovell et al. 2009; Bluhm and Surovell 2019) supports a conservative test for an increased demographic footprint in the Levant. The maximum in radiocarbon calibration PD—whether taphonomically adjusted or not—is archaeologically associated with the Early Natufian, Late/Final Natufian, and Harifian technocomplexes. With these, we see a proliferation of durable structures and installations, along with the use of caves as ritual locales. Because these sites are more durable or protected, the taphonomic correction may underestimate the time-averaged overall census size across the communities that built, dwelled in, or utilized Early and Late Natufian hamlets, base camps, and ritual sites.

In clarifying signal and noise in the existing radiocarbon data, this study also highlights the current limits to the Levantine radiocarbon record's temporal resolution.

The model for long-term biocultural adaptation and niche construction of carrying capacity across spatial ecological gradients (presented in Sect. 14.2 above) may be well motivated on evolutionary and ecological grounds. The available radiocarbon evidence is nonetheless insufficient to indicate whether warmer and wetter periods tended to catalyse higher rates of innovation and carrying-capacity increase. Nor do the data support evaluating whether substantial population fluctuations and social reorganizations were likely to have occurred in wetter vegetation zones during warm periods. Nevertheless, in line with earlier analyses (Stutz et al. 2009; Stutz 2019), the results make it clear that cooler periods did not necessarily cause sustained demographic downturns, and biocultural evolutionary trends in carrying capacity transgressed climatic fluctuations (see Fig. 14.3). Notably, exploitation of wetland habitats and aquatic resources—in Mediterranean and arid zones alike—also persisted across millennial-scale climatic fluctuations (Ramsey and Rosen 2016; Nadel 2017; Yeomans et al. 2017; Sharon et al. 2020; Munro et al. 2021; Ramsey 2023). The regional environmental effects of Final Pleistocene climate change were unlikely to have been as substantial as once thought (Weinstein-Evron 1998; Caracuta et al. 2016b; Hartman et al. 2016; Yeomans et al. 2017). We may conclude that Epipalaeolithic hunter-gatherer communities tended to be resilient to prevailing declines in biomass productivity or water availability that climate change occasionally forced. However, it remains unclear why this adaptability encompassed recurrent adoption of organizational and technological innovations that raised maximum carrying capacity. In the remainder of this chapter, I address why it is so theoretically central to consider currently archaeologically invisible demographic fluctuations, their impacts on risk-taking, and their likely complex interplay with spatial biomass productivity clines.

Emphasizing that the observed sub-millennial fluctuations in the Levantine Epipalaeolithic calibration PDD do not exceed those from the bootstrap test, I offer a broader observation that contextualizes Levantine forager adaptability. The dated buried archaeological components comprising this study sample encompass the recurrent settlement and abandonment of localities on the landscape. The theoretical point of departure for this study is in the intersection between human demographic dynamics and evolution in complex human–environment systems. For this reason, this chapter has focused on *long-term adaptive change in culturally mediated carrying capacity*, considered in relation to systemically unpredictable and localized population fluctuations that varied in frequency and depth across strong biomass productivity gradients. For much of the Epipalaeolithic time frame, settlement localities were used as seasonal camps of varying occupational duration. Some were occupied briefly, perhaps only reused once or a handful of times (Goring-Morris 1987). Others were repeatedly reoccupied an unknown number of times, over centennial or even millennial scales. Cases falling into the latter category are especially well documented for the Early and Late/Final Natufian technocomplexes, but earlier examples are also well published (Bar-Yosef 1998; Moore et al. 2000; Bocquentin 2003; Valla et al. 2010; Richter et al. 2013, 2017; Yaroshevich et al. 2016; Nishiaki et al. 2017; Macdonald et al. 2018; Sharon et al. 2020). The forager networks that made, populated, were affected by, and then abandoned diverse settlement localities also maintained, reproduced, and negotiated change in a range of archaeologically recognizable technological practices across substantial geographic areas. This suggests continuous cross-generational cultural transmission throughout the Epipalaeolithic time span.

According to the model outlined above, ecologically structured demographic fluctuations—involving localized Malthusian downturns and recoveries—must have recurrently braked the centennial- and millennial-scale pace of increase in culturally mediated carrying capacity. It bears clarification that, especially in light of anthropological research on heterogeneity in life histories and demographic outcomes, population pressure is ever present in human–environment systems (Richerson et al. 2001, 2009; Bogin et al. 2007; Stutz 2020b; Stutz et al. 2021). Especially challenging for non-industrial populations are periods in which environmental deterioration coincides with relatively strong population regulation at prevailing culturally mediated carrying capacity. However, this is a situation in which the community would face the greatest downside risks for innovation; a failed strategy would have particularly dire consequences for average well-being (Rogers 1994). From a longer-term perspective, the interplay between spatially asynchronous, variably intense demographic fluctuations and their recurrence over time offers an opportunity for relatively low-risk adoption of innovations in recovery phases, followed by spreading to neighbouring regions (Stutz 2024). With the current resolution level in the Levantine Epipalaeolithic record, we still face the archaeological challenge of making visible these hidden hazards that are expected to have contributed to the long-term upward ratcheting of culturally mediated carrying capacity for hunter-gatherer-fisher populations in the final millennia of the Pleistocene.

14.6 Conclusion

At first glance, it may seem that this chapter has replaced one concern over teleology and prime-mover explanations with another. Neolithic agriculture and village life was neither foreordained nor evolutionarily inevitable. How, then, do we explain the preceding, long-term Levantine Epipalaeolithic increase in culturally mediated carrying capacity? Millennial-scale change in coupled human–environment systems unfolded at a critical biocultural intersection, which encompassed:

1. complex processes of cultural reproduction and intergenerational cultural transmission
2. the low-mortality-high-fertility human life history strategy
3. cycles in future-discounting forced by sporadic Malthusian downturns and recoveries
4. cultural management of social relationships, knowledge, and technologies for mobility, foraging, and dwelling across strong spatial gradients in ecological productivity.

The interplay between biocultural adaptation and niche construction would have been highly complex and, at times, chaotic. The system dynamics are unlikely to have generated a steady-state pattern of technological and organizational innovation, one that led to recurrent growing aggregate investment in reproduction and transfers to dependent offspring, underwriting a predictable long-term rise in carrying capacity. The results presented in this chapter suggest that further inquiry is needed into feedbacks among spatial gradients in biomass productivity, population fluctuations, and the adoption of innovations. Avoiding teleological or prime-mover arguments, this line of inquiry is offered as part of a more satisfying approach to explaining long-term prehistoric trends in human population growth.

Taking a concluding view, it is suggested that ongoing inquiry into coupled human–environment system change *across the Pleistocene-Holocene boundary* in the Levant would benefit from a focus on this intricate biocultural intersection. Here, it may be conceptually helpful to focus on figuring out a paradox, one that the study results reveal, when considered in light of recent work on plant domestication, settlement, and life history outcomes. On the one hand, recent research indicates that broad-spectrum gathering and low-level cultivation remained economically and culturally fundamental to communities throughout the Levant for nearly 2000 years of early Neolithic life. Certainly, Pre-Pottery Neolithic A and Early Pre-Pottery Neolithic B settlements (ca. 12,000–10,000 cal BP) exhibited substantial size increases over their Natufian predecessors, incorporating communal food storage and processing installations (Kuijt and Finlayson 2009; Finlayson et al. 2011b; Whitlam et al. 2023). Yet, the people who dwelled in them were hunter-gatherers who engaged in cultivation (Belfer-Cohen and Goring-Morris 2014; Kabukcu et al. 2021; Mithen 2022; Weide et al. 2022). They were not early farmers who had abandoned foraging. The hunter-gatherer cultural system was highly resilient.

On the other hand, the wider human–environment system that Levantine hunter-gatherer cultures were part of ratcheted up carrying capacity, via a long-term nonlinear complex dynamic. In the early Holocene, the feedback between change in settlement, food resource management, carrying capacity, and demographic fluctuations began to impact life history outcomes, resulting in rising mortality linked to domestication and agriculture in the Late PPNB, PPNC, and early Pottery Neolithic. Figure 14.7 illustrates results from a recent study (Stutz et al. 2021), showing the trend, by period, in the juvenility index (the proportion of individuals aged 5–19 years out of all individuals $\approx$5 years) for a comprehensive sample of individuals interred in Levantine Natufian and early Neolithic contexts. Several demographic analyses have found that the juvenility index—along with other measures sensitive to the proportions of juvenile individuals in archaeological mortuary assemblages—correlates most strongly with change in the population's fertility rate (Bocquet-Appel and Masset 1977; Sattenspiel and Harpending 1983; Bocquet-Appel 2011). More recently, Milner and Boldsen (2023) have shown that, when mortality is modelled as separate early-life, old-age, and age-independent components, the juvenility index is even more responsive to changes in the latter variable. For time-averaged archaeological samples, such as those underlying Fig. 14.7, the juvenility index may be seen as a rough, joint indicator of change in fertility and age-independent mortality.

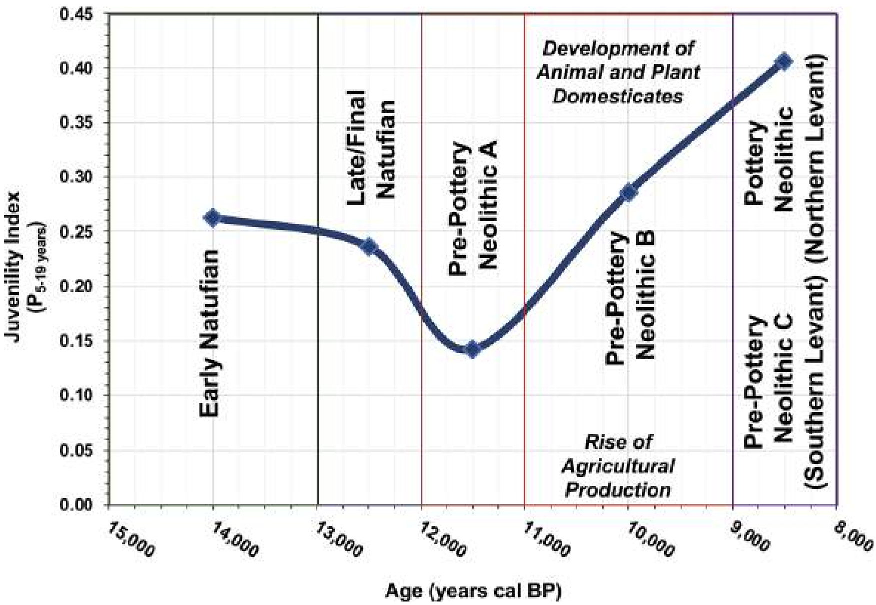

Fig. 14.7 Juvenility index (proportion of individuals 5–19 years old out of all individuals 5 years or older) for pooled Levantine mortuary samples by time period, with boundaries approximated to nearest millennium. Original data compiled by F. Bocquentin, B. Chamel, and M. Anton, analysed and published in Stutz et al. (2021). Modified after Stutz et al. (2021: Fig. 6)

With an expanded Natufian and Neolithic mortuary sample, Stutz et al. (2021) build on an earlier study (Guerrero et al. 2008), showing that the pre-agricultural trough in the juvenility index is associated with the PPNA, rather than the Late/Final Natufian. Moreover, they present evidence of the strong statistical association of early-life stress—skeletally recorded in dental linear enamel hypoplasias—with adolescent and early adult mortality (10–30 years at death). Earlier interpretations of the juvenility index have emphasized the rise in fertility with transition to agriculture, but it is now clearer that empirical data suggest a primary "Neolithic demographic transition" in which fertility and age-independent mortality followed a complex dynamic, eventually rising together with domestication and widespread adoption of dry-field agriculture (Bocquet-Appel 2008). In light of the theoretical ideas in this chapter, it may be argued that agriculture and village life emerged in the Middle and Late PPNB, when further upward ratcheting of culturally mediated carrying capacity co-developed with more frequent Malthusian downturns, accelerating cycles of future-discounting and innovation.

If this proves to have been the case, then forager cultural adaptive responsiveness, on the one hand, and coupled demographic fluctuation-innovation cycles, on the other, must be understood as operating on different timescales. The former was constituted by social experience and social interaction in material and semiotic environments shaped by technology and practice. It was the domain of lived, material lives, residing within the sphere of cultural practice and agency, rather than at the wider ecosystem level. For most of the Epipalaeolithic and early Neolithic, the latter occurred sporadically and unpredictably over intergenerational timescales, likely impossible to perceive and track through cultural systems. Thus, hunter-gatherers creatively used, reproduced, and altered available semiotic systems—often materialized in architecture, graves, figurines, tools, vessels, and food—to regenerate and care for social relationships, across substantial geographic areas. All the while, they traversed ecological zones, whose environmental possibilities for pluripresence (Bird-David 2017) changed over seasons, generations, centuries, and millennia, often thanks to cumulative anthropogenic ecological perturbation. The cultural capacity for being with many—in flexibly many ways—gave resilience to hunter-gatherers' socially constituted worlds, across complicated cycles of sedentism and mobility that cut through climatic fluctuations and transformative niche-construction impacts on food resource patches, built environments, and demographic systems. In the later transition to domestication and agriculture, did this resilience dissipate imperceptibly over generations? Or were more frequent demographic perturbations and recoveries experienced as a new kind of crisis?

Acknowledgements I am grateful to Sonja Grimm and Isabell Schmidt for their critical comments. I am also grateful to Marcel Bradtmöller for his editorial support and collegial encouragement. As author, I remain responsible for any and all shortcomings in this chapter.

Data Availability The data and Excel VBA code for this study are available in the open-access project dataset on the Mendeley data repository at https://doi.org/10.17632/7h6yd4vzkp.1.

References

Abadi I, Torfstein A, Friesem DE et al (2024) Heinrich Event 2 (ca. 24 ka BP) as a chrono-climatic anchor for the appearance of Epipaleolithic backed bladelets microlith industries in the Southern Levant. Quat Sci Rev 332:108649. https://doi.org/10.1016/j.quascirev.2024.108649

Anderson PC (ed) (1999) Prehistory of agriculture: new experimental and ethnographic approaches. University of California, Los Angeles, Los Angeles, Institute of Archaeology

Asouti E, Kabukcu C (2014) Holocene semi-arid oak woodlands in the Irano-Anatolian region of Southwest Asia: natural or anthropogenic? Quatern Sci Rev 90:158–182. https://doi.org/10.1016/j.quascirev.2014.03.001

Asouti E, Kabukcu C, White CE et al (2015) Early Holocene woodland vegetation and human impacts in the arid zone of the southern Levant. Holocene 25:1565–1580. https://doi.org/10.1177/0959683615580199

Aurenche O, Galet P, Régagnon-Caroline E, Évin J (2001) Proto-Neolithic and Neolithic cultures in the Middle East—the birth of agriculture, livestock raising, and ceramics: a calibrated 14C chronology 12,500–5500 cal BC. Radiocarbon 43:1191–1202. https://doi.org/10.1017/S0033822200038480

Bar-Matthews M, Ayalon A, Kaufman A et al (1999) The Eastern Mediterranean paleoclimate as a reflection of regional events: Soreq cave, Israel. Earth Planet Sci Lett 166:85–95. https://doi.org/10.1016/S0012-821X(98)00275-1

Barton CM, Riel-Salvatore J, Anderies JM et al (2011) Modeling human ecodynamics and biocultural interactions in the Late Pleistocene of Western Eurasia. Hum Ecol 39:705–725. https://doi.org/10.1007/s10745-011-9433-8

Bar-Yosef O (1998) The Natufian culture in the Levant, threshold to the origins of agriculture. Evol Anthropol 6:159–177. https://doi.org/10.1002/(SICI)1520-6505(1998)6:5%3c159::AID-EVAN4%3e3.0.CO;2-7

Bar-Yosef O (2009) Review of Le site néolithique de Tell Mureybet (Syrie du Nord). En hommage à Jacques Cauvin. Vol. I et II. (BAR Int. Ser. 1843). Paléorient 35:125–135

Bar-Yosef O, Belfer-Cohen A (1989) The origins of sedentism and farming communities in the Levant. J World Prehist 3:447–498. https://doi.org/10.1007/BF00975111

Bar-Yosef O, Belfer-Cohen A (1991) From sedentary hunter-gatherers to territorial farmers in the Levant. In: Gregg SA (ed) Between bands and states. Center for Archaeological Investigations, Carbondale, Illinois, pp 181–202

Bar-Yosef O, Kra RS (eds) (1994) Late quaternary chronology and paleoclimates of the eastern mediterranean. Radiocarbon in association with the American School of Prehistoric Research, Peabody Museum, Harvard University, Cambridge, MA, USA

Barzilai O, Rebollo N, Nadel D et al (2017) Radiocarbon dating of human burials from Raqefet Cave and contemporaneous Natufian traditions at Mount Carmel. Antiquity 91:1137–1154. https://doi.org/10.15184/aqy.2017.136

Belfer-Cohen A (1995) Rethinking social stratification in the Natufian culture: the evidence from burials. In: Campbell S, Green A (eds) The archaeology of death in the ancient Near East. Oxbow Books, Oxford, pp 9–16

Belfer-Cohen A, Bar-Yosef O (2002) Early sedentism in the Near East: a bumpy ride to village life. In: Kuijt I (ed) Life in Neolithic farming communities: social organization, identity and differentiation. Kluwer Academic/Plenum Publishers, New York, pp 19–37

Belfer-Cohen A, Goring-Morris N (2014) North and south—variable trajectories of the Neolithic in the Levant. In: Finlayson B, Makarewicz C (eds) Settlement, survey, and stone: essays on near eastern prehistory in honour of Gary Rollefson. Ex Oriente, Berlin, pp 61–71

Belfer-Cohen A, Goring-Morris N (2020) From the Epipalaeolithic into the earliest Neolithic (PPNA) in the South Levant. Documenta Praehistorica 47:36–52. https://doi.org/10.4312/dp.47.3

Belli C, Caracuta V, Nadel D et al (2023) Archaeobotany of el-Wad Terrace, Mount Carmel (Israel): insights into plant exploitation along the Natufian sequence. Veget Hist Archaeobot. https://doi.org/10.1007/s00334-023-00905-5

Benz M, CoǅCkun A, Hajdas I et al (2012) Methodological implications of new radiocarbon dates from the Early Holocene Site of Körtik Tepe, Southeast Anatolia. Radiocarbon 54:291–304. https://doi.org/10.1017/S0033822200047081

Birch-Chapman S, Jenkins E (2019) A Bayesian approach to calculating Pre-Pottery Neolithic structural contemporaneity for reconstructing population size. J Archaeol Sci 112:105033. https://doi.org/10.1016/j.jas.2019.105033

Bird-David N (2017) Us, relatives: scaling and plural life in a forager world. Univ of California Press, Berkeley

Bluhm LE, Surovell TA (2019) Validation of a global model of taphonomic bias using geologic radiocarbon ages. Quat Res 91:325–328. https://doi.org/10.1017/qua.2018.78

Blockley SPE, Pinhasi R (2011) A revised chronology for the adoption of agriculture in the Southern Levant and the role of Lateglacial climatic change. Quatern Sci Rev 30:98–108. https://doi.org/10.1016/j.quascirev.2010.09.021

Blockley SPE, Blockley SM, Donahue RE et al (2006) The chronology of abrupt climate change and Late Upper Palaeolithic human adaptation in Europe. J Quatern Sci 21:575–584. https://doi.org/10.1002/jqs.1041

Bocquentin F (2003) Pratiques funéraires, paramètres biologiques et identités culturelles au Natoufien: une analyse archéo-anthropologique. Thèse Doctorale

Bocquet-Appel JP (2011) The agricultural demographic transition during and after the agriculture inventions. Curr Anthropol 52:S497–S510. https://doi.org/10.1086/659243

Bocquet-Appel JP, Bar-Yosef O (2008) The neolithic demographic transition and its consequences. Springer Science & Business Media

Bocquet-Appel JP, Masset C (1977) Estimateurs en paléodémographie. L'Homme XVII:65–90

Bocquet-Appel JP (2008) Explaining the Neolithic demographic transition. In: Bocquet-Appel J-P, Bar-Yosef O (eds) The Neolithic demographic transition and its consequences. Springer Science+Business Media B.V., Cham, pp 35–55

Bogin B, Silva MIV, Rios L (2007) Life history trade-offs in human growth: adaptation or pathology? Am J Hum Biol 19:631–642. https://doi.org/10.1002/ajhb.20666

Boserup E (1965) The conditions of agricultural growth: the economics of Agrarian change under population pressure. Allen & Unwin, London

Bowles S, Choi JK (2013) Coevolution of farming and private property during the early Holocene. PNAS 110:8830–8835. https://doi.org/10.1073/pnas.1212149110

Boyd B (2006) On 'sedentism' in the Later Epipalaeolithic (Natufian) Levant. World Archaeol 38:164–178. https://doi.org/10.1080/00438240600688398

Bradtmöller M, Grimm S, Riel-Salvatore J (2017) Resilience theory in archaeological practice—an annotated review. Quatern Int 446:3–16. https://doi.org/10.1016/j.quaint.2016.10.002

Caracuta V, Weinstein-Evron M, Kaufman D et al (2016a) 14,000-year-old seeds indicate the Levantine origin of the lost progenitor of faba bean. Sci Rep 6:37399. https://doi.org/10.1038/srep37399

Caracuta V, Weinstein-Evron M, Yeshurun R et al (2016b) Charred wood remains in the Natufian sequence of el-Wad terrace (Israel): new insights into the climatic, environmental and cultural changes at the end of the Pleistocene. Quatern Sci Rev 131:20–32. https://doi.org/10.1016/j.quascirev.2015.10.034

Colson E (1979) The Harvey lecture series. In good years and in bad: food strategies of self-reliant societies. J Anthropol Res 35:18–29

Contreras DA, Meadows J (2014) Summed radiocarbon calibrations as a population proxy: a critical evaluation using a realistic simulation approach. J Archaeol Sci 52:591–608. https://doi.org/10.1016/j.jas.2014.05.030

Crema ER, Bevan A, Shennan S (2017) Spatio-temporal approaches to archaeological radiocarbon dates. J Archaeol Sci 87:1–9. https://doi.org/10.1016/j.jas.2017.09.007

Davison R, Gurven M (2022) The importance of elders: extending Hamilton's force of selection to include intergenerational transfers. Proc Natl Acad Sci 119:e2200073119. https://doi.org/10.1073/pnas.2200073119

Downey SS, Bocaege E, Kerig T et al (2014) The Neolithic demographic transition in Europe: correlation with Juvenility Index supports interpretation of the Summed Calibrated Radiocarbon Date Probability Distribution (SCDPD) as a valid demographic proxy. PLoS One 9:e105730. https://doi.org/10.1371/journal.pone.0105730

Dubreuil L (2004) Long-term trends in Natufian subsistence: a use-wear analysis of ground stone tools. J Archaeol Sci 31:1613–1629. https://doi.org/10.1016/j.jas.2004.04.003

Edwards PC (2012) Wadi Hammeh 27, an early Natufian settlement at Pella in Jordan. BRILL, Leiden

Eitam D (2019) Cereal processing in stone agri-technological system at late Natufian Huzuq Musa in the Jordan Valley. In: Squitieri A, Eitam D (eds) Stone tools in the Ancient Near East and Egypt: ground stone tools, rock-cut installations and stone vessels from Prehistory to Late Antiquity. Archaeopress, Oxford, pp 162–178

Fernández-López de Pablo J, Gutiérrez-Roig M, Gómez-Puche M et al (2019) Palaeodemographic modelling supports a population bottleneck during the Pleistocene-Holocene transition in Iberia. Nat Commun 10:1872. https://doi.org/10.1038/s41467-019-09833-3

Finlayson B, Mithen S, Smith S (2011a) On the edge: Southern Levantine Epipalaeolithic-Neolithic chronological succession. Levant 43:127–138. https://doi.org/10.1179/175638011X13112549592961

Finlayson B, Mithen SJ, Najjar M et al (2011b) Architecture, sedentism, and social complexity at Pre-Pottery Neolithic A WF16, Southern Jordan. PNAS 108:8183–8188. https://doi.org/10.1073/pnas.1017642108
Fitzhugh B (2001) Risk and invention in human technological evolution. J Anthropol Archaeol 20:125–167. https://doi.org/10.1006/jaar.2001.0380
Freeman J, Byers DA, Robinson E et al (2018) Culture process and the interpretation of radiocarbon data. Radiocarbon 60:453–467. https://doi.org/10.1017/RDC.2017.124
Freeman J, Hard RJ, Mauldin RP et al (2021) Radiocarbon data may support a Malthus-Boserup model of hunter-gatherer population expansion. J Anthropol Archaeol 63:101321. https://doi.org/10.1016/j.jaa.2021.101321
Freeman J, Mauldin RP, Whisenhunt M et al (2023) Repeated long-term population growth overshoots and recessions among hunter-gatherers. Holocene 09596836231183072. https://doi.org/10.1177/09596836231183072
Friesem DE, Abadi I, Shaham D et al (2019) Lime plaster cover of the dead 12,000 years ago—new evidence for the origins of lime plaster technology. Evol Hum Sci 1:e9. https://doi.org/10.1017/ehs.2019.9
Goring-Morris AN (1987) At the edge: terminal Pleistocene hunter-gatherers in the Negev and Sinai. British Archaeological Reports, Oxford
Goring-Morris AN, Belfer-Cohen A (2017) The Early and Middle Epipalaeolithic of Cisjordan. In: Enzel Y, Bar-Yosef O (eds) Quaternary environments, climate change and humans in the Levant. Cambridge University Press, New York, pp 639–649
Goring-Morris AN, Goldberg P, Goren Y et al (1999) Saflulim: a Late Natufian base camp in the Central Negev Highlands, Israel. Palest Explor Q 131:36–64. https://doi.org/10.1179/peq.1999.131.1.36
Goring-Morris AN, Belfer-Cohen A (2003a) More than meets the eye: studies on Upper Palaeolithic diversity in the Near East. Oxbow
Goring-Morris N, Belfer-Cohen A (2003b) Structures and dwellings in the Upper and Epi-Palaeolithic (ca 42–10k BP) Levant: profane and symbolic uses. In: Vasil'ev SA, Soffer O, Kozlowski J (eds) Perceived landscapes and built environments: the cultural geography of Late Paleolithic Eurasia. British Archaeological Reports, Oxford, pp 65–81
Goring-Morris AN, Belfer-Cohen A (2008) A roof over one's head: developments in Near Eastern residential architecture across the Epipalaeolithic–Neolithic Transition. In: Bocquet-Appel J-P, Bar-Yosef O (eds) The Neolithic demographic transition and its consequences. Springer Science+Business Media B.V., Cham, pp 239–286
Goring-Morris N, Belfer-Cohen A (2019) Packaging the Levantine Epipalaeolithic: a view from the Negev and Sinai. In: Astruc L, McCartney C, Briois F et al (eds) Near Eastern Lithic technologies on the move. Interactions and contexts in Neolithic traditions. 8th International conference on PPN chipped and ground stone industries of the Near East, Nicosia, November 23rd–27th 2016. Astrom Editions, Nicosia, pp 429–448
Grosman L, Munro ND (2016) A Natufian ritual event. Curr Anthropol 57:311–331. https://doi.org/10.1086/686563
Grosman L, Munro ND (2017) The Natufian culture: the harbinger of food-producing societies. In: Enzel Y, Bar-Yosef O (eds) Quaternary environments, climate change and humans in the Levant. Cambridge University Press, New York, pp 699–707
Grosman L, Munro ND, Abadi I et al (2016) Nahal Ein Gev II, a Late Natufian community at the Sea of Galilee. PLoS One 11:e0146647. https://doi.org/10.1371/journal.pone.0146647
Grosman L (2013) The Natufian chronological scheme—new insights and their implications. In: Bar-Yosef O, Valla FR (eds) Natufian foragers in the Levant: terminal Pleistocene social changes in Western Asia: [papers from a symposium held in 2009]. Ann Arbor, pp 622–637
Guerrero E, Naji S, Bocquet-Appel JP (2008) The signal of the Neolithic demographic transition in the Levant. In: Bocquet-Appel JP, Bar-Yosef O (eds) The Neolithic demographic transition and its consequences. Springer Science & Business Media, New York, pp 57–80

Gunderson LH, Holling CS (eds) (2001) Panarchy: understanding transformations in human and natural systems. Island Press
Gurven MD, Davison RJ (2019) Periodic catastrophes over human evolutionary history are necessary to explain the forager population paradox. PNAS 116:12758–12766. https://doi.org/10.1073/pnas.1902406116
Gurven M, Kaplan H (2007) Longevity among hunter- gatherers: a cross-cultural examination. Popul Dev Rev 33:321–365. https://doi.org/10.1111/j.1728-4457.2007.00171.x
Hamilton MJ, Walker RS (2018) A stochastic density-dependent model of long-term population dynamics in hunter-gatherer populations. Evol Ecol Res 19:85–102
Hamilton MJ, Milne BT, Walker RS et al (2007) The complex structure of hunter–gatherer social networks. Proc R Soc B 274:2195–2203. https://doi.org/10.1098/rspb.2007.0564
Hardy-Smith T, Edwards PC (2004) The Garbage Crisis in prehistory: artefact discard patterns at the Early Natufian site of Wadi Hammeh 27 and the origins of household refuse disposal strategies. J Anthropol Archaeol 23:253–289. https://doi.org/10.1016/j.jaa.2004.05.001
Hartman G, Bar-Yosef O, Brittingham A et al (2016) Hunted gazelles evidence cooling, but not drying, during the Younger Dryas in the southern Levant. PNAS 113:3997–4002. https://doi.org/10.1073/pnas.1519862113
Henry DO (1989) From foraging to agriculture: the Levant at the end of the Ice Age. University of Pennsylvania Press, Philadelphia
Hill KR, Hurtado AM (1996) Aché life history: the ecology and demography of a foraging people. Aldine de Gruyter, New York
Hill K, Hurtado AM, Walker RS (2007) High adult mortality among Hiwi hunter-gatherers: implications for human evolution. J Hum Evol 52:443–454. https://doi.org/10.1016/j.jhevol.2006.11.003
Hill K, Barton M, Hurtado AM (2009) The emergence of human uniqueness: characters underlying behavioral modernity. Evol Anthropol Issues News Rev 18:187–200. https://doi.org/10.1002/evan.20224
Jacobsson P (2019) Challenges and prospects for building radiocarbon chronologies of the earlier Holocene of the Levant. Levant 51:6–25. https://doi.org/10.1080/00758914.2019.1689747
Jenkins D (2009) Cubic splines. In: Newton Excel Bach. http://newtonexcelbach.wordpress.com/2009/07/02/cubic-splines/. Accessed 5 Jul 2013
Kabukcu C, Asouti E, Pöllath N et al (2021) Pathways to plant domestication in Southeast Anatolia based on new data from aceramic Neolithic Gusir Höyük. Sci Rep 11:2112. https://doi.org/10.1038/s41598-021-81757-9
Kelly RL, Surovell TA, Shuman BN et al (2013) A continuous climatic impact on Holocene human population in the rocky mountains. PNAS 110:443–447. https://doi.org/10.1073/pnas.1201341110
Kuijt I, Finlayson B (2009) Evidence for food storage and predomestication granaries 11,000 years ago in the Jordan Valley. PNAS 106:10966–10970. https://doi.org/10.1073/pnas.0812764106
Kuijt I, Prentiss AM (2009) Niche construction, macroevolution, and the Late Epipaleolithic of the Near East. In: Prentiss A, Kuijt I, Chatters JC (eds) Macroevolution in human prehistory. Springer, New York, pp 253–271
Lee RD (1986) Malthus and Boserup: a dynamic synthesis. The state of population theory: forward from Malthus. Basil Blackwell, London, pp 96–130
Macdonald DA, Allentuck A, Maher LA (2018) Technological change and economy in the Epipalaeolithic: assessing the shift from early to middle Epipalaeolithic at Kharaneh IV. J Field Archaeol 43:437–456. https://doi.org/10.1080/00934690.2018.1504542
Maher LA, Banning EB, Chazan M (2011a) Oasis or mirage? Assessing the role of abrupt climate change in the prehistory of the Southern Levant. Camb Archaeol J 21:1–30. https://doi.org/10.1017/S0959774311000011
Maher LA, Stock JT, Finney S et al (2011b) A unique human-fox burial from a pre-Natufian cemetery in the Levant (Jordan). PLoS One 6:e15815. https://doi.org/10.1371/journal.pone.0015815

Maher LA, Richter T, Stock JT (2012) The pre-Natufian epipaleolithic: long-term behavioral trends in the Levant. Evol Anthropol Issues News Rev 21:69–81. https://doi.org/10.1002/evan.21307
Maher LA, Macdonald DA, Pomeroy E, Stock JT (2021) Life, death, and the destruction of architecture: hunter-gatherer mortuary behaviors in prehistoric Jordan. J Anthropol Archaeol 61:101262. https://doi.org/10.1016/j.jaa.2020.101262
McDonald JH (2014) Handbook of biological statistics, 3rd edn. Sparky House Publishing, Baltimore, Maryland
Milner GR, Boldsen JL (2023) Population trends and the transition to agriculture: global processes as seen from North America. Proc Natl Acad Sci 120:e2209478119. https://doi.org/10.1073/pnas.2209478119
Minc LD (1986) Scarcity and survival: the role of oral tradition in mediating subsistence crises. J Anthropol Archaeol 5:39–113. https://doi.org/10.1016/0278-4165(86)90010-3
Mithen S (2022) Shamanism at the transition from foraging to farming in Southwest Asia: sacra, ritual, and performance at Neolithic WF16 (southern Jordan). Levant 54:158–189. https://doi.org/10.1080/00758914.2022.2104559
Mohlenhoff KA, Codding BF (2017) When does it pay to invest in a patch? The evolution of intentional niche construction. Evol Anthropol 26:218–227. https://doi.org/10.1002/evan.21534
Moore AMT, Hillman GC, Legge AJ (eds) (2000) Village on the Euphrates: from foraging to farming at Abu Hureyra. Oxford University Press, Oxford and New York
Munro ND (2004) Zooarchaeological measures of hunting pressure and occupation intensity in the Natufian: implications for agricultural origins. Curr Anthropol 45:S5–S34. https://doi.org/10.1086/422084
Munro ND, Grosman L (2010) Early evidence (ca. 12,000 B.P.) for feasting at a burial cave in Israel. PNAS 107:15362–15366. https://doi.org/10.1073/pnas.1001809107
Munro ND, Bar-Oz G, Meier JS et al (2018) The emergence of animal management in the Southern Levant. Sci Rep 8:9279. https://doi.org/10.1038/s41598-018-27647-z
Munro ND, Petrillo AN, Grosman L (2021) Specialized aquatic resource exploitation at the Late Natufian site of Nahal Ein Gev II, Israel. Archaeol Anthropol Sci 13:6. https://doi.org/10.1007/s12520-020-01257-1
Nadel D (2017) Ohalo II: A 23,000-year-old fisher-hunter-gatherer's camp on the shore of fluctuating Lake Kinneret (Sea of Galilee). In: Enzel Y, Bar-Yosef O (eds) Quaternary environments, climate change and humans in the Levant. Cambridge University Press, New York, pp 291–294
Nishiaki Y, Yoneda M, Kanjou Y et al (2017) Natufian in the North: the Late Epipaleolithic cultural entity at Dederiyeh Cave, Northwest Syria. Paléorient 43:7–24
Nørskov Pedersen P, Richter T, Arranz-Otaegui A (2016) Preliminary analysis of the Late Natufian ground stone from Shubayqa 1, Jordan. J Lithic Stud 3:379–402. https://doi.org/10.2218/jls.v3i3.1647
Odling-Smee FJ, Feldman MW, Laland KN (2003) Niche construction: the neglected process in evolution. Princeton University Press, Princeton
Paige J, Perreault C (2022) How surprising are lithic reduction strategies? The information entropy of the modes A-I framework. Lithic Technol 0:1–16. https://doi.org/10.1080/01977261.2022.2113699
Palmisano A, Woodbridge J, Roberts CN et al (2019) Holocene landscape dynamics and long-term population trends in the Levant. Holocene 29:708–727. https://doi.org/10.1177/0959683619826642
Puleston C, Winterhalder B (2019) Demography, environment, and human behavior. In: Prentiss AM (ed) Handbook of evolutionary research in archaeology. Springer International Publishing, Cham, pp 311–335
Ramsey CB (1998) Probability and dating. Radiocarbon 40:461–474
Ramsey MN (2023) Ecological-cultural inheritance in the wetlands: the non-linear transition to plant food production in the southern Levant. Veget Hist Archaeobot. https://doi.org/10.1007/s00334-023-00908-2

Ramsey MN, Rosen AM (2016) Wedded to wetlands: exploring Late Pleistocene plant-use in the Eastern Levant. Quatern Int 396:5–19. https://doi.org/10.1016/j.quaint.2015.10.109

Reimer PJ, Austin WEN, Bard E et al (2020) The IntCal20 northern hemisphere radiocarbon age calibration curve (0–55 cal kBP). Radiocarbon 1–33.https://doi.org/10.1017/RDC.2020.41

Richerson PJ, Boyd R, Bettinger RL (2001) Was agriculture impossible during the Pleistocene but mandatory during the Holocene? A climate change hypothesis. Am Antiq 66:387–411. https://doi.org/10.2307/2694241

Richerson PJ, Boyd R, Bettinger RL (2009) Cultural innovations and demographic change. hbio 81:211–235. https://doi.org/10.3378/027.081.0306

Richter T, Maher LA, Garrard AN et al (2013) Epipalaeolithic settlement dynamics in southwest Asia: new radiocarbon evidence from the Azraq Basin. J Quatern Sci 28:467–479. https://doi.org/10.1002/jqs.2629

Richter T, Arranz-Otaegui A, Yeomans L et al (2017) High resolution AMS dates from Shubayqa 1, northeast Jordan reveal complex origins of Late Epipalaeolithic Natufian in the Levant. Sci Rep 7:17025. https://doi.org/10.1038/s41598-017-17096-5

Richter T, Bocaege E, Ilsøe P et al (2019) Ochre, ground stone, and wrapping the dead in the Late Epipalaeolithic (Natufian) Levant: revealing the funerary practices at Shubayqa 1, Jordan. J Field Archaeol 44:440–457. https://doi.org/10.1080/00934690.2019.1645546

Riris P, Silva F, Crema E et al (2024) Frequent disturbances enhanced the resilience of past human populations. Nature 1–6. https://doi.org/10.1038/s41586-024-07354-8

Rivals F, Rabinovich R, Khalaily H et al (2020) Seasonality of the final Natufian occupation at Eynan/Ain Mallaha (Israel): an approach combining dental ageing, mesowear and microwear. Archaeol Anthropol Sci 12:232. https://doi.org/10.1007/s12520-020-01190-3

Rogers AR (1994) Evolution of time preference by natural selection. Am Econ Rev 84:460–481

Rosen AM, Rivera-Collazo I (2012) Climate change, adaptive cycles, and the persistence of foraging economies during the late Pleistocene/Holocene transition in the Levant. PNAS 109:3640–3645. https://doi.org/10.1073/pnas.1113931109

Rosenberg D, Nadel D (2014) The sounds of pounding: boulder mortars and their significance to Natufian burial customs. Curr Anthropol 55:784–812. https://doi.org/10.1086/679287

Rosenberg D, Gluhak TM, Kaufman D et al (2021) Exploring exchange and direct procurement strategies for Natufian food processing tools of el-Wad Terrace, Israel. Sci Rep 11:9480. https://doi.org/10.1038/s41598-021-88484-1

Sattenspiel L, Harpending H (1983) Stable populations and skeletal age. Am Antiq 48:489–498. https://doi.org/10.2307/280557

Sharon G, Grosman L, Allué E et al (2020) Jordan River Dureijat: 10,000 years of intermittent Epipaleolithic activity on the shore of Paleolake Hula. PaleoAnthropology 2020:34–64. https://doi.org/10.4207/PA.2020.ART141

Shennan S, Edinborough K (2007) Prehistoric population history: from the Late Glacial to the Late Neolithic in Central and Northern Europe. J Archaeol Sci 34:1339–1345. https://doi.org/10.1016/j.jas.2006.10.031

Shennan S, Downey SS, Timpson A et al (2013) Regional population collapse followed initial agriculture booms in mid-Holocene Europe. Nat Commun 4:2486. https://doi.org/10.1038/ncomms3486

Smouse PE, Long JC, Sokal RR (1986) Multiple regression and correlation extensions of the mantel test of matrix correspondence. Syst Zool 35:627–632. https://doi.org/10.2307/2413122

Solich M, Bradtmöller M (2017) Socioeconomic complexity and the resilience of hunter-gatherer societies. Quatern Int 446:109–127. https://doi.org/10.1016/j.quaint.2017.06.064

Stiner MC, Munro ND (2002) Approaches to prehistoric diet breadth, demography, and prey ranking systems in time and space. J Archaeol Method Theory 9:181–214. https://doi.org/10.1023/A:1016530308865

Stuiver M, Reimer PJ (1993) Extended 14C data base and revised CALIB 3.0 14C age calibration program. Radiocarbon 35:215–230. https://doi.org/10.1017/S0033822200013904

Stutz AJ (2009) The "Nature of Transitions" in the stone age: a comparative perspective. In: Shea JJ, Lieberman DE (eds) Transitions in prehistory: papers in honor of Ofer Bar-Yosef. Harvard University American School of Prehistoric Research, Cambridge, MA, USA, pp 477–498
Stutz AJ (2014) Modeling the pre-industrial roots of modern super-exponential population growth. PLoS One 9:e105291. https://doi.org/10.1371/journal.pone.0105291
Stutz AJ (2020a) The Middle-Upper Paleolithic transition: a long-term biocultural effect of anatomically modern human dispersal. In: Groucutt HS (ed) Culture history and convergent evolution: can we detect populations in prehistory? Springer International Publishing, Cham, pp 157–186
Stutz AJ (2020b) A niche of their own: population dynamics, niche diversification, and biopolitics in the recent biocultural evolution of hunter-gatherers. J Anthropol Archaeol 57:101120. https://doi.org/10.1016/j.jaa.2019.101120
Stutz AJ, Munro ND, Bar-Oz G (2009) Increasing the resolution of the broad spectrum revolution in the Southern Levantine Epipaleolithic (19–12 ka). J Hum Evol 56:294–306. https://doi.org/10.1016/j.jhevol.2008.10.004
Stutz AJ (2019) Near east (including Anatolia): geographic description and general chronology of the Paleolithic and Neolithic. In: Encyclopedia of global archaeology, 2nd edn. Springer Nature Switzerland AG, New York. https://doi.org/10.1007/978-3-319-51726-1_1910-3
Stutz AJ, Bocquentin F, Chamel B, Anton M (2021) The effects of early childhood stress on mortality under neolithization in the Levant: new perspectives on health disparities in the transition to agriculture. Paléorient 47:45–70
Stutz AJ (2024) Spatial ecological gradients and non-equilibrium niche construction dynamics in the Levantine Middle-Upper Palaeolithic transition. J Archaeol Sci Rep 55:104504. https://doi.org/10.1016/j.jasrep.2024.104504
Stutz AJ (2025) The Natufian Archaeological culture in southwestern Asian Epipalaeolithic context. In: Nilsson Stutz LG, Peyroteo-Stjerna R, Torv M (eds) The Oxford handbook of Mesolithic Europe. Oxford University Press, Oxford, pp 401–420
Surovell TA, Byrd Finley J, Smith GM et al (2009) Correcting temporal frequency distributions for taphonomic bias. J Archaeol Sci 36:1715–1724. https://doi.org/10.1016/j.jas.2009.03.029
Tallavaara M, Luoto M, Korhonen N et al (2015) Human population dynamics in Europe over the Last Glacial maximum. PNAS 112:8232–8237. https://doi.org/10.1073/pnas.1503784112
Valla FR, Khalaily H, Samuelian N et al (2010) What Happened in the final Natufian? Mitekufat Haeven: J Israel Prehist Soc 131–148
Weide A, Green L, Hodgson JG et al (2022) A new functional ecological model reveals the nature of early plant management in southwest Asia. Nat Plants 8:1–12. https://doi.org/10.1038/s41477-022-01161-7
Weinstein-Evron M (1998) Early Natufian El-Wad revisited. University of Liège, Liège
Weinstein-Evron M, Yeshurun R, Kaufman D et al (2012) New 14C dates for the Early Natufian of El-Wad Terrace, Mount Carmel, Israel. Radiocarbon 54:813–822. https://doi.org/10.1017/S0033822200047469
Weinstein-Evron M, Yeshurun R, Ashkenazy H et al (2018) After 80 years—deeper in the Natufian Layers of el-Wad Terrace, Mount Carmel, Israel. J Israel Prehist Soc 48:5–61
Weissbrod L, Marshall FB, Valla FR et al (2017) Origins of house mice in ecological niches created by settled hunter-gatherers in the Levant 15,000 y ago. PNAS 114(16):201619137. https://doi.org/10.1073/pnas.1619137114
Whallon R (1989) Elements of cultural change in the later Paleolithic. In: Mellars P, Stringer CB (eds) The human revolution: behavioural and biological perspectives on the origins of modern humans. Edinburgh University Press, Edinburgh, pp 433–454
Whallon R (2006) Social networks and information: non-"utilitarian" mobility among hunter-gatherers. J Anthropol Archaeol 25:259–270. https://doi.org/10.1016/j.jaa.2005.11.004
Whitlam J, Finlayson B, Bogaard A et al (2023) Processing and storage of tree fruits, cereals and pulses at PPNA Sharara, southern Jordan. Veget Hist Archaeobot. https://doi.org/10.1007/s00334-023-00938-w

Wicks K, Finlayson B, Maričević D et al (2016) Dating WF16: exploring the chronology of a pre-pottery Neolithic a settlement in the Southern Levant. Proc Prehist Soc 82:73–123. https://doi.org/10.1017/ppr.2015.21

Winterhalder B, Puleston C, Ross C (2015) Production risk, inter-annual food storage by households and population-level consequences in seasonal prehistoric agrarian societies. Environ Archaeol 20:337–348. https://doi.org/10.1179/1749631415Y.0000000025

Wood JW (1998) A theory of preindustrial population dynamics. Demography economy and well-being in Malthusian systems. Curr Antropol 39:99–135

Wright KI (2014) Domestication and inequality? Households, corporate groups and food processing tools at Neolithic Çatalhöyük. J Anthropol Archaeol 33:1–33. https://doi.org/10.1016/j.jaa.2013.09.007

Yaroshevich A, Bar-Yosef O, Boaretto E et al (2016) A unique assemblage of engraved plaquettes from Ein Qashish South, Jezreel Valley, Israel: figurative and non-figurative symbols of Late Pleistocene hunters-gatherers in the Levant. PLoS One 11:e0160687. https://doi.org/10.1371/journal.pone.0160687

Yeomans L, Richter T, Martin L (2017) Environment, seasonality and hunting strategies as influences on Natufian food procurement: the faunal remains from Shubayqa 1. Levant 49:85–104. https://doi.org/10.1080/00758914.2017.1368820

Yeshurun R, Bar-Oz G, Kaufman D et al (2014a) Purpose, permanence, and perception of 14,000-year-old architecture: contextual taphonomy of food refuse. Curr Anthropol 55:591–618. https://doi.org/10.1086/678275

Yeshurun R, Bar-Oz G, Weinstein-Evron M (2014b) Intensification and sedentism in the terminal Pleistocene Natufian sequence of el-Wad Terrace (Israel). J Hum Evol 70:16–35. https://doi.org/10.1016/j.jhevol.2014.02.011

Yeshurun R, Boaretto E, Lev M et al (2025) A Natufian demographic cycle at el-Wad Terrace, Israel: The rise and fall of the architectural compound. Archaeol Res Asia 41:100599. https://doi.org/10.1016/j.ara.2025.100599

Zhu D, Galbraith ED, Reyes-García V, Ciais P (2021) Global hunter-gatherer population densities constrained by influence of seasonality on diet composition. Nat Ecol Evol 5:1536–1545. https://doi.org/10.1038/s41559-021-01548-3

Chapter 15
Resilience, Disaster, Risk and Hazard studies—The Benefits of Multidisciplinary Studies and Future Aspirations

Astrid J. Nyland, Noa Lavi, Marcel Bradtmöller, and Sonja B. Grimm

Abstract This paper synthesises returned-to terms, concepts and themes used throughout the book. Building on how the authors of the book have utilized central terms and concepts, we discuss six of the dominant terms (resilience, vulnerability, disasters, hazards, sustainability, and hunter-gatherers/small-scale societies). Through this, a need for continued inter-disciplinary conversations and acknowledgement of these terms' origins and research histories are emphasised. The multiple stories that this book has given voice to are also addressed, rooted in the various sources and methods used in the case studies that span a wide geographical scene (from Scandinavia to Japan), and offer a truly deep-time perspective (ranging from recent disasters to challenges with climate change in the Epi-Palaeolithic). The chapter closes with some future aspirations and lessons for working with human-environment interactions on different scales and more general implications for the possible role of small-scale decision-making for living well with environmental and climate change.

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M. Bradtmöller et al. (eds.), *Under Pressure?*, Human-Environment Interactions 10,
https://doi.org/10.1007/978-3-031-85348-7_15

Keyword Terminology · Scale · Inter-disciplinarity · Human-environment interactions

15.1 The Gap Between Knowledge and Action

In current research and everyday language, terms like resilience, sustainability, vulnerability, hazards and disasters are becoming increasingly common in conversations. The weather systems have become unpredictable, with the sun, rain, snow and wind causing intensified draughts, floods, avalanches (mud and snow), tornadoes and hurricanes. People are already living with hazards and the effects of climate change all over the world. Strong impacts are causing human suffering, but, like their ancestors, people are also adapting (Castro and Sen 2022).

Research on past climate change and knowledge of large-scale "geo-events" are currently providing data to reconstruct past trajectories aiding predictive modelling of future scenarios. The Arctic glaciers give detailed records of fluctuations in temperature and precipitation, ocean current changes and global geological events, like volcano eruptions. We therefore know that for the last 11,000 years in which humans invented domestic food production, metallurgy, writing, social inequality or industrialisation, the planet has been in an interglacial mode. This period, known as the Holocene, has been one of comparatively stable climatic conditions. This has sustained paleoclimate records which tell us that the scale and speed of the changes happening now are unprecedented compared with former Holocene fluctuations and the glaciers from which these paleoclimate data are collected are now melting.

All is not lost though. Due to data collection from the ice and advances in different sciences and monitoring equipment, there is increased understanding of the causes, developments and effects of climate changes on a global scale. For example, we understand why sea levels, climate and weather are changing, and why more natural hazards such as hurricanes, landslides, floods and draughts can turn into disasters. We should, therefore, be well-equipped to deal with hazards and take the necessary measures to prevent catastrophes or environmental degradation. But unfortunately, this is not the case. Despite a myriad of scientific data, when it comes to modelling future scenarios, drawing the necessary conclusions and taking appropriate actions, we are in unknown territory (pers.com. Kikki Flesche Kleiven, Director of the Bjerknes Centre for Climate research at the conference *Under Pressure*, Stavanger, June 2022) and the need for other, deep-time types of data becomes increasingly obvious (e.g. Burke et al. 2021; Degroot et al. 2021).

15.2 No Natural Disasters?

In an influential short paper by O'Keefe et al. (1976), they argue that to understand the root causes of what makes hazards become disasters, we need to acknowledge that there is nothing "natural" about disasters. This position is also taken by some of the authors of this volume (see Chmutina and von Meding Chap. 2; Heitz Chap. 4; Walker Chap. 5). Taking the "naturalness" out of the perception of why disasters happen, the understanding of the socio-political structures and mechanisms that either build resilient societies or leave these vulnerable to hazards come to the forefront. Combining this perspective with an intent to not only look for symptoms of an occurring or past disaster is the key to moving beyond environmental determinism. It also enables us to go beyond scientific misconceptions that "small-scale" societies or "hunter-gatherers" (see Chap. 1) were ruled only by climate and hazards that affected resources, forcing societies to react or adapt after the event. However, changing the focus is challenging, especially when studying the fragmented remains of prehistoric societies, where a tendency to reduce social developments to environmental adaptation caused by environmental changes still lingers (see the discussion in Robinson and Riede 2018). Acknowledging also the social ontology of disasters and crises (see Barrios Chap. 3; Nyland Chap. 7) is then a way forward to increase our understanding of social organisation, social strategies, and social mechanisms in past societies. This recognition also broadens our perception of the materiality of disasters and what a resilient or vulnerable society is or can be. The contribution of disciplines such as archaeology, anthropology and sociology can thus be instrumental in stimulating the building of more *inclusive, safe, resilient and sustainable* settlements and societies, as encouraged by the UN sustainable development goals (United Nations 2015). However, to achieve this, there are more issues that need to be addressed.

15.3 What's in a Name?

As mentioned in Chap. 1 and by several of the authors in this book, a recurring problem in interdisciplinary studies is that different fields of study or scientific disciplines use the same words or terminology but fill them with different meanings. With this book, we aim to maintain a dialogue across the boundaries and jargon of research disciplines. It is therefore interesting to compare similarities and differences in the use of terminology between the chapters that come from different disciplines and research fields, but also within the same field.

We return first to the mentioned increased reluctance to characterise societies based on their subsistence, like the general notion of people being "hunter-gatherers". Other characteristics brought to the fore are that these societies are small-scale, non-sedentary/highly mobile, and/or egalitarian. Yet, all of these (including the initial definition of hunter-gatherers) are only partial descriptions of any studied group and, moreover, put a universal label on rather diverse groups of people. In this volume, we acknowledge such diversity. To avoid the pitfalls of overarching classifications, each chapter provides a description of the specific context (social and environmental) of the case study presented in it.

Six terms are used regularly in this book: disasters, hazards, vulnerability, resilience, capacities and sustainability. Most chapters in the book use the definitions proposed by the United Nations Office for Disaster Risk Reduction (UNDRR; https://www.undrr.org/drr-glossary/terminology). Finding common ground and using different subjects and themes from multiple disciplines to discuss these concepts is helpful in many ways, including revitalising and challenging the concepts themselves. Cross-disciplinary conversations are also necessary for building strong/robust knowledge and may, in turn, support policymakers or the societies at large. Awareness of terminology is essential. However, there are also challenges, as we will address more specifically in the five subchapters below with capacities being mentioned in the other sections.

15.3.1 Disaster

Several of the authors (e.g. Chmutina and von Meding Chap. 2; Heitz Chap. 4; Nyland Chap. 7; Mangalasseri et al. Chap. 8; Riede et al. Chap. 13) have used the UNDRRs characterisation of *disaster.*

A *disaster* is defined as a "*serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity*". However, a disaster can also be further refined by adding adjectives to characterise its nature, separating between "sudden" and "creeping"," man-made" or "accidental" disaster categories (Chmutina and Von Meding Chap. 2). However, as Chmutina and von Meding also warn, this has opened a strong tendency of silo thinking, which in turn influences how disasters are perceived, and hence what actions are taken to prevent them. This concept was also developed for extreme events happening in contemporary societies, which makes some argue for discipline-specific definitions. Kilhavn (Chap. 12), for example, points out how, for him, Wisner et al.'s (2004, 50) concept is a better fit than the UNDRR's concept for studying specific prehistoric events using archaeological methods: "*A disaster occurs when a significant number of vulnerable people experience a hazard and suffer severe damage and/or disruption of their livelihood system in such a way that recovery is unlikely without external aid. By 'recovery' we mean the psychological and physical recovery of the victims, and the replacement of physical resources and the social relations required to use them*". Yet herein lies again the key question: Is it better for interdisciplinary conversations to apply the same definitions, or should each discipline endeavour to adjust its content to its subject? Applying a term without knowing its history or biases may unintentionally add meaning, offend, create biases, or obfuscate important points. The most important issue is, then, perhaps the importance of explaining what one means when applying certain terms and concepts.

15.3.2 Hazard

While a *disaster* is seen as a disruption to normal life, an event that has happened, a *hazard* is defined as a "*process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation*" (UNDRR). UNDRR's page list 302(!) different hazard information profiles and terminology, all well-explained and referenced. All hazard-related concepts, explanations and definitions offered on the UNDRR page are widely recognised and applied, which enables on-topic interdisciplinary debate. It is also important to note that hazards may cause havoc but must not necessarily do so. As several of the authors comment (Walker Chap. 5; Bradtmöller and Lübke Chap. 11), not all hazards cause disasters. Even within the range of large geo-hazards, there may be several grades of impact where it may be a disaster for only parts of a population, depending on how the society was rigged to cope beforehand (cf. Walker et al. 2023).

15.3.3 Vulnerability

Consequently, if the aim is to understand why disasters occur and why disasters do not affect all communities and societies equally, as argued by Chmutina and von Meding (Chap. 2), it might be helpful to focus on identifying *vulnerabilities* instead. The concept has been used in anthropology to describe the ability of groups or individuals to foresee, handle, resist and recover from disasters (Faas 2016, 14; Wisner et al. 2004). However, the UNDRR broadens the scope by defining *vulnerability* as "*the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards*" (UNDRR), i.e. it is a highly complex concept and might change with age, race, gender, class, etc. The concept thus requires focus on individual and collective skills, knowledge, and available resources, underscoring also that vulnerability is not the opposite of capacity (Chmutina and von Meding Chap. 2). Clarifying the type of vulnerability, for who and why, is necessary in order to identify required capacities. The identification of such can help in current attempts to engage with people who otherwise widely consider humanity as doomed (Piper et al. Chap. 6). Aiming at types of vulnerability and necessary capacities, intersectional approaches have been suggested (Chaplin et al. 2019; Kuran et al. 2020; Chisty et al. 2021; Lotfata and Munenzon 2022; Ayanlade et al. 2023). These approaches show that discussing the concept of vulnerability is also highly relevant when attempting to operationalise *resilience* (Bradtmöller et al. 2017).

15.3.4 Resilience

Resilience is an often-used approach in archaeology and anthropology (cf. Chap. 1), but it is also a term that has been questioned (cf. Barrios Chap. 3). The main point of criticism is thereby that its use often rests on a generic assumption of what a society is. As ethnographical, anthropological and archaeological studies have demonstrated, societies may be organised in very different ways in time and space. Consequently, Heitz (Chap. 4) proposes "*a conceptualization of resilience and vulnerability that is open to the diversity of temporalities and spatialities of climate-related hazards*". She considers resilience and vulnerability as relational, phenomenologically interrelated concepts and suggests "*that the subjects' resilience capabilities and vulnerabilities are related through memory and learning based on already experienced hazards and disasters—and thus are socially constructed*" (Heitz, Chap. 4). In another chapter, Riede et al. (Chap. 13) use resilience in the archaeological record more broadly as "*an emergent feature of behavioural change in domains related to mobility, social structure, and economy"* that is interpreted "*in the sense of selective pressures acting on a variable repertoire of socio-ecological habits and options*".

While Heitz (Chap. 4) discusses "resilience capacities", Stutz (Chap. 14) discusses the "carrying capacity" of societies in the Levant. In prehistoric studies, specifying what is considered essential for the resilience of a society is key in order to know what to look for in the archaeological material (e.g. Nyland Chap. 7). But it is also a major challenge to argue for the relevance of the fragmented material culture available for study (Bradtmöller and Lübke Chap. 11).

15.3.5 Sustainability

Finally, *sustainability* is at the root of several of the definitions above (cf. Heitz Chap. 4; Piper et al. Chap. 6; Temple et al. Chap. 10). As mentioned in Chap. 1, the United Nations has agreed on 17 global goals for *a sustainable development* (United Nations 2015), making it a relevant concept worldwide. In this agenda, sustainable development has been defined according to the United Nations Brundtland Commission 1987 as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs.*" (United Nations 1987). However, most of the above definitions follow the common use of sustainability as "*the long-term viability of a community, set of social institutions, or societal practice*" (Meadowcroft 2024). As Stutz (Chap. 14) shows, the long-term outcome of sustainable behaviour at one point in time may indeed compromise the ability of future generations to meet their own needs. This example highlights the value of deep-time case studies for our collective sustainable future.

15.4 Avoiding Silo Thinking

A comparison of approaches between the chapters in this book shows that there are similarities between the disciplines, but there are also differences in how the concepts are operationalised for different issues. One aim of this book is to avoid sweeping generalisations and instead acknowledge the local context and individual variation demonstrated by the many case studies. However, there is an attempt to bridge a perceived gap between the underlying causes, i.e. the political system, and the symptoms, i.e. the socio-spatial arrangements in disaster-affected places and societies (Barrios Chap. 3). In prehistoric disaster studies, one may search for symptoms or effects like societal collapse or demographic downturns, but political systems are, especially in hunting-gathering-based societies, something which is not often addressed. However, Mangalasseri et al. (Chap. 8), Barrios (Chap. 3), and Chmutina and von Meding (Chap. 2) all stress that societal vulnerability does not start with the occurrence of natural hazards or geo-hazards. The systems, regulations, and policies of the societies of the various regions have either prepared the communities well to handle and cope with hazards, or not. As Stutz (Chap. 14) states: "*The cultural capacity for being with many—in flexibly many ways—gave resilience to hunter-gatherers' socially constituted worlds*". Hence, capacities can cut across cycles of sedentism and mobility, climatic fluctuations, adapting resource exploitation, built environments and demographic systems.

It follows that silo science and silo thinking will obstruct any understanding of the root causes for hazards to become disasters, as well as the many potential aspects of resilience and reasons for vulnerability. It is, therefore, necessary to address "*broader political economic and power-laden relationships that often extend well beyond the boundaries of disaster-affected sites*" (Barrios Chap. 3). This idea of connectedness and relations moving beyond cause and effect is of particular relevance to prehistoric studies. Contextualisation and recognition of themes, works and entanglements of life in prehistory (cf. Ingold 2013; Hodder 2012) are key aspects if wanting to explain and develop a new understanding of past lives. Many of the chapters (e.g. Heitz Chap. 4; Riede et al. Chap. 13, Stutz Chap. 14; Walker Chap. 5), therefore, utilise models, that is, theoretical and methodological frameworks to illustrate chains of events, or elements potentially causing vulnerabilities or bring developments through pushing and pulling, such as the "Pressure and Release Model" by Wisner et al. (2004) or Gunderson and Holling's (2002) adaptive cycle model.

Models are good to think with, but if we want to avoid ending up with generalisations, we must return to what makes a society resilient in each case. For example, is it a community that has the ability to change, one that has strategies in place to not change and stay the same, or one that makes sure traditions survive climate changes or large-scale geo-events that are most resilient? Moreover, how much impact is required for a society to need or want to change, or to warrant immediate or gradually developing minor or major changes (Nyland and Damlien 2024)?

15.5 Datasets

In addition to the challenges caused by concepts, terms and theories, we also need to consider the bias embedded in the empirical data. In their combination of human behavioural ecology theory and models derived from disaster resilience studies, Riede et al. (Chap. 13) find the archaeological record to be empirically limited. Their "dates as data" analysis supports their multi-proxy study of the Danish Middle to Late Mesolithic, evaluating behavioural responses on mobility, social networks, cultural transmission dynamics and resource use. Although using different materials and methods as points of departure, taphonomic loss of data is also discussed by both Kilhavn (Chap. 12) and Stutz (Chap. 14). Although they discuss different hazards and regions, using different approaches, both raise the same point. Stutz uses statistical modelling of 14C dates (summed radiocarbon calibration PDDs with a taphonomic correction factor), while Kilhavn builds on a GIS-based analysis of the distribution of site locations. Stutz suggests that one explanation for a dramatic decline in population, may be a "*shift in intra-settlement density and geographic settlement distribution across the Levant*". Kilhavn raises the same question based on an emerging, yet unlikely pattern, indicating that more people lived in the Norwegian Early Mesolithic than in the Late Mesolithic. Their case studies illustrate that the results from big data must be scrutinised too. It is not a given set that fluctuations in the data show real demographic booms and busts caused by vulnerable or resilient societies responding to natural hazards, climate change or disasters. As research on the Storegga tsunami has shown, the impact may vary greatly on a local level and between regions (Walker et al. 2023). It is thus never a one-to-one question as to how much environmental impact is needed to explain shifts in mobility and settlement patterns and organisation. There is also the question of whether change is necessarily immediate or if the story of a dramatic event may became myth, geomythology, which over time came to constitute part of a group's memory, history or ancestry that in turn became part of a group's social identity that influences practices (cf. Walker Chap. 5; Nyland Chap. 7; Grimm 2019).

Observable changes in the archaeological record, as Stutz (Chap. 14) concludes, may also have operated at different scales. Some changes are directly linked to climatic or environmental changes, while others came to be due to local social interaction and practices. Observed changes in material culture, technology, style or raw material use, resource exploitation, rituals or more mundane practices are also argued to result from aspects that are unattainable if only analysing dates or sites as numbers. Discussing what to expect from an encounter with a monstrous geo-event, like a tsunami, Nyland (Chap. 7) argues that we need to discuss in which aspects of human societies we would see alterations as a response to a crisis. That is, what is the materiality of crisis that archaeologists can capture? Is the most important knowledge derived from an encountered crisis that securing broad knowledge transfer is the best social strategy for making sure traditions, or a culture, survive even if people disappear? Does it make more sense to search for changes in, or intensification of ritual practices than changes in lithic production to identify human responses to a potential trauma?

15.6 Giving Voice to Multiple Stories

15.6.1 Disaster Movies

In the 1976 paper by O'Keefe et al., the authors noted an increase in the frequency of disasters in the world over the previous 50 years. 50 years later, this trend has not slowed down. Quite the contrary and so has the interest in disaster studies in the fields of archaeology, anthropology and sociology, as well as among the general public. Disaster movies often depict devastating apocalyptic situations caused by geological or natural hazards. In these types of films (e.g. "2012", "The Wave", "The Quake", "The Day After Tomorrow", "Don't Look Up", "Twisters" and others), catastrophes are caused by earthquakes, volcanic eruptions, extreme weather, tsunamis, meteors or landslides. The appeal of the disaster scenario is not only to play on the public's fascination with special effects, but as Chmutina and von Meding (Chap. 2) point out: "*Disasters don't simply bring about suffering—they expose it*." The appeal of disaster narratives is also discussed by Walker (Chap. 5) and others (Budhwa 2021; Mackenthun 2021). Indeed, there is a solid market for unilinear and simple explanations and theories of what leads to societal collapse, as commented by Riede et al. (Chap. 13). As both Riede et al. (Chap. 13) and Chmutina and von Meding (Chap. 2) state, apocalyptic scenarios make great stories. Stories of single-event disasters are told in religions, popular media, ethnography, and literary sources, and there are scientifically identified historical and prehistorical disasters of great magnitude that are identified geologically. In our book, the Storegga tsunami, the volcanic eruption that buried Pompeii, the effects of an earthquake in Guatemala, Hurricane Mitch in Honduras, landslides in Sweden and India, and COVID-19 in Costa Rica are just a few examples. So, if for no other reason, bringing attention to disasters or working with identified disasters—or even monsters (Nyland Chap. 7)—will add to our knowledge of responses to crisis both by prehistoric and contemporary societies.

However, there is an increased focus on potential or past disasters what we need in order to grasp the seriousness of the current situation. If presented as simple doomist narratives, these can make people, at best, fall into a reactive mode but mostly into an alarmists' stasis or even an active denial (Piper et al. Chap. 6). Careful consideration of the manner of which we disseminate our results is then important in addition to highlighting the importance of the temporal, spatial and social scale on which a disaster unfolds (cf. Stutz Chap. 14).

15.6.2 The Voice of Local Communities

In disaster movies, the standard plot often contains a single scientist who has to fight to be heard by the general public, policymakers and politicians. They are first viewed as eccentric or overly cautious and not worth listening to, but as it turns out, they have foreseen the catastrophe that happens. Barrios (Chap. 3) shows how this scenario does not only play out in current movies, but in real life in South America. Furthermore, the case study presented by Mangalasseris et al. (Chap. 8) involves voices from villages currently experiencing the threat of landslides in India. In these cases, as in many others around the world, local voices and strategies have been under-represented (or even disregarded) in official and scientific discussions on disaster management in their region. This is despite the fact that these communities are among those most impacted by landslides. Their coping strategies are, on one hand, innovative and, on the other, deeply rooted in long-standing community knowledge, values and relationships. In this sense, the perception of the professional "scientist saviour" works to mask the importance of taking local voices into account in policy decision-making processes. Furthermore, taking these voices seriously can change our understanding of these communities as vulnerable or resilient, which in turn can impact the level of involvement open to them in designing the sort of aid they receive.

Our book is an academic book, and perhaps we are preaching to the choir, but if we are to fight prejudices and scientific powerlessness, the next step is to acknowledge how science, terms and implications are always political and relational (Barrios Chap. 3; Chmutina and von Meding Chap. 2). This knowledge is also important to disseminate to a wider audience. As demonstrated by Piper et al. (Chap. 6), it is possible via public dissemination, specifically in teaching and via social media, to show the possibilities and capabilities that contribute to preparing societies for a better future. A key point here is that archaeology, with its long-term perspective, can help tell transformative narratives that point to actionable solutions and inspire activism rather than fear-driven reactivism or rigidity in such long-term challenges (cf. Bradtmöller and Lübke Chap. 11)).

15.6.3 Voices Within the Datasets

Utilising knowledge of disasters or geo-hazards in archaeological knowledge production is not uncommon. In areas with a history of volcanic eruptions, like Iceland, research has taken advantage of frequently occurring geo-events and used the tephra layers, airborne fragments or pyroclasts from eruptions to create solid chronologies (Blockley et al. 2014; Smith and Albert 2023). The Storegga tsunami that wrecked the coast on both sides of the North Sea, left thick deposits of gravel turf and mud in peat and lakes along the coast, demonstrating its force and physical impact. Such documented and well-dated events provide so-called "before/after-moments" in prehistory or crucial events (Cavalli 2006) that may have had potential catastrophic results (e.g.

Weninger et al. 2008; Riede and Sheets 2020; Walker et al. 2023). Together with data on the climatic cold 8.2 ka event, the Storegga tsunami makes for a specific point of departure for several of the chapters in this book (Walker Chap. 5; Nyland Chap. 7; Kilhavn Chap. 12; cf. Riede et al. Chap. 13). From being primarily a disaster story, the event is here used to explain fluctuating demography and site distribution patterns, but also potential gaps in knowledge transmission expressed through (lithic) technology allowing for social strategies to have been in place and potentially reduced or managed societal risks in the Mesolithic.

The importance of considering which voices get to be heard when available sources and materials are compiled or studied is an important aspect of understanding the complexity of disasters. Contrasting the archaeological approaches is Larsson's historic study of an area in Sweden hit by a massive landslide 400 years ago (Chap. 9). His sources are written accounts from archives, in addition to the geological reports testifying to its magnitude. Although attempting to number the death toll, Larson also strives to piece together the individual fates. He thereby describes the individuality and variation in impact that even only one death may bring about. It is again a solid testimony to the necessity of considering scale and avoiding generalisations. Being recorded in a different socio-political era, it is interesting to note what was deemed important only 400 years ago. Larsson (Chap. 9) also examines how the landslide continued to impact practices even a hundred years after the event. In both, the usefulness of considering the concept of "post-memories" (as discussed in Nyland Chap. 7) and the acknowledgement of local voices for more nuanced storytelling is apparent.

15.7 Human–Environment Relations

In 1976, O'Keefe et al. described a disaster as marking "*the interface between an extreme physical phenomenon and a vulnerable human population*" (1976, 566), i.e. without humans (on the receiving end), there are no disasters. In many ways, the chapters in this book also use this perspective, as our main concern has been with humans and human societies, survival capabilities, vulnerabilities and resilience. The environment is acknowledged, but its agency is in many ways reduced to setting the scene, kicking off the stories, and being the forces that impact societies. Geohazards, environmental proxies and climate fluctuations are identified, counted or measured. The impact is measured for the human species, but it is not only human societies that are affected by disasters or hazards. It is also a disaster when birds are killed off by major oil spills, or when bee populations lack the nutrition to survive winter seasons due to urban expansion. But in these instances "ecological" or "environmental" is used to categorise the disaster (e.g. www.treehugger.com/americas-worst-man-made-environmental-disasters-4869316). If we are to acknowledge the diverse, manifold and sometimes unpredictable developing character of human–environment relations, more focus should be put on the non-human agents. Perhaps we should stop using the phrase human–environment relations because the use of the hyphen sets humans apart. As Donna Haraway (2015, 159) points out:

> The constant question when considering systemic phenomena has to be, when do changes in degree become changes in kind, and what are the effects of bioculturally, biotechnically, biopolitically, historically situated people (not Man) relative to, and combined with, the effects of other species assemblages and other biotic/abiotic forces? [she answers herself:] It's more than climate change; it's also extraordinary burdens of toxic chemistry, mining, depletion of lakes and rivers under and above ground, ecosystem simplification, vast genocides of people and other critters, etc, etc, in systemically linked patterns that threaten major system collapse after major system collapse after major system collapse.

Almost all hazards on Haraway's list here are humanly made. Add this to political, social and even criminal economically driven agendas with not necessarily positive recursions for inhabitants (human and non-human) of an area, and one may well have a recipe for disaster. Humans are perhaps optimising their living conditions, but that is not necessarily what is good for the rest of the environment. Therefore, is resilience always a good thing, as Stutz asks (Chap. 14)? Population growth and strategies for more people to survive bring new challenges and risks (cf. Gronenborn et al. 2017). Becoming more people within a confined area generates risks for the spread of diseases and depleting resources. Thus, we need to debate and ask for whom the resilience, growth and robustness of systems are good, even beyond the human population. This requires a type of collective or assemblage thinking for the collection of entities of intersectional perspective, even beyond human societies.

15.8 Scale Matters!

As stated above, the scale of studies affects which results or impact you can identify (cf. Widlok and Cruz 2022), but scale is also a factor when considering which actions, strategies or adaptations are chosen when it comes to the effect on society's resilience or survival. This point was raised already in 1972 by Donella Meadows and colleagues, who argued how the human perspective differentiates on both a socio-temporal and socio-spatial scale, and that the number of people thinking beyond their own lifetime—and on a global scale—is rather small (Meadows et al., 1972, 19; Fig. 1). This means that sometimes, what will enable your family to survive in the short term may be negative for the society at large in the long term, i.e. the long-term outcome is negative (e.g. Stutz Chap. 14). To model potential future developments of our societies, we must understand the premises our society/ies rest on. For example, palaeoenvironmental sciences show climatic and non-human processes, whereas history and archaeology may demmonstrate human impact or responses to such. Yet, returning to the question of scale, strategies and developments of small societies cannot simply be compared with current societies in global networks. That is, one must consider whether one is upscaling (or downscaling) behaviour without justification, ignoring the different temporal dimensions and particular historical developments of each society. Furthermore, acknowledging variation and particularity, we may risk becoming lost in too complex entanglements of past, present and future individuals, communities, and humanity as well.

Allowing for scale creates apparent challenges, for example with the belief in progress and the future. Will the growing amount of data, refined theories and increasingly sophisticated techniques be able to save us all? Should we put our faith in big data, artificial intelligence and theories about complexity (e.g. Bentley and Maschner 2003; Walby 2007; Norberg and Cumming 2008; Boulton et al. 2015; Uher 2018; Silva 2021; Heron 2024)? Is there time to act or react on proposed paths towards a better future and to live well with hazards? The world is changing rapidly, and there is a mosaic of reactions already in motion. To this mosaic, this book contributes basic research from the present and the deep past, including examples of strategies that have previously worked. It certainly shows that "one solution fits all" is out of the question and that a choir of voices is needed. It is also about acknowledging the endless human relations to the environment and accepting that we all need to *live well together in this one world*.

References

Ayanlade A, Smucker TA, Nyasimi M et al (2023) Complex climate change risk and emerging directions for vulnerability research in Africa. Clim Risk Manag 40:100497. https://doi.org/10.1016/j.crm.2023.100497

Bentley RA, Maschner HDG (2003) Preface: considering complexity theory in archaeology. In: Bentley RA, Maschner HDG (eds) Complex systems and archaeology. The University of Utah Press, Salt Lake City, p 1–8

Blockley SPE, Bourne AJ, Brauer A et al (2014) Tephrochronology and the extended INTIMATE (integration of ice-core, marine and terrestrial records) event stratigraphy 8–128 ka b2k. Quatern Sci Rev 106:88–100. https://doi.org/10.1016/j.quascirev.2014.11.002

Boulton JG, Allen PM, Bowman C (2015) Embracing complexity. Strategic perspectives for an age of turbulence. Oxford University Press, Oxford

Bradtmöller M, Grimm S, Riel-Salvatore J (2017) Resilience theory in archaeological practice—an annotated review. Quat Int 446:3–16. https://doi.org/10.1016/j.quaint.2016.10.002

Budhwa R (2021) Witnessing catastrophe: correlations between catastrophic palaeoenvironmental events and first nations' oral traditions in North America's Pacific Northwest. In: Mackenthun G, Mucher C (eds) Decolonizing "prehistory": deep time and indigenous knowledges in North America. University of Arizona Press, Tucson, pp 89–111

Burke A, Peros MC, Wren CD et al (2021) The archaeology of climate change: the case for cultural diversity. PNAS 118(30):e2108537118. https://doi.org/10.1073/pnas.2108537118

Castro B, Sen R (2022) Everyday adaptation: theorizing climate change adaptation in daily life. Glob Environ Change 75:102555. https://doi.org/10.1016/j.gloenvcha.2022.102555

Cavalli A (2006) Memory and identity: how memory is reconstructed after catastrophic events. In: Rüsen J (ed) Meaning and representation in history. Berghahn Book, New York, pp 169–182

Chaplin D, Twigg J, Lovell E (2019) Intersectional approaches to vulnerability reduction and resilience-building. Resil Intel 12(1):1–35

Chisty MA, Dola SEA, Khan NA et al (2021) Intersectionality, vulnerability and resilience: why it is important to review the diversifications within groups at risk to achieve a resilient community. Continuity Resil Rev 3(2):119–131. https://doi.org/10.1108/CRR-03-2021-0007

Degroot D, Anchukaitis K, Bauch M et al (2021) Towards a rigorous understanding of societal responses to climate change. Nature 591(7851):539–550. https://doi.org/10.1038/s41586-021-03190-2

Faas A (2016) Disaster vulnerability in anthropological perspective. Ann Anthropol Pract 40(1):14–27. https://doi.org/10.1111/napa.12084

Grimm SB (2019) Resilience and reorganisation of social systems during the Weichselian Lateglacial in North-West Europe: an evaluation of the archaeological, climatic, and environmental record. Monographien des Römisch-Germanischen Zentralmuseums, vol 128. Römisch-Germanisches Zentralmuseum, Mainz. https://doi.org/10.11588/propylaeum.735

Gronenborn D, Strien H-C, Lemmen C (2017) Population dynamics, social resilience strategies, and adaptive cycles in early farming societies of SW Central Europe. Quatern Int 446(2017):54–65. https://doi.org/10.1016/j.quaint.2017.01.01

Gunderson LH, Holling CS (eds) (2002) Panarchy: understanding transformations in human and natural systems. Island Press, Washington DC

Haraway DJ (2015) Anthropocene, capitalocene, plantationocene, chthulucene: making Kin. Environ Hum 6:159–165

Heron T (2024) Complexity theory and archaeology: a multi-scalar investigation into the evolutionary dynamics of human societies as complex adaptive systems. Dissertation, Bangor University, Gwynedd

Hodder I (2012) Entangled: an archaeology of the relationships between humans and things. Wiley-Blackwell, Chichester

Ingold T (2013) Making: anthropology, archaeology, art and architecture. Routledge, London

Kuran CHA, Morsut C, Kruke BI et al (2020) Vulnerability and vulnerable groups from an intersectionality perspective. Int J Disast Risk Reduct 50:101826. https://doi.org/10.1016/j.ijdrr.2020.101826

Lotfata A, Munenzon D (2022) The interplay of intersectionality and vulnerability towards equitable resilience. In: Brears RC (ed) The Palgrave Encyclopedia of urban and regional futures. Springer International, Cham, pp 946–961. https://doi.org/10.1007/978-3-030-87745-3_324

Mackenthun G (2021) Sustainable stories: managing climate change with literature. Sustainability 13(7):4049. https://doi.org/10.3390/su13074049

Meadowcroft J (2024) Sustainability. Encyclopedia Britannica. https://www.britannica.com/science/sustainability. Accessed 20 Nov 2024

Meadows DH, Meadows DL, Randers J et al (1972) The limits to growth: a report for the Club of Rome's project on the predicament of mankind. Universe Books, New York

Norberg J, Cumming GS (eds) (2008) Complexity theory for a sustainable future. Columbia University Press, New York

Nyland AJ, Damlien H (2024) Lithic Stories of broken Relations after the Storegga Tsunami in Mesolithic western Norway? World Archaeol (special issue: Lithic Ontologies). https://doi.org/10.1080/00438243.2024.2357384

O'Keefe P, Westgate K, Wisner B (1976) Taking the naturalness out of natural disasters. Nature 260(5552):566–567

Riede F, Sheets P (eds) (2020) Going forward by looking back. Archaeological perspectives on socio-ecological crisis, response, and collapse. Berghahn, New York, Oxford

Robinson E, Riede F (2018) Cultural and palaeoenvironmental changes in late glacial to middle Holocene Europe: gradual or sudden? Quatern Int 465:159–161. https://doi.org/10.1016/j.quaint.2018.02.001

Silva T (2021) Complexity theory and the historical study of religion: navigating the transdisciplinary space between the Humanities and the Natural Sciences. História da Historiografia 14(36):167–196. https://doi.org/10.15848/hh.v14i36.1669

Smith VC, Albert PG (2023) An introduction to tephrochronology and the correlation of sedimentary sequences using volcanic ash layers. In: Pollard M, Armitage RA, Makarewicz C (eds) Handbook of archaeological sciences. Wiley, London, pp 133–149. https://doi.org/10.1002/9781119592112

Uher J (2018) Taxonomic models of individual differences: a guide to transdisciplinary approaches. Philos Trans Royal Soc B: Biol Sci 373(1744):20170171. https://doi.org/10.1098/rstb.2017.0171

United Nations (1987) Our common future. Report of the world commission on environment and development. A/42/427. Accessed 20 Nov 2024

United Nations (2015) Transforming our world: the 2030 agenda for sustainable development. A/RES/70/1. Accessed 15 June 2024

Walby S (2007) Complexity theory, systems theory, and multiple intersecting social inequalities. Philos Soc Sci 37(4):449–470. https://doi.org/10.1177/0048393107307663

Walker J, Nyland AJ, Bergsvik KA, Kilhavn H, Gibbons S, Glimsdal S (2023) A multiproxy approach to understanding the impact of the Storegga tsunami upon Mesolithic hunter-fisher-gatherers across different regions of Western Norway. Quartern Sci Rev 324(108433). https://doi.org/10.1016/j.quascirev.2023.108433

Weninger B, Schulting R, Bradtmöller M et al (2008) The catastrophic final flooding of Doggerland by the Storegga Slide tsunami. Documenta Praehistorica 35:1–24

Widlok T, Cruz MD (eds) (2022) Scale matters. The quality of quantity in human culture and sociality. Culture & theory, vol 263. Transcript, Bielefeld

Wisner B, Blaikie P, Cannon T, Davis I (2004) At risk. Natural hazards, people's vulnerability and disasters, 2nd edn. Routledge, London