Kathleen Schwerdtner Máñez
Bo Poulsen *Editors*

Perspectives on Oceans Past

A Handbook of Marine Environmental History

Springer

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Purse seine fishermen, Spermonde Archipelago, Indonesia. Photo by Kathleen Schwerdtner Máñez

Preface

The idea for a book on marine environmental history was put forward by Alexandrine Cheronet from Springer Publishers after listening to a talk by one of the editors at the YouMaRes Conference in Bremerhaven (Germany) in 2011. It came at a perfect time. We, the editors, both had worked for a number of years in what we think of as an exciting multidisciplinary and interdisciplinary new field of environmental and historical research: marine environmental history. We had seen promising research coming together at the Oceans Past conference series, as well as in large collaborative projects such as the History of Marine Animal Populations (HMAP) project of the Census of Marine Life. Moreover, marine environmental history gained increasingly attraction in the historical sciences as well as within the environmental sciences through a number of monographs, edited volumes and journal articles. Further recognition of this emerging subfield was reached in 2008, as the International Council for the Exploration of the Sea (ICES) supported the establishment of an expert group for the history of fish and fisheries, which is still in existence.

Yet, we also felt something was missing. As more researchers entered the field from diverse backgrounds ranging from zoo-archaeologists to mathematical modelers, from marine ecologists to human ecologists, there was in increasing need to take stock of all the new methods and techniques coming along at the intersection of the development of human society and marine ecosystems over time. This is what this book is about.

This volume offers a collection of theoretical and methodological considerations on how to do marine environmental history across traditional disciplinary boundaries. This goes even across what C. P. Snow, more than half a century ago, lamented as the two cultures, the humanities and the natural sciences, where a dialogue is much needed, but too rarely occurs. To further this dialogue, our idea has been that each chapter should be readily accessible for social scientists and natural scientists alike, as well as for any interested student at an institution for higher learning. In this way, we hope to solidify a subfield, where diversity is an intellectual strength on the one hand, but on the other hand, lends a fragile basis for community building.

The extent to which we have succeeded, the reader will have to judge. However, there is no doubt that any success of this book owes to the committed and diligent contributions we received from colleagues around the world spanning a wide series of disciplines and themes of interest. Any mistake or shortcoming on the other hand is entirely the responsibility of us as editors.

In addition to the contributors, we would like to extend our gratitude to a number of people that have lent their support to this project. Over the past 4 years, we have profited from frequent encouragement and moral support from the Executive Board of the Oceans Past Initiative, (www.oceanspast.net). We presented the idea of having this volume at a session of the Oceans Past IV conference in Fremantle, Australia, in November 2012. We are very grateful for the feedback we received on this occasion. More recently, we received financial support for promoting this volume from the EU network, COST Action IS1403: Oceans Past Platform. The scope of Bo Poulsen's contributions was significantly improved through the work of his parallel research project, 'Navigator – Johannes Schmidt, ICES and the Carlsberg Laboratory, c. 1898–1933' sponsored by the Carlsberg Foundation. We would also like to acknowledge the support from our home institutions, Aalborg University (Denmark) and the Leibniz Center for Tropical Marine Ecology in Bremen (Germany). Special thanks to the librarians at ZMT Bremen, particularly to Hanna Thimm, who provided invaluable support with final formatting and references. Springer Publishers, namely, Alexandrine Cheronet and Judith Terpos, have been extremely helpful and very patient during the 4 years which we needed to finalize this volume.

Finally, we would like to thank our families for their support and for reminding us that there is a world outside of history and science. In fact, Kathleen Schwerdtner Máñez's interest in marine environmental history was only drawn by her wife (Gracias, María, para todo). As we both had a child during the course of making this book, we would like to dedicate the volume to our loved ones in Ashausen (Germany), María and Laia Edith, and in Dronninglund (Denmark), Anne Dorthe, Astrid, Niels and Laura.

Ashausen, Germany — Kathleen Schwerdtner Máñez
Dronninglund, Denmark — Bo Poulsen
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Of Seascapes and People: Multiple Perspectives on Oceans Past

Kathleen Schwerdtner Máñez and Bo Poulsen

Introduction

> The sea surrounds us. It gives us life, provides us with the air we breathe and the food we eat. It is where we came from, and what we are made of; it represents home and migration, ceaseless change and constant presence. It covers two-thirds of our planet, yet caught up in our everyday lives; we seem to ignore it, and what it might mean. (From "The Sea Inside" by Philip Hoare)

The interaction of humans with the sea is a long story, of which not all has been told. Some scientists are convinced that it started with the earliest hominids wading and climbing in swampy or coastal forests in Africa–Arabia, searching for molluscs. They also believe that the story continues by Homo descendants later migrating to or remaining near the Indian Ocean coasts, where they could exploit waterside resources. Marc Verhaegen and his colleagues call them our "aquaboreal ancesters", arguing that they may have given rise to early modern humans: furless, long legged waders and divers with subcutaneous fat and the ability to control their breath (Verhaegen et al. 2002). With these characteristics, they were able to explore the manifold resources in coastal environments. The archaeologist Jon Erlandson is convinced that it was this adaptation to a coastal livelihood which enabled human migration out of Africa. The rich resources of kelp forests, mangrove systems and coral reefs, provided early modern humans with abundant food on their way to Asia and the Americas (Erlandson 2001).

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But despite the long common history of men and the sea, until the turn of the twenty-first century historical information did play a negligible role in the analysis, conservation and management of marine ecosystems. Marine and fisheries sciences used data that mostly came from scientific monitoring, with data series which hardly went back further than 20–50 years. Consequently, historical reference points for earlier exploitation or other impacts were missing (Lotze and Worm 2009). In his book *Scaling Fisheries*, Tim D. Smith stated that fisheries scientists had come to suffer from historical myopia, a blindness towards the past (Smith 1994).

In a similar way, historians did show little interest in environmental issues. That changed with the growing public awareness of environmental problems such as air and water pollution or the dumping of solid waste. In the 1960s and 1970s, the large-scale green movements in the United States made American historians looking for the origins behind contemporary environmental problems. The publication of Rachel Carson's *Silent Spring* (1962), dealing with the side effects of DDT and other pesticides, is often mentioned as the final kick off, of American environmental history (McNeill 2003). The institutionalisation of environmental history started with the foundation of the *American Society for Environmental History* in 1975. More than 20 years later, the *European Society for Environmental History* was created in order to unify and coordinate different European initiatives which had been established by then.

Until the late 1990s, environmental historians were mainly concerned with terrestrial topics such as forest history or the origins of air pollution. The sea, especially everything beneath its surface, was largely left out. One remarkable example of the 1980s is Arthur McEvoy's *The Fisherman's Problem*, where the rise and fall of the great mid-twentieth century California sardine fishery is investigated in a combined light of market forces, fisheries management, fishing impact, and environmental forcing (McEvoy 1986). This ignorance of marine issues might be explained by the once widespread perception of oceans as a source of inexhaustible resources. John R. Gillis has also argued that "… the persistent reluctance to tackle the oceans is due … to western civilization's unique cultural relationship to the sea itself. Other societies have felt much more at home with the sea. We, however, have consistently defined it as "other," as alien and exotic." (Gillis 2011).

This is not to say that historians have not been engaged in the history of fisheries before. There is a long tradition of studying the lives of fishermen; fishing families and the economic performance of the fishing industry (see Holm, this volume). Throughout the twentieth century however, the actual reservoir for harvesting the fruits of the sea was largely treated as an interchangeable constant, something to be left out of the equations of sorting out the roots and causes of human enterprise in the maritime world.

Inventing Marine Environmental History

Historians began to look into history's connectivity with the marine environment from the late 1990s on, and within the last decade or so the field has been growing in scope and volume within and across the fields of history; and within various intersections between history, social sciences and historical ecology.

In his famous two pages on 'Anecdotes and the shifting baselines syndrome of fisheries", Daniel Pauly argued that fisheries managers and fisheries scientists worked with time series that were too short to properly determine natural or desirable states of fish stocks. Scientific monitoring usually spans a few decades only. If then the earliest measurement was from 1960, then the notion was that this would be the original stock size to be targeted by management. But, asked Pauly, what if a fish stock was already decimated by 1960? The short time series wold not be able to properly capsulate significant changes in the observed ecosystem (Pauly 1995). Three years later, Pauly published his seminal paper "Fishing down marine food webs", which showed that the trophic levels of some 220 species groups had declined from 1950 to 1994 (Pauly et al. 1998). A similar impression was made by Jeremy Jackson's article on the changes in Caribbean reefs since their discovery by European explorers (Jackson 1997). In the following years, a wave of papers revealed a devastating truth: that human impacts on marine ecosystems were much more severe, and also often much older than previously thought. This so-called 'historical turn' in marine sciences had a major influence on the formation of marine environmental history. The raising scientific awareness was also accompanied by the increasing attention of the broader public, visible for example in the publication of several popular science books such as *The Empty Ocean* (Ellis 2004), *The End of the Line – How Overfishing is changing the World and what we eat* (Clover 2008), or *The Unnatural History of the Sea* (Roberts 2009).

Eventually, the broad sense of marine systems as endangered, yet insufficiently understood boosted the largest research effort in the history of marine science from 2000 to 2010. Funded by the A. P. Sloan Foundation, the **Census of Marine Life** (CoML) engaged more than 2000 natural scientists and historians in finding answers to three major questions: What does live in the oceans? What did live in the oceans? What will live in the oceans? The second question prompted the establishment of an historical research enterprise entitled, History of Marine Animal Populations (HMAP), focusing on what marine life looked like in the past (Holm et al. 2001). Some of the more than 200 hundred publications coming out of this programme were summarized in the chapter, 'A New Look back in Time' (Holm et al. 2010). Additionally, in a 2013 theme issue of *Environmental History*, several results arising from HMAP were brought forward, mainly focusing on American historiography (Chiarappa and McKenzie 2013).

Meanwhile, marine environmental history underwent an equally significant development in scholarly settings with less direct engagement with the natural sciences. In a topical fashion the book chapter, 'Marine Environmental History' tried to present the diversity in marine environmental history by the end of the first decade of the twenty-first century (Poulsen 2012). Much more has been published since then, and by now, there is in fact too much research to mention for an introductory chapter such as this. However, throughout this volume, the various contributors frame their topic in the light of existing research. The book stands on the shoulders of a number of collected volumes and journal theme issues which have addressed the fields of marine environmental history and historical marine ecology from various angles over the past decade or so.

In 2007 for instance, the anthology *Oceans past*: *Management insights from the history of marine animal populations* showed some of the scope of marine environmental history. They range from contributions on the history of global whaling, over nineteenth century attempts to fisheries management, to the use of restaurant menus as sources of information. In the same year, the journal *Fisheries Research* hosted a theme issue on results coming out of the HMAP programme (Ojaveer and MacKenzie 2007). A few years later the anthology *Shifting Baselines. The Past and the Future of Ocean Fisheries* presented a series of case studies attempting to cross the divide between the human and natural sciences (Jackson et al. 2011). Recently, a theme issue of the Journal *Isis* focuses on the history of marine science, where the papers cover aspects of physical and biological oceanography and their historiography with contributions from across North America (Rozwadowski 2014). While this volume is written solely by historians, conversely, another recent volume, namely *Marine Historical Ecology in Conservation*: *Using the Past to Manage for the Future* is written largely by marine scientists (Kittinger et al. 2014).

The mainstream research agenda as such is on the move as well. Most of the above collections provide future recommendations on a background of existing scholarship. Such recommendation is also part of a recent essay with the telling title: 'Time is an affliction: Why ecology cannot be as predictive as physics and why it needs time series,' where the authors state that there is still a great potential in more research efforts within historical marine ecology. They particularly argue that the research field still needs to prove itself in a managerial context (Boero et al. 2015). Another recent paper calls for more research in currently underrepresented topics and geographical regions. This includes the role of gender in historical marine resource exploitation, which is addressed in this volume (Schwerdtner Máñez and Pauwelussen), but also more in-depth studies on coastal regions in Asia, Africa, and Latin America (Schwerdtner Máñez et al. 2014).

Challenges of Interdisciplinarity

Following the great surge in research output within marine environmental history and historical marine ecology, English ecologist, Callum Roberts in 2007 was able to paraphrase Tim Smith's notion of historical myopia. Following Roberts, a combination of certain reluctance to acknowledge environmental changes in the marine realm, and a "collective amnesia" had prevailed in the sense that until now hardly anyone did realize the far-reaching alterations of marine and coastal ecosystems (Roberts 2009). In fact, looking at the field of marine environmental history from the practitioners' point of view, such as the contributors to this volume, the potential, the achievements and the appropriateness of the suggested approaches may seem obvious.

A key factor, highlighted in several contributions in this volume, is the interdisciplinary nature of much marine environmental history. Here, interdisciplinarity is defined as the scholarly practice, where theories, methods and data arising in the arena of social science endeavours cross over to natural science papers and vice versa. Oral history for instance, developed as an historical method of inquiry in the 1970s, is now applied by marine scientists teasing out knowledge of past ecosystems that were otherwise hidden or simply lost (Thurstan et al. this volume). In the chapter by Coll and Lotze the authors present a whole range of methods and tools, which can – and have been used when seeking to reconstruct significant features of past marine ecosystems (Coll and Lotze this volume). Conversely, the chapter on archaeological methods and contributions shows several examples, where natural science techniques such as the isotopic composition of human bones can be used to infer the contribution of marine protein to human diet in for instance the late Middle Ages, where such analysis have been carried out on remains from graveyards (Orton, this volume). In this fairly distant past, paper or parchment documents are rare to find, and they will seldom be able to give a precise account of the composition of vegetables, meat and fish in people's diet. Within the past c. 400 years though, historical studies based on paper documents preserved in archives have become ever more prolific. In this way fishermen's logbooks, landing certificates and similar types of records have been deployed as a means to test methodology from marine science to tease out the historical variability of species abundance and the impact of fishing pressure (Poulsen, this volume; Engelhard, this volume). A particular challenge for both modern day fisheries managers and scientists trying to record what goes on at high sea is the phenomenon of "IUU" which stands for Illegal, Unreported and Unregulated fisheries. In his chapter, Joseph Christensen places this phenomenon in an historical perspective focusing on the Southern hemisphere (Christensen, this volume).

Nonetheless, institutional inertia and scholarly and scientific blindness to the interdisciplinary aspects of marine environmental history still prevail. In some, also influential corners of academia, one can even find the proposition that the interdisciplinary aspirations of marine environmental history are futile or impossible.

More than half a century ago, English physical chemist and novelist, C. P. Snow lamented the fact that, as he observed it, the natural sciences and the humanities were living two separate worlds within the larger realm of academia as well as in public discourse. These 'The Two Cultures' as his book on the subject was titled, were devoid of serious interest in appropriating learning from the other culture. Snow found this to be a tremendous loss to a society, whose leaders in government and administration tended to be trained solely in the humanities ignorant to the advances of modern science. Conversely, Snow found a danger in the fact the engineers of modern technology fell short, when it came to training in moral judgements. Snow's observations were critical of this division of the two cultures (Snow 1966). In an article from 1996, American environmental historian, Donald Worster, took C. P. Snow's critique to the then rapidly emerging field of environmental history, highlighting how environmental history was an important and necessary meeting point for sharing the environmental challenges between the humanities and social sciences on the one hand, and the environmental sciences on the other hand (Worster 1996).

Nonetheless, many commentators on the subject of scholarly division in the human and natural sciences simply adhered to this a fact, not disputing the soundness thereof. A twenty-first century example of this is the widely used textbook by English historian, Arthur Marwick who gives the following view on the two cultures: '… there is a fundamental difference in the subject of study: the natural sciences are concerned with the phenomena of the natural world and the physical universe, while history is concerned with human beings and human societies in the past. There is a difference in the phenomena studied, and these phenomena are very different in character.' (Marwick 2001: 248). This is true, when one believes it to be true, and the traditional divisions between disciplines at universities around the world indeed support and encourage such a more mono-disciplinary approach to science. However, many insights will remain out of sight if this is the only way human and natural sciences are practiced.

From an epistemological point of view, this volume attempts to highlight the value of multiple perspectives provided by scientists from a number of different disciplinary backgrounds. One of its interdisciplinary aspirations has been to facilitate considerations of the potential in the common denominator of human and natural sciences. Fundamentally they are both sciences. As stipulated by other commentators on the nature of the sciences, this means that historians, archaeologists, sociologists, ecologists, fisheries scientists are all focusing on posing open-ended questions or transparent hypotheses serving as guiding principles for ones' inquiry, or scholarly pursuit as one might also call it. Any scientific enquiry then is based on some sort of observation. The historian or social scientist will often rely on written testimonies or conduct interviews. Yet, as we will see in several contributions to this volume, this type of data is also of relevance to natural science oriented investigations (Chalmers 2000; Paludan 1990).

The natural sciences do foremost deliver answers to questions concerning the physical surroundings, but studies of for instance the natural variability of fish populations, environmental forcing and fishing pressure can be thought of in connection with societal developments, for instance of fishing communities, with promising results (Holm, this volume).

In many cases multiple perspectives are likely to result in a more rewarding study than the singular perspective of just one disciplinary approach. The decisive point as to whether or not a study should be classified as natural science, human science or interdisciplinary science, is not defined by the object of one's study, but by the perspective from which questions are asked. When a scientist uses material for data, or as sources, as the historian would have it, such material exist as data only for so far as it is being used to serve as a remedy in addressing the scholarly question. Thus data are not scientific data in their own right, but merely a function of the investigative process, or scholarly pursuit trying to address a problem.

If the addressed problem is primarily oriented towards a problem within the realm of human society, one would label it social science or as belong to the humanities, but if the problem addressed tackles an issue of relevance to both of 'the two cultures', then you could call it an interdisciplinary study. Thus, it follows that there is a certain degree of relativism at play in between the subject of inquiry, i.e. the scientist, and the observed phenomenon.

One of the prejudices against interdisciplinary or multi-disciplinary research is a bit peculiar. In the anglo-saxon world of academia, the human sciences are commonly known as the *arts*. This gives rise to common claim that history or archaeology are not real science. Nonetheless, this is a problem only in the English speaking parts of academia, and has been labelled an ‘eccentricity of the English language’ (Evans 1997). In most Germanic and Latin languages the same word for scholarly pursuits are being used in the humanities and in the social and natural sciences. In German for instance, the equivalent terms are *Geschichtswissenschaft*, *Sozialwissenschaft* and *Naturwissenschaft*, respectively.

From a different point of view, the degree of relativism is exactly what has given rise to criticism of history as a science. English historian Keith Jenkins has promoted the view that history should not be looked upon as a science. He proposes that history falls within the realm of craftsmanship or a bundle of literary conventions enabling historians to tell stories in the same way as novelists writing fiction. Since history is often occupied with the past – a phenomenon, which by definition does not exist, because it is gone – the claim is that history is unscientific (Jenkins 1995).

Quite rightly, there are elements of construction in the practice of history, but this is true of any scientific inquiry, also within the natural sciences. Often Newton’s laws of physics are brought to the table as an example of how, in for instance physics, scientists are occupied with undeniably factual relationships, while scientists in the humanities are focusing on cultural attitudes and particularities. Nonetheless, this is in many cases an unfruitful stereotype. Within the so-called life sciences, such as ecology, conservation biology, zoology or botany, practitioners in the field are equally self-critical and aware of elements of construction, as many historians or social scientists would be. Conversely, one could also stipulate that much human science embarks from the point of view that certain elements in the world can be taken for granted as factual; rationality for instance. While explicitly, rational choice theory is centred on the rational action by standardized individuals, this is implicitly the case assessments of most human activity.

Reading contributions to important scientific journals such as *Social Science History* or *Fish and Fisheries*, the published articles share the exact same ambitions to strive for exactness in the research presented, not least through the use of quantitative methods. Within fisheries research for instance, fishermen can be expected to fish to earn a living. It is rational to maximize the output of fishing within certain technological limits dictated by boats, fishing gear and availability of fish stocks. Yet, in many societies, fishermen do not fish on Sundays, or they stay at home during weekends. From a strict economic point of view this is irrational, but to properly assess the irrationality of fishermen’s actions, a certain notion of the opposite is to be assumed. Thus, differences in cultural preferences come to mind, when a fisherman’s logbook is consistently marked by blank spots on any given Sunday, a strong hint that fishermen, wholesalers or restaurants are observing the Christian day of rest. In a study of Catalan shrimp fishermen, the observation was made that the catch rates increase from Monday to Friday. During the weekend, the fishermen rested, and then on Monday and Tuesday their catch was lower, because the fishermen had to first find the shrimp after the weekend break (Sardà and Maynou 1998).

Moving from the level of individual agents to the level of human societies or marine ecosystems, the element of construction becomes even clearer. When a biologist operates within the framework of an ecosystem or a food web, these are all models of Mother Nature, in just the same way as the social scientist deploys concepts such as class or community – both abstract notions based on observed phenomena from the physical world.

To phrase it little more squarely, one could say that whereas much social science oriented writings of history, such as economic history, has the same nomothetic ambition as much classical natural science, that is to define scientific laws or regularities, or at least categories of development within certain given contexts. However, within the humanities in general, there is a strong ideographical tradition, which means that what is in focus is the study of the description of what is special, peculiar or even unique. Here, specific generalizations are often avoided.

There are more to the discussion about bridging *The Two Cultures* than the nature of how to do proper science. Several more practical and contextual issues or challenges for multi- and inter-disciplinary work deserve mentioning. One of the most widespread and real prejudice from the humanities towards the natural sciences springs out of the difference in traditions for academic publishing. Natural scientists tend to publish their most prestigious results in a selected number of scientific journals, whereas in the case of the humanities, a standard chat-up line at a conference is: 'So, what is your next book about?' Historians do publish in journals, and some are very highly appreciated. However, in some corners of academia shared authorship is frowned upon. Not because it needs to be so, but because of the fact that it is widely *perceived* to be so out of necessity. Attitudes towards different styles of publication are very conservative. This is indeed odd. The focal point deserves to be the shared goal of obtaining new research results, new knowledge about the world. The division of labour characterising the practices and traditions of much natural science is one area, where the humanities can really learn from *the other culture*. In many cases a short message entailed in a brief manuscript is much to desire, when compared to a quirky book of several hundred pages. From the other side of the fence between scientific cultures, similar obstacles persist. Publishing in a format other than the peer-reviewed scientific journal is not very attractive for natural scientists, which would not get credit for other types of publications, often labelled as 'grey literature'. Rarely marine scientists write big humanities style books, but some who did so have made an enormous impact, such as Callum Roberts.

In This Volume

The ambition of this volume is to present some of the major advances within the intersection of marine environmental history and historical marine ecology within the last 20 years. It can, however, not cover all aspects of the discipline, but focuses on the changing relationships between human societies and natural marine resources over time. Analysing these relationships requires new, often unconventional and innovative concepts and methods. The book seeks to present some of the main methodological challenges in reconstructing past marine resource use. Leading scholars in the field introduce major theories and methods, such as new tools in archaeology, developments in modelling, or the proper frameworks for studying historical fishing communities.

Ideally, the chapters written by historians and social scientists are supposed to be readable for interested researchers and practitioners with a natural science background. Vice versa, we hope that historians can gain insights and inspiration from the methodologies presented in the chapters written by authors with a marine science background.

Global research initiatives such as the History of Marine Animal Populations (HMAP) as well as numerous smaller projects have studied coastal and marine systems all over the globe, although many regions including large parts of South America and Africa have so far been left out (Schwerdtner Máñez et al. 2014). Hopefully, the studies presented in this volume can be an inspiration to engage with these issues on a truly global scale as well as in a wide range of regional contexts.

Marine environmental history will hopefully continue to thrive as a dynamic meeting point between the natural, social and historical sciences – arguably forming an open-ended sub-discipline of its own, with distinct traits and characteristics. This book seeks to encapsulate some of the major novelties of this fascinating new discipline and its contribution to the management, conservation and restoration of marine and coastal ecosystems as well as the cultural heritages of coastal communities in different parts of the world.

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Acknowledging Long-Term Ecological Change: The Problem of Shifting Baselines

Emily S. Klein and Ruth H. Thurstan

What Is the Shifting Baselines Syndrome?

Our relationship with marine systems has deep historical roots. People have lived adjacent to coasts and oceans for millennia, relying upon their resources for food and other goods and services (Rick and Erlandson 2008). Due to this long history, most systems today have been significantly altered by people (Jackson et al. 2001; Lotze et al. 2006; Myers and Worm 2003). Even degradation that appears recent often has its beginnings not decades, but centuries in the past, with human use impacting natural systems over significantly longer time periods than currently acknowledged or accounted for by science or management (Jackson et al. 2001; Pandolfi et al. 2003). This lack of awareness has considerable implications for the future of our oceans. For example, if system health is a goal for the future, appreciation of conditions prior to intense anthropogenic pressures can offer unique insight into healthier ecosystem structure, function, and dynamics. This is significant for appreciating our marine resources and managing them more successfully (also see Steneck and Carlton 2001; Smith and Link 2005; Jackson et al. 2011).

This chapter introduces the shifting baselines syndrome, a foundational concept for understanding our troubling ignorance of the past, especially in the marine realm. First, we need to define what a baseline is. A baseline describes a reference or starting point used to evaluate change or difference. In ecological studies, this

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may involve using a geographical location or particular community as a reference to compare other locations or communities across space. The changing status of an ecosystem over time can also be measured using a baseline, in this case anchored at some point in the past. For these temporal baselines, knowledge of past conditions is required. In both spatial and temporal comparisons, the critical question is the same: what constitutes a baseline appropriate for what you want to measure, be that change through time or health of the current state? As a simple example, if we want to determine the impacts of certain types of fishing in a particular area, we need a baseline of that system before that fishing occurred. Defining this appropriate baseline for an ecosystem usually results from a combination of how much we know about that particular ecosystem, and a value judgment (that is, what do we consider an ideal or natural state for that ecosystem?). This value judgment is because we often lack a clear starting place. In our simple example, perhaps we do not have data for exactly when that fishing was initiated. We make a judgment call about when it started having a significant impact within the time frame of our knowledge, and what the ecosystem likely looked like given our current understanding.

Here, we are most concerned about temporal baselines. In recent years, we have discovered that our lack of knowledge about the past has a direct bearing upon the way we determine and assess temporal baselines. This in turn affects how we judge the condition of the ecosystem and understand its structure as we know it today. Within marine ecology, Daniel Pauly (1995) was the first to use the term "shifting baselines syndrome". Using fisheries as an example, he defined this syndrome as occurring "because each generation of fisheries scientists accepts as a baseline the stock size and species composition that occurred at the beginning of their careers, and uses this to evaluate changes" (p. 430). This means that the first observations or knowledge a scientist has provides the baseline they subsequently use to determine what is healthy and desirable for a marine ecosystem, for example, in terms of what kinds of fish are present, and how many of them there are. Over time, as successive scientists observe a changing and often degraded system, past ecosystem states are forgotten. Hence, the baseline used shifts to a more and more degraded state: i.e. the shifting baselines syndrome (Fig. 1).

Dayton and others (1998, p. 319) furthered in defining the shifting baselines syndrome, stating:

> It is virtually impossible to make [distinctions about ecosystem change and human impacts] without some form of benchmark criteria of "normal." In terrestrial situations, here are usually parks, wilderness areas, and other means of at least developing a general idea of what a natural habitat might look like. However, we have almost no such insights for marine systems. We have a sliding and continually reduced expectation or concept of what the natural system should be. It is as though one attempted to recreate a rain forest or tall-grass prairie when all we have ever known is horizon-to-horizon corn or wheat fields, or, more appropriately, strip-mined areas unable to recover for lack of seed sources and recruitment habitats. This is not an exaggeration: many of the most productive continental shelf habitats in the world are dredged and dragged several times per year.

In addition to scientists, the shifting baselines syndrome also manifests in the changing perception of different generations of fishers. Studies, explored more fully

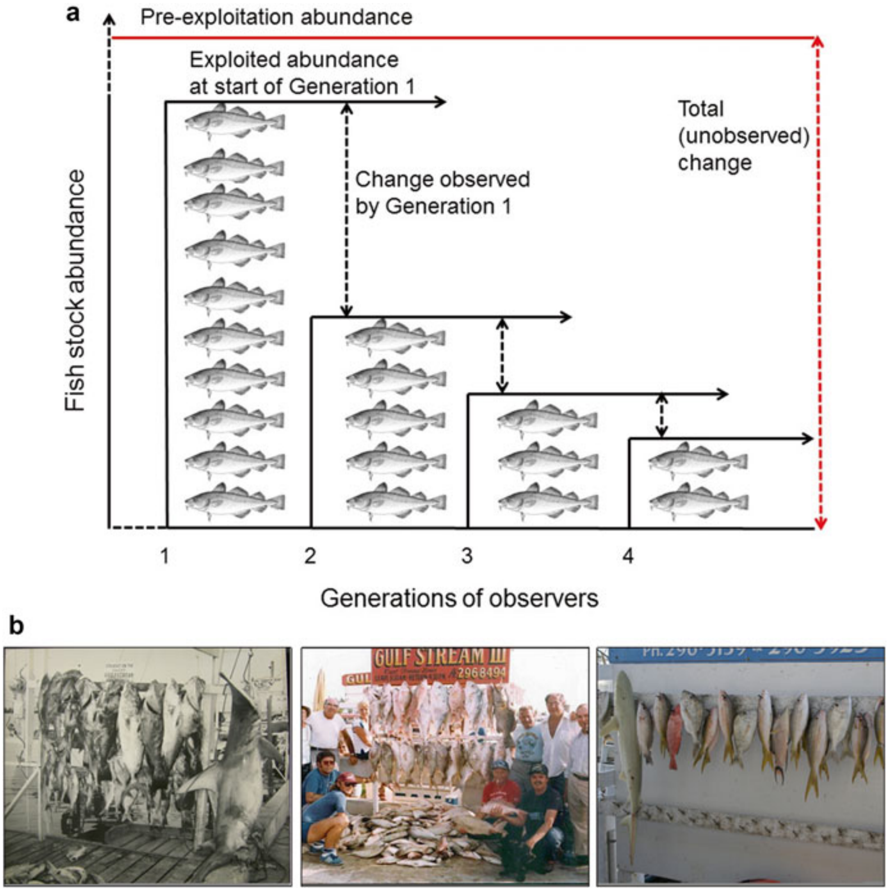

Fig. 1 The shifting baselines syndrome. **a** (*top*) is a conceptual diagram showing shifts in what subsequent generations of observers perceive as a natural population (in this example, a fish stock). Generation 1 initially perceive a stock size slightly declined from pre-exploitation levels, and throughout their lifetime (*solid horizontal arrow*) preside over further declines (*dashed vertical arrow*). Generation 2 do not perceive previous declines that occurred prior to their lifetimes, and instead observe yet smaller levels of decline, and so forth. The *dashed vertical red line* shows the real level of decline, of which generation 4 perceive just a fraction throughout their lifetimes. **b** (*below*) shows how this occurs in practice, as McClenachan (2009) demonstrated using these photographs (used with permission): Trophy fish caught by Key West charter boats from the same company and displayed at the same dock, *left* to *right* 1957, early 1980s, and 2007

in Thurstan et al. (this volume), have shown that when species have declined across many years, older fishers perceive more acute depletions in target species than younger fishers (Saenz-Arroyo et al. 2005; Lozano-Montes et al. 2008). McClenachan (2009) provided photographic and archival evidence showing that the size and number of species caught by fishers declined over the course of two to three generations, and the loss of cultural memory of once common species has also been demonstrated within fishing communities (e.g. Turvey et al. 2013; Alleway and Connell 2015). Consequently, resource users, who are sometimes the first to perceive swift or dramatic changes in target populations due to their close connection to the ecosystem, commonly fail to distinguish gradual degradation in target stocks, particularly when it occurs across multiple generations (Fig. 1). Of additional concern, the younger generations of fishers are not aware of these declines, despite older fishers still being alive. Indeed, even when provided with evidence, these fishers sometimes fail to accept that their cumulative activities might have had a negative impact upon fish stocks or the environment (McClenachan 2013).

Why Does the Shifting Baselines Syndrome Matter?

Implications for Scientific Inquiry and Understanding

According to Pauly (1995), the shifting baselines syndrome means we see a "*gradual shift of the baseline, a gradual accommodation of the creeping disappearance of resource species, and inappropriate reference points for evaluating economic losses resulting from overfishing, or for identifying targets for rehabilitation measures*" (p. 430). Often, the current status of many stocks is not the result of contemporary declines, but decades and even centuries of human use (Jackson et al. 2001; Pandolfi et al. 2003; Roberts 2007), while scientific study exists on a much shorter time scale. This is clearly a concern for understanding change in single species abundance and the number of species present in a system. Moreover, we cannot manage populations without a clear understanding of changes in species biomass, and the loss of species may go ignored if we are unaware of their previous presence. Yet the impact of shifting baselines goes beyond the numbers of individuals of a single species, or the number of species in an area. The shifting baselines syndrome also applies to whole ecosystems and multiple human and environmental impacts, resulting in, for example, simplified food webs or lost relationships and interdependencies. Consequently, we are unable to assess long-term changes or patterns in a system more broadly, or see the impacts of environmental variability in isolation from those of human use. Most critically for current management and future sustainability, we are left ill equipped to assess the health of the contemporary system, or how it may change in the future.

Another general consequence of the shifting baselines syndrome is the common assumption that marine ecosystems are resilient to human pressures, and have remained much the same over time (Bolster 2006). Perceptions of resilience and plenty are found throughout historical as well as contemporary discourses. For example, in the nineteenth century, respected fisheries scientist Thomas Huxley famously stated that, "…*in relation to our present modes of fishing, a number of the most important sea fisheries, such as the cod fishery, the herring fishery, and the mackerel fishery, are inexhaustible*" (Huxley 1883). While Huxley did not foresee the rapid advances in fishing power to come with the industrial revolution and was subsequently proved wrong about the inexhaustibility of these fisheries, analogous debates surrounding the health and resilience of the oceans continue today. The most intense commonly manifest around access to, and perceived conflicts over, ocean resources. For example, a number of seal and whale populations have rebounded during the late twentieth and early twenty-first centuries, after hunting of these populations was reduced or banned altogether. In some regions the interactions of these species with local fisheries has ignited debate about whether these species are currently at abnormally high levels, resulting in competition with fishermen for fish. However, as hunting of these species occurred over such long periods of time, commonly several centuries, our ability to accurately describe the size of pre-hunting populations is compromised (Roman et al. 2015).

The shifting baselines syndrome also means we are ignorant of how systems changed through time, and that we can assume they exist at a single equilibrium. Marine historical ecology itself has attempted to define past systems as baselines that are "natural" or "pristine" (e.g. Pauly 1995; Jackson et al. 2001), terms that insinuate there is a single previous state that has been disrupted by anthropogenic change. The further implication is that this state would be stable, or perhaps even static, without human interruption. However, as research in historical ecology reaches further back in time in search of an appropriate "baseline," what instead becomes clear is the extraordinary change and variability in ocean ecosystems. In conjunction with growing evidence from other studies (e.g. Scheffer et al. 2001; McCann 2000; Hollowed et al. 2000; Sutherland 1974), this suggests ecosystems are changeable and dynamic, and likely do not have a single past "pristine" state (Campbell et al. 2009; Sugihara 2010). Instead, systems are continually adapting to a variable world (Peterson et al. 1998), although adaptation may prove slow or fast (e.g. Holling 2001). They may exist in periods of relatively *stability*, where the system may respond to a disturbance but returns to its original steady state, and *resilience*, where the system persists by absorbing outside impacts (Holling 1973, also Holling 2001).

The reality of system change through time suggests they are not simply shifted away from an equilibrium to which they would return if pressures such as fishing were removed. Instead, fishing and other anthropogenic pressures may have fundamentally altered these systems, and returning to a previous state may be very difficult or impossible. If so, previous states of higher abundance and productivity more ecologically and economically preferable may be out of reach, or only achievable with great care and consequence. This does not negate the importance of the shifting baselines syndrome. Quite the contrary. The shifting baselines syndrome means we cannot see the previous states of the system at hand, or how we moved through them. Without this insight, we have no way to comprehend how the present state was achieved, how preferable other states may be, or how we might alter current conditions. Understanding how systems have moved through various states, what those have looked like, and how stable or resilient they were to change is crucial for anticipating future sustainability.

In addition to system state, research has demonstrated that variability itself can be vastly different across systems. For example, at the global scale, research has shown the species assemblages in coral reefs to be relatively stable for millennia (e.g. Aronson et al. 2002; Pandolfi 2002; Pandolfi and Jackson 2007), while the upwelling ecosystems of anchovies (*Angraulis* spp) and sardines (*Sardinops* spp) exhibit sometimes massive but predictable fluctuations (MacCall 2011). In addition, the rate and pathways of change and pattern may also vary. Systems may change gradually, or exhibit critical thresholds and sudden, sometimes catastrophic, shifts (Scheffer et al. 2001; Knowlton 2004; Hughes et al. 2013). With shifting baselines, we are rendered unable to truly perceive either the fluctuations or rates of change through time. Such information is vital for anticipating change in the future, especially if it is to come as massive fluctuations or critical thresholds. Such change will be unexpected and can be disastrous if current systems are assumed stable or changing slowly.

Finally, the shifting baseline syndrome also means we are unable to see long-term change and patterns not caused by people, such as those of the environmental or climate (Schwerdtner Máñez et al. 2014). We cannot ascertain our impacts from those naturally occurring. This is especially concerning with the growing need to address climate change. Although climate change is man-made, disentangling its consequences from those of overfishing is proving more and more necessary. If we understand the natural impacts of climate in the past, we are better prepared to predict consequences of anthropogenic climate change in the future, and to assess this in conjunction with fishing effects. Being naïve to the past means we cannot see the effects of people that can or should be altered in the future versus those outside our control. This is key for disentangling these effects from those we have caused and can potentially change.

Management and Analytical Implications

Shifting baselines is also very troubling when we consider scientists and managers tasked with maintaining the sustainability of an ecosystem, evaluating its health, or setting management and recovery targets. If such work starts with a shifted baseline, recommendations for sustainability or recovery targets will likely be underestimated, and health or resilience overestimated. This is particularly problematic in fisheries management, which can rely heavily on 'reference points' to assess stock or ecosystem health, set limits, and determine management action. Critical to these references is the idea of 'virgin stock size' or 'initial biomass' (B_0), used to evaluate the current stock, set fishing limits, and initiate precautionary action. Estimating initial biomass is very rarely based on actual pre-fishing biomass or an alternative informed baseline determined by the history of the fishery. Instead it typically refers to the onset of 'reliable' data, or is assessed using biomass or recruitment estimates based on the current system and conditions only. These avenues are subject to varying levels of uncertainly, but all are vulnerable to the shifting baselines syndrome, especially if environmental conditions are changing (Pinnegar and Engelhard 2008) and overfishing and other human impacts have reduced stock sizes prior to reference points (Rosenberg et al. 2011). As a result, baselines are likely incorrect, or inappropriate to fully ascertain change or the consequences of impacts (Sheppard 1995).

These concerns are exacerbated as management is increasingly tasked with addressing more complex and ambitious ecosystem-based objectives. These objectives often require the use of progressively sophisticated modeling and analytical techniques. This shift is also occurring in modeling studies and other analyses of ecosystem or species pattern and change, which also require information on baselines or initial conditions. These techniques come with expanding data needs, and hence often have to rely upon short-term datasets that are unable to account for earlier changes (Pinnegar and Engelhard 2008). This further exacerbates our inability to perceive long-term pattern and change, and is particularly problematic for recognizing when an ecosystem or ecosystem components are acting outside of their historical range of variability.

Restoration is another aspect of management where baselines are required, and thus the shifting baselines syndrome is an issue. As Dayton et al. (1998) pointed out, we cannot restore what is not known. For example, in Hawaii, green turtle (*Chelonia mydas*) numbers have been increasing since protection was enacted in the 1970s, primarily through one major nesting site, where 90 % of green turtle nesting occurs. The success of this population has led to inferences about broader recovery. However, while numbers of green turtles are certainly improving, historical data shows that 80 % of historical nesting populations remain extirpated or severely reduced in abundance. Such data makes it clear that this population, while recovering, is still vulnerable and historical nesting sites remain unpopulated (Kittinger et al. 2013).

Social-Ecological Implications

The shifting baseline has implications for people, as well. It matters to us because marine ecosystems are *social-ecological systems*, meaning the human and natural systems are intrinsically linked (Fig. 2). People influence the marine realm, and are in turn affected by it. We rely on marine ecosystems for resources and goods, like fish to eat, as well as services, like clean water, carbon sequestration, and a place to enjoy nature. We depend on our oceans for these *ecosystem services*, which are reduced if that ecosystem is degraded. The consequences of shifting baselines therefore affects all of us across a range of needs, uses, and experiences, especially as the global community becomes more tightly linked. It is thus crucial for our own well-being that we understand the current state of our marine resources and how they have changed. This is especially true as we look forward to climate change and increasing global human population.

Moreover, the shifting baselines syndrome also obscures the social and economic consequences resulting from change and especially degradation in marine ecosys-

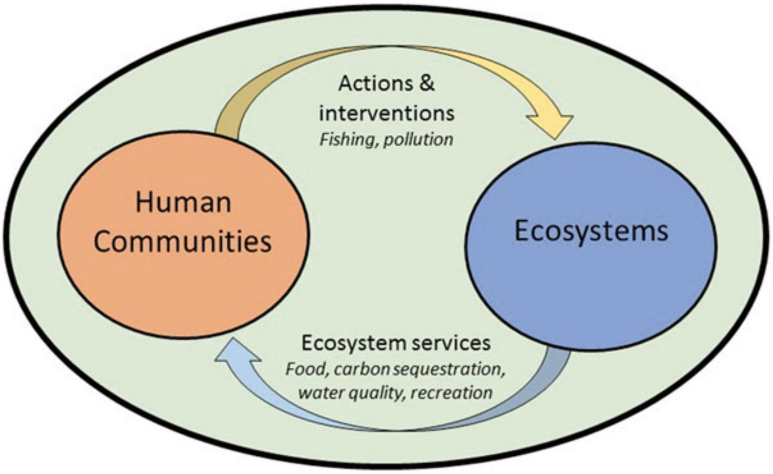

Fig. 2 Schematic of a *social-ecological system* (also described in the literature as a *coupled human-natural system*), demonstrating that human (or social) communities and ecological communities (or ecosystems) are intrinsically linked and interdependent. Ecosystems are altered and shaped by human actions and interventions, such as fishing, and in turn we as people are impacted by the ecosystem goods and services ecosystems can in turn provide. These relationships include feedbacks, as our impact on the natural world in turn effects how it can support us, and vice versa. These linkages make human and natural systems inseparable in the social-ecological perspective

tems over time. Our disconnection from the past means we may set restoration goals that do not match the potential productivity of an ecosystem. Given past productivity and corresponding ecosystem services, such misaligned goals are likely to be less than socially and economically desirable to us. The shifting baselines syndrome obscures our knowledge of what is ecologically feasible, therefore limiting our expectations for ecological restoration, as well as goals for the ecosystem goods and services humans rely on (also see Rosenberg et al. 2011).

Shifting baselines also applies to human communities more directly. For example, cutting-edge contemporary management includes ecosystem-based approaches, precautionary principles, and spatial closures. These ideas appear new, as these terms we currently use to describe them were introduced within recent decades. However, *as ideas* and management objectives, they have been recommended and used in management for centuries. In the United States, spatial management and ecosystem principles were adopted practice by the late 1800s, with the first fisheries management laws invoked in the seventeenth century to combat overfishing (Leavenworth 2008). In Europe, management policies date back even earlier. Regulations on gear and spatial closures, again due to overfishing, began in the Middle Ages (Roberts 2007). Looking back to the outcomes of these actions to see when they were successful and what undermined their outcome could prove critical to more effective and efficient management in the future (Rosenberg et al. 2011).

Shifting baselines in human communities is likely also prevalent beyond management. As potential evidence, take current assumptions about fishing communities themselves. Today we tend to assume large-scale fishing ventures operate under the *tragedy of the commons*, wherein the oceans belong to all (is a 'commons') and therefore fishermen compete for fewer and fewer fish, ignoring the communal good in favor of their own self-interest (Hardin 1968). However, a broader temporal perspective of fishing communities demonstrates a wide range of behavior and communal use over time (Berkes 1985; Feeny et al. 1996). For example, historically, deep-water codfishing in the Northwest Atlantic was more communal and collaborative (Rosenberg et al. 2005; Vickers 1994), and Maine fisheries held communal responsibility for future sustainability as a cornerstone to resource use generally (Judd 1997; Leavenworth 2008). If we have a shifted baseline of community and exploitation behavior, we fail to see these additional examples and may assume fisheries communities and fishermen themselves act in certain ways. These assumptions have direct bearing on the way in which we manage these communities and our expectations about them. Moreover, understanding human behavior is necessary for effective management, and is currently a key source of uncertainty around management outcomes (Fulton et al. 2011; Fogarty 2014).

Addressing the Shifting Baselines Syndrome

The Importance of Retrospective Data: Highlighting the Prevalence of Shifting Baselines

Combating the shifting baselines syndrome requires an understanding of the past. This necessitates the acquisition, organization, and analysis of retrospective data, and is exemplified by the disciplines of marine historical ecology and environmental history. Since Pauly's (1995) paper, researchers in these disciplines have used numerous data sources and approaches to clearly demonstrate shifting baselines for numerous species and in diverse habitats around the world. For an example, we turn to a classic paper in marine historical ecology. Collating palaeoecological, archaeological, historical and ecological records for marine and coastal ecosystems, including kelp forests, coral reefs, seagrass and oyster beds, Jeremy Jackson and colleagues (2001) provided some of the first ecosystem-wide examples of how change and declines have been underestimated or misinterpreted. Jackson et al. (2001) argued that while most fisheries data extends back 30 years or less, many coastal systems have been exploited for hundreds to thousands of years or longer. In one Northern Pacific example, they highlighted the effect of human hunting on interactions between predators and prey (Fig. 3).

Here, the shifted baselines syndrome results in contemporary descriptions naïve to the past presence and extent of kelp forests in the region. Kelp is a critical habitats for numerous species, thus misjudging its abundance undermines expectations for the ecosystem as a whole. Jackson et al. (2001) used this and other examples to argue that the shifting baselines syndrome has resulted in the magnitude and rate of

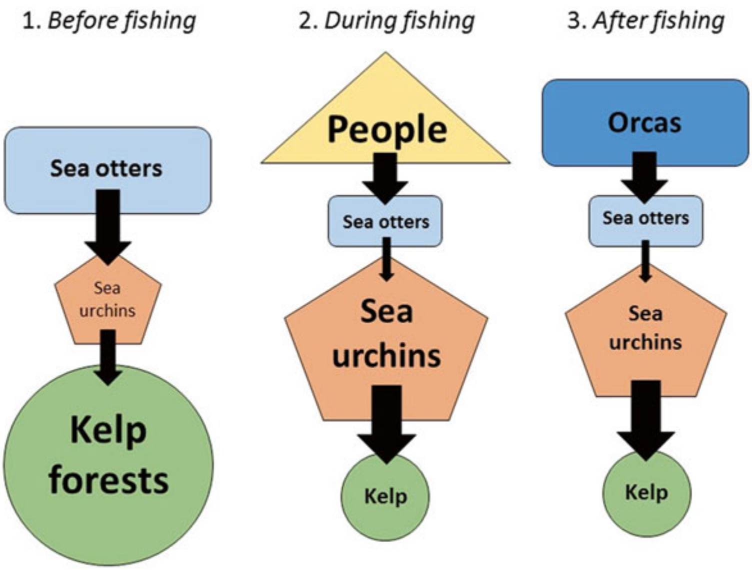

Fig. 3 The impact of fishing on the predator-prey dynamics of a coastal marine ecosystem. Before hunting, sea otters predated upon sea urchins, which in turn grazed kelp. Sea otters were hunted by Aboriginal Aleuts from 2500 B.P., and then subsequently almost to extinction by fur traders during the 1800s. With sea otters at critically low levels, sea urchins, increased dramatically. At such high numbers without predation by sea otters, they overgrazed their main food, kelp, causing the collapse of kelp forests. When hunting ended sea otters gradually recovered, partially reversing these patterns, until orcas began to predate sea otters, causing urchin numbers to increase again. A shifted baseline that did not include this history is unable to see the past presence and extent of kelp forests in this region, which are critical habitats for numerous other species (From Jackson et al. (2001))

decline being underestimated for many marine ecosystems. Indeed, a very similar kelp forest example exists for the Gulf of Maine, on the U.S. East Coast (Bourque et al. 2008).

A few years later, Lotze et al. (2006) also used a range of long-term sources to reconstruct past changes in 12 estuaries and coastal seas. These authors demonstrated that human activities, in particular fishing but also habitat degradation, transformed all coastal ecosystems observed, affecting multiple species and habitats. Observable resource depletion began early on, up to 2500 years ago in one system, but transformation of ecosystems had accelerated in the last 150–300 years. None of these historical changes had been picked up with current ecological or fisheries monitoring data, collation of which did not begin until the twentieth century in most instances, long after much of the degradation took place. As current research and management relied on this modern data, this study further established the prevalence of the shifting baselines syndrome across ecosystems and habitats.

These two classic papers in marine historical ecology (Jackson et al. 2001; Lotze et al. 2006) demonstrate that human impacts obscured by the shifting baselines syndrome happen in disparate ecosystems around the globe, from tropical coral reefs to northern latitude seas. Species that inhabit coastal ecosystems may be particularly vulnerable. Some considered naturally rare today may once have been more common, but their populations declined long before records were kept. For example, sawfish populations are known to have declined in coastal habitats due to habitat destruction and exploitation, but we rarely know how abundant they would have been prior to the intensification of human activities in the coastal zone. Again, retrospective data is the only avenue for illuminating these widespread changes. Using such sources, Dulvy et al. (2016) demonstrated that sawfish were once distributed in the waters of 90 countries and territories, yet are now entirely gone from 20 of these, and 43 had lost at least one species of sawfish (Dulvy et al. 2016). Similar loss of iconic species in coastal waters range from snapper in Australia (Thurstan et al. 2016b) to salmon and river herring (Klein 2013), sturgeon (Bolster 2008), and halibut (Grasso 2008) in the U.S. Gulf of Maine, and Atlantic cod across the North Atlantic (e.g. Bolster 2008, 2012; Leavenworth 2008; Rosenberg et al. 2005). That such recognizable species can decline to the point of local or regional extinction shows the pervasiveness of the shifting baseline syndrome, and the importance of work to reverse it.

Studies using retrospective data also help us see natural variability that occurs on the order of decades to centuries, other aspects obscured by the shifting baselines syndrome. One example at the decadal scale is the Continuous Plankton Recorder survey, which has been sampling plankton communities in the North Atlantic since 1946 (Beaugrand et al. 2002). Using this dataset, researchers provided evidence for large-scale changes in biodiversity and distribution of warm and cold-water plankton communities during the late twentieth century, with corresponding consequences for the fish species that feed upon them (Beaugrand et al. 2002). At the centennial scale, palaeoecology provides the necessary insights. For example, Pandolfi and Jackson (2006) demonstrated that Caribbean coral community composition remained stable across tens of thousands of years, which is in direct contrast to our recent observations of this system.

Where retrospective data has not been available or robust enough to identify shifted baselines, research across systems can sometimes provide a substitute. This is called *space for time substitution*. In this approach, an existing contemporary system in a different location less impacted by people is chosen as the baseline, instead of one back in time. However, as marine historical ecology increasingly shows, even ecosystems assumed more isolated have been impacted by humans. We must be cautious when choosing reference sites to evaluate change and health, observing an area for the first time, and setting baseline surveys. These endeavors must be done in light of any available previous knowledge in historical sources or especially among local communities. Local ecological knowledge of these communities can prove vital to setting standards and expectations for how 'natural' a spatial reference site is (Sheppard 1995).

In sum, looking to historical and other deeper time records is essential for exposing the shifting baselines syndrome. Such work already demonstrates just how prevalent this problem is, and are the sole avenue for uncovering past distributions, abundances, as well as species relationships and ecosystem processes. They allow us to identify and understand the impacts of people, how we achieved the state we are in currently, and what we may expect in the future. These data and results are the only opportunity to truly determine what a healthy ecosystem looked like before human pressures. The studies we have cited herein exemplify the information possible, and there are many more in the literature and in this book. Here, several other chapters provide additional examples of the variety of ways retrospective data is being used to extend our knowledge through time to address the shifting baselines syndrome. Data in these examples include fisheries records, oral histories (local and traditional ecological knowledge), and archaeological and paleontological data. Records depicting social, technological and economic information also provide critical contextual information into how humans drove, and have in turn been affected by, ecological change.

Incorporating Long-Term Data into Contemporary Science and Management

While continued efforts to collate historical and other retrospective information to illuminate the shifting baselines syndrome is crucial, it is progressively clear that simply demonstrating it has occurred is not enough. As we have demonstrated here, this work has direct consequences for contemporary research in a tangible way. Further, the importance of directly linking this information with management and policy has not received enough attention in our view. As management of our marine resources relies heavily on recent (on the order of decades or less) data often gathered after large-scale human impacts and overfishing, the shifting baselines syndrome also affects the targets and strategies we set in resource use. Therefore, historical work has definitive implications for both research and management. We must communicate findings to the greater scientific and policy communities, and encourage their incorporation into current study and management. Only then will we fully address the shifting baselines syndrome.

Communicating and integrate long-term data and results into science and management entails meeting a number of challenges. First, data needs must be considered. Many contemporary science and management frameworks have large, and increasing, data requirements. Often, current research and management also place a greater prominence upon the analysis and interpretation of familiar forms of quantitative data, such as conventionally reported fishery-independent surveys and traditionally reported fisheries catch time series. This has sometimes resulted in available historical information being overlooked or dismissed, as it may be less precise or perceived to be otherwise incompatible with contemporary sources (Alexander et al. 2011). However, an increasing number of studies are accessing and applying a range of retrospective data in new ways (e.g. Thurstan et al. 2016b; Klein 2013; Alexander et al. 2009). Moreover, the increasing importance placed upon ecosystem-based management and the advent of new techniques for acquiring and using non-traditional forms of data, such as expert knowledge, are creating opportunities for greater acceptance and application of historical data to assessment and management frameworks (see Coll and Lotze this volume; Thurstan et al. this volume, 2016a).

A second challenge to using retrospective data and addressing the shifting baselines syndrome is the diffusion of shifted baselines into the scientific, management, and fisheries communities themselves. Frequently in these realms, the pervasiveness of the shifting baseline syndrome not only results in the current state taken as 'natural', these communities may also find evidence to the contrary difficult to accept. This is especially true when it differs substantially from the established paradigm of what is 'natural'. The opposition to work using retrospective data to tackle these shifted baselines manifests in two ways: (1) acceptance of results themselves, and (2) acknowledgement of their value or ability to comment on contemporary science or management.

In the first case, results are often called inaccurate and based on biased or incomplete data. There is some basis for this skepticism. In the past, historical ecology has not always made clear the levels of uncertainty in the data used and its subsequent interpretation. Research that explains the potential uncertainties or biases may encourage its acceptance and incorporation into science and management (e.g. Thurstan et al. 2016a). This is especially pertinent, as the uncertainty in the data and subsequent analyses are often similar to those in contemporary data. Indeed, many of the concerns about retrospective data are not unique to it, therefore making this clear as well as addressing concerns plainly is essential in confronting this challenge. In addition, studies using retrospective data have often been quite clever in dealing with uncertainty and novel data sources, and have significant lessons for contemporary work (see Thurstan et al. 2016a; MacKenzie and Mariani 2012; Orton et al. 2011).

Second, work addressing the shifting baselines syndrome has also met with some cynicism about its relevance, especially to current management and conservation questions (e.g. Marsh et al. 2005; Hilborn 2007; Hobday 2011). Fundamentally, these challenges are borne of the shifting baselines syndrome itself, and ignore the now well-documented history of human influence. That is, they value only the current system. To confront this, research must demonstrate directly how retrospective work has value, and, more importantly, how it can be applied. Engelhard et al. (2015) uses case studies to demonstrate the significance of applying historical data and approaches to develop baselines and reference levels, and highlights work already being incorporated in management and policy. In their recent book, Jackson et al. (2011) argue that addressing shifting baselines is decisive for contemporary understanding, and can guide more informed research in the future. Within this book, Rosenberg and others (2011) draw special attention to the need for understanding the shifting baselines syndrome for future effective policy and management. Kittinger et al. (2015) also draw attention to the application potential of historical ecology research to fisheries management and conservation planning, among others.

Further work that translates research tackling the shifting baselines syndrome into direct actions science and management can take will also help. We encourage work that engages with management and policy makers to understand how historical and other data can address specific needs, such as setting more realistic targets, providing new baseline data, and assessing changes in distribution and abundance. For example, research that demonstrates how previous species as well as ecosystem relationships and structure have changed and were lost can also inform on the potential for recovery. As management shifts towards ecosystem goals, insight on how ecosystem structure and function has changed, and how this may be vital for sustainability and recovery goals, will also be increasingly valuable (Rosenberg et al. 2011, also Coll and Lotze this volume). Additionally, collaborative research can provide insight on the extent and timing of natural variability, and the speed and pathways of change that might be expected from a system given its past. It can also inform on previous and potential future system resilience and ecosystem characteristics that promote it (Klein 2013). Finally, there is much work to be done demonstrating how a deeper time perspective can parse out human and climate influences (Schwerdtner Máñez et al. 2014). All are especially important in a future of climate change and rapidly growing human needs.

Finally, although it has been used primarily in the ecological context, we have noted that the shifting baselines syndrome likely permeates to other aspects of marine social-ecological systems (Fig. 2). Indeed, Saenz-Arroyo et al. (2005) argued it "*is general and applies to all sectors of society.*" Experts from other fields have a great wealth of information on human communities, and on changes within human attitudes, values, management, and social structure. Such knowledge and study needs to continue to be brought in to the conversation on shifting baselines, and can inform on the potential responses of human communities to both ecological change and management action. We may also be better able to incorporate human values and attitudes into both research and management, a necessary and previously underemphasized enterprise. This is a rich area of research, ripe for continued collaborative and cross-disciplinary study.

Communicating the Issue of Shifting Baselines to a Broader Audience

Accepting the magnitude of change in marine systems requires more than acknowledgement by scientists and managers, it also requires communication with resource users and the general public. Outreach around the shifting baselines syndrome to these larger audiences will aid in its acceptance as a condition of the current science, and provide motivation for reducing and preventing it. However, in many cases, the shifting baselines syndrome is as ingrained in the public consciousness as it is for scientists and managers, and as difficult to address. To reach this wider audience, historical ecologists and environmental historians need to communicate their findings in a variety of ways. These include more traditional methods of dissemination, such as peer-reviewed articles and conference proceedings, but increasingly the communication of findings through other avenues, including social media, popular articles, and books. In such cases, historical data – particularly narrative or visual information – can play a valuable role in informing resource users and the public that major changes have occurred (e.g. results from McClenachan 2009, and see Thurstan et al. 2015). In our experience, people connect readily with history, and it is a ready medium for public outreach, in terms of shifting baselines and for ocean sustainability and conservation more broadly.

Conclusions

The vast majority of ecological studies usually cover only a short period, a time frame that does not encompass the lifespan of many species, let alone long-term climatic and oceanic cycles, important environmental disturbances, or extreme weather (Jackson et al. 2001). In addition, there is overwhelming evidence that the largest and most devastating of human influences, overfishing, has deep historical roots. Effects of impacts may not be felt for decades or even centuries, a fact that cannot be accounted for by contemporary investigations (Jackson et al. 2001; Hughes et al. 2013). Moreover, there are increasing indications that past human influence, namely overfishing, is a precursor to many changes assumed to be recent. Due to previous, and often immense, removal of organisms, overfished systems are severely weakened and more vulnerable to invasive species and disease, and less able to deal with environmental changes such as eutrophication (Jackson et al. 2001). Because of our ignorance of the past, the shifting baselines syndrome means our reference for a system ignores this history, and our perspectives of ecosystems and their health becomes more simplistic in terms of trophic levels and species as succeeding biologists fail to recognize locally extinct species and declining populations (Pauly 1995; Jackson et al. 2001; Dayton et al. 1998).

Addressing the deep history of our impacts on the oceans and combating the shifting baselines syndrome is crucial. Our naiveté undermines effective management of our global seas, which is vital for human as well as ecological well-being worldwide. An estimated 10–12 % of the world's population rely on fisheries or aquaculture for their livelihoods (FAO 2014), more when considering the infrastructure and market for fisheries at the local, regional, and international scales. Fish are also an essential source of protein for about 650 million people on the planet, making it vital for food security, especially in developing countries (FAO 2014). Moreover, developments in the global market mean that fish is available far from the coast, making it a staple to an increasing number of people not near any sea. In addition to protein we also depend on the oceans for other services, such as clean water, climate moderation, carbon sequestration, and recreational activities. The consequences of shifting baselines thus affects all of us, especially as we are more and more tightly connected into the global community. It is therefore vital we understand the current health of our marine resources, and the path forward under future change.

Shifting baselines reveals that the seas are not as healthy as we may believe, and that we are ignorant to past change and variability. However, as much marine historical ecology has demonstrated, the shifting baselines syndrome can be addressed. As this book and others like it (e.g. Jackson et al. 2011; Kittinger et al. 2015) show, studies that reveal shifting baselines are increasing. Research is also demonstrating how this work can be directly applied to science and management, and how we can outreach to the public. Shifts in management from single species to more holistic and ecosystem-based approaches are further encouraging, and will likely provide greater opportunities for a wider range of data, including retrospective sources and insight. Together, work demonstrating the shifting baselines syndrome can provide more realistic and hopeful goals of a vastly more productive ocean in the future (Rosenberg et al. 2005; Jackson et al. 2011).

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Historical Fishing Communities

Poul Holm

What Is a Community?

To the marine environmental historian a key question must be how do humans manage a hostile environment? The sea is an alien space in a sense which the land is not, and it takes conscious decision, technology and stamina to reap benefits from the sea. Fishing requires skills which must be learnt, it presupposes culinary preferences and a backdrop of material and intangible culture. Historians, ethnologists and sociologists often emphasise communities as a key concept to understand how humans survive and manage. Communities are social networks, larger than the single boat-crews or fishing businesses, which provide group resilience in the face of environmental and market factors. Communities pass down skills through generations. So what are they and how do they interact with the natural environment?

There is no agreed overall definition to cover all the studies that deserve the label 'community studies'. Bell and Newby (1971) listed over 90 different definitions of community with 'man' as the one common element! The *Encyclopedia Britannica* defines a community in very broad terms as "a group of people with common characteristics and living together within a larger society". In the natural sciences 'community ecology' is an established term for the study of interspecific predation – including fishing if we accept humans as part of the ecosystem. The concept may therefore seem a promising meeting point for interdisciplinary dialogue. However, we should note that human communities come not just with the objective characteristics of the animal world but with mental characteristics such as shared interpretations and often even expectations of mutuality and trust. These mental characteristics distinguish human communities and make interdisciplinary dialogue more difficult – but no less relevant.

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For the purposes of this essay I shall distinguish between a geographical and an occupational sense of the concept. A *geographically*-defined community is a collection of people in a defined space, who typically are close-knit, inter-married, and have inherited occupational structures and gender systems. Moreover, the daily activities of a community, work and non-work, take place within this area. In a maritime setting the geographic focus takes on another character than in an agricultural setting. To the fisher, the local resource area might extend from a few to many hundred miles to sea, and in recent decades globalisation has obviated any localised sense of resource area in some fisheries.

An *occupational* community, on the other hand, has no spatial characteristics; it exists between people who share an integrating ethos related to work content; the community is defined by sharing an experience which dominates members' existence for a period of time in spite of ethnic, linguistic, religious and other divides. Differences in ascribed social or hierarchical status are perceived as subordinate to the collegiate. The ship in that sense may be defined as a 'total institution', albeit for a limited time, typically for the duration of a voyage (Weibust 1969; Fricke 1973; Aubert 1962). Communities might work within an entire fleet of fishing vessels as demonstrated by Dutch herring fishermen who maximised their catches in the premodern era by maintaining close communication and collaboration at fishing locations even a thousand kilometres from home port (Poulsen 2008). Geographic and occupational communities may of course reinforce each other and often do, depending on recruitment patterns and their perceived sense of attachment, commonality or self-interest.

As with most other social categories, community is a fluid concept. There is a lack of definitional rigour which defies rigid administrative units. A geographical community may cover a village or a residential area within a town or a larger region or area. Commonalities may be and indeed very often are layered so that some members of one community may self-identify as members of other communities. Not every fisher will identify membership of a fishing community as the primary community and may put the interest of the fishing community behind the interest of other communities. Nevertheless, the community must be perceived as such by members who share certain values and incorporate (a hierarchy of) social roles.

Stacey (1969) dismissed 'community' as a non-concept because of its intangible nature and preferred to map networks and measure the density of relations. The problem of this approach, however, is that it dismisses the uniquely human aspect of relations, namely that they are not just webs but communication systems of meaning. The benefits of the concept are that it helps the researcher to identify shared meaning and responses by a community to outside environmental and social factors. 'Community' is a way of interpreting the natural and social environment and collaborating to cope with challenges. Failing to maintain social roles and a shared moral system is equivalent to the breaking-up of the community. Change may be caused by and/or may expose a community to outside environmental stress or to economic, social or ideological/moral factors. Further, the concept enables comparative study across time and place by identifying a social nucleus and opens up for a holistic interpretation of varied and seemingly contradictory social responses. The disadvantages of the concept are that it may lead to a myopic and conservative view of the area of study. The concept tends to capture the integral rather than the partial and to identify the harmonious rather than the antagonistic aspects of the study (Ambercrombie et al. 1984). To counter such problems it is vital that community studies consider the larger environmental and social fabric, and that researchers are open to interpreting the break-up of community in both positive and negative terms such as innovation, coping with change, and crisis.

Community studies have benefitted from contributions by scholars from many disciplines, including ethnologists and sociologists, whose dominant methodology is qualitative fieldwork, including taped interviews and archival sources. Their preference is for life histories and suggestive examples rather than statistical analyses. Most studies do blend qualitative and quantitative evidence, but numbers are rarely presented in a way to make them easily comparable to other findings. To environmental historians oral evidence is most often not available and we tend to give higher priority to quantitative evidence. Nevertheless, historians have often used the community concept as a heuristic tool and identified communities by material practices such as settlements or behavioural patterns. However, a loose use of the concept may unconsciously lead to mind traps. This essay therefore aims to provide some comprehension of the way in which scholars have tried to make sense of the idea.

I shall first outline some of the theoretical background in disciplines such as social anthropology, ethnology and sociology before I illustrate some historical uses of the concept. While I refer to some basic texts of anthropology and sociology, this is not a review of these fields but of historical fishing community studies, primarily of the nineteenth and twentieth centuries. The reason for the time frame is not that the community concept is irrelevant to ancient and medieval history but that most of the research discussion of the concept has developed in a dialogue between anthropologists, sociologists and modern historians.

Theories of Community

The dichotomy between community and society was developed by the German Ferdinand Tönnies (1887) in his book *Gemeinschaft und Gesellschaft*. To him there were three basic elements of community: blood, place and mind – interpreted sociologically as kinship, neighbourhood and friendship – and these ingredients make up all that is good and virtuous. By contrast, society is impersonal, rational. To Tönnies, community went beyond the local community to comprise also religion and authority, whereas secularity and power were associated with society. The value judgements so evident in this dichotomy is present even in modern community studies that are often prompted by a longing for the good life of old.

A new twist to community studies was offered by social anthropologists in the twentieth century. The Polish-born British anthropologist Bronislaw Malinowski (1960) studied the Trobriand Islands in the Pacific and broke the path both as regards methodology (the fieldwork) and theory (functionalism). The essence of social anthropology was conceived as a fieldwork that described the totality of a particular society. The description of a local community was a means to analyse culture as a whole, rather than to conceive of culture as a series of disparate elements. In this functionalist tradition the fieldworker tended to choose small well-defined societies, preferably on an island, and the end result of analysis was a reconstruction of the cultural perception of the world, which served human needs and bound the community together. On the basis of Malinowski's and later Radcliffe-Brown's perceptions, social anthropology classified and compared a rapidly growing number of fieldwork studies of non-European maritime and terrestrial communities.

Few communities parallel the remoteness of the Trobriand Islands, and fieldworkers realised that even the most isolated communities have relations to a surrounding world. The American sociologist Robert Redfield (1960) tried to map relations between local communities and the surrounding society (the great and the little tradition) and saw the little community as a homogeneous and well-integrated entity. His strongly functionalist perspective had a romanticising tone. The traditional village was seen as a wellbalanced and harmoneous system, and outside influences were described in terms of dissolution and disintegration. The model did not leave room for changes within the community, change had to be afflicted from the outside.

In the 1960s, quite a different inspiration to community studies came from the Norwegian Fredrik Barth's 'processual analysis' or 'generative model' (Barth 1963, 1966). He stressed the analysis of 'opportunity situations', in which individual 'entrepreneurs' seize the opportunity to alter and direct the course of events. Barth changed the perspective from community to individuality, taking individual initiative rather than economic, political and other conditions as his field of study.

While earlier community studies tended to view communities in a positive light, recent studies often highlight the conflicted and darker sides of communities. Concepts such as belonging, solidarity and support-network continue to be identified, but problems such as exclusion, inequality and oppression figure strongly in a recent overview of 100 community studies. Similarly, concepts such as social capital, resilience, networking, virtuality and innovation are now playing a transformative role in the use of the concept (Crow and Mah 2013).

The Uses of the Community Concept in Marine Environmental History

Historical fisheries studies owe much to the functionalist school of social anthropology. The definition of a community lends itself easily to studies of 'the rise and fall of the community x'. The basic model is reflected in many historic expositions. Often a structuralist analysis is inimical to a diacronical study but attempts have been made to analyse communities as homeostatic organisms, i. e. communities which are constantly changing and by that upholding themselves.

While early studies tended to focus on the conservative or resilient nature of fishing communities, later studies have pointed to revitalising or activist modes of communities. Barth's model influenced sociological studies by showing the importance of community entrepreneurs and political action. By studying communities in Newfoundland and Northern Norway Faris (1966/1972) and Brox (1966) advocated that community studies be conducted in the interest of the periphery. This 'action research' influenced many politically motivated community studies not just in Scandinavia but internationally (e.g. Davis 1992; Jentoft 1993).

Eco/Ethnohistory

While the environmental impact of communities tended to be seen as unproblematic or benign in early studies of fishing communities, environmental conflicts are highlighted in later studies. In the 1930s the influence of anthropology was being felt in the field of European ethnology, which had developed in France, Germany and Scandinavia as a specialist field. Culture was defined as two things: as a cognitive system – knowledge, values and interests – common to a specific group of people, and as cultural products – tools, buildings, popular ballads and legends. Taking the fieldwork method of social anthropology to European communities, the ethnologists studied mainly peasant material culture serving the needs of museums, but with little or no interest for maritime environments. Common to this field was a romanticising search for unspoilt rural origins.

In Sweden, Olof Hasslöf began interviewing sailors and fishermen in the 1920s, and his study of the small island of Smögen north of Gothenburg (Hasslöf 1941) set a new standard for museum documentation and at the same time he broke away from the agricultural confines. His massive doctoral dissertation on Swedish West Coast fishermen (Hasslöf 1949) was a history of 500 years of rural community building. Hasslöf presented the merchants of Gothenburg and state bureaucrats as ignorant reformers who tried to bring mercantilist and later capitalist organisations to the coast. By contrast the coastal people relied on ancient collegial organisations and the pooling of capital to cope with an unfriendly nature. Hasslöf seemed to attribute a moral superiority to the fishing community in relation to both urban and peasant cultures, and he found the roots of seamen's love of freedom in the Viking era, characterised by free peasant-seafarers. Hasslöf's basic assumptions of the unspoilt nature of coastal life resonated with a growing interest in the response by rural communities to modern urban life.

In the 1970s the Swedish ethnologist Orvar Löfgren (1972, 1979) combined Hasslöf's ethnohistory and Barth's entrepreneurial model with an ecological approach. Löfgren's main fieldwork (1977) was carried out in the parish of Bua at Värö peninsula south of Gothenburg. He described how at the beginning of the nineteenth century deforestation had created an impoverished community split between cash-crop farmers in the inland and marginalised crofters along the coast who provided cheap labour to the farmers and subsisted on a pluriactive economy, including fishing, keeping a cow and a few sheep, and collecting heather and driftwood for fire. Löfgren showed how the crofters' 'primitive life' was the result of market forces, and how later the introduction of decked vessels brought money to the crofters. Rather than pointing to the traditionalism of small communities, Löfgren stressed how almost every generation through the nineteenth century reacted to ecological problems and created their own solutions. Thus, instead of the 'historicising' model of Hasslöf, Löfgren (by means of Barth's theory of the entrepreneurs) presented a history of crofters changing their plight to an independent life as fishermen. However, Löfgren just as Hasslöf presented his community as an 'island' with little relation to the outside world. The history of big society and economy only becomes relevant to his presentation when government in the 1970s decided to build a nuclear power plant Ringhals at Bua, and the community was suddenly and forcefully exposed to external forces and succumbed.

Löfgren's description of the democratic values of the fishing community as a marginalised local community on the edge of an industrial society won considerable international approval, especially as a contrasting picture to the proletarian development of the fishing community on Newfoundland (Faris 1972), and similar generally rather depressing studies of North Atlantic communities (Andersen and Wadel 1972). Löfgren's study of independent fishermen became a model which stressed the actor role in community studies.

Community and Capitalism

In sharp contrast to this picture of the free Scandinavians stands British sociologist Jeremy Tunstall's portrayal of the miseries of the Hull fishermen (Tunstall 1962). Tunstall's book is a classic example of the fieldwork of a participant/observer/interviewer, who documents his findings through taped interviews. As such his description is devoid of the historicising ethnology so typical of the Scandinavian school, but it is no less passionate.

Tunstall presented a merciless and moving picture of human degradation in the fishing district of Hull around Hessle Road. The area was undergoing a radical change in the 1950s when Tunstall did his fieldwork. Some fishermen had broken up from the Hessle Road area to settle in suburbs, and the skippers were to be found in much more affluent surroundings. The fishermen's 'community' was thus changing from a residential pattern to an occupational community with less contact between families. When Tunstall carried out his research, trawler fishing was still going strong, though its decline as a result of lack of investment was clearly just around the corner. Tunstall's descriptions of the degrading conditions for ordinary fishermen and their families at sea and on land shocked contemporary Britain. Today the stark contrasts between the works of Hasslöf and Tunstall stand out.

Tunstall's work set the stage for a series of studies by a team of British historians, studying a combination of oral and written sources. Paul Thompson's book, *Living the Fishing*, (Thompson 1983), is undoubtedly the most influential community study of the decade, and should be read alongside the similar but less openly polemical analysis of East Anglian fisheries by Trevor Lummis (1984). The main theme of these works is how unrestricted fleet-owner capitalism undermined the spirit of the fishing communities, so that e.g. the protestant fishing community of Aberdeen was allegedly transformed in the space of a generation into a hell of wife-beating and alcohol misuse. Thompson maintains that lack of interest on the part of the fishermen and owners alike led to falling investments and a blind conservatism regarding access to traditional fishing grounds around Iceland despite environmental degradation and rising Icelandic protectionism of its home waters. Lack of adaptation resulted in a decline of trawl fishing in the 1970s and the consequent loss of capital investment and work force. This process of decline is used by Thompson as an illustration of the evils of unrestrained capitalism. He finally presents the more egalitarian Scandinavian model in Hasslöf's mould – which he also thought characterised the Shetland Islands – as worthy of emulation.

The approach common to the authors presented here is an analysis of a capitalist form of fishing, which is assumed to destroy local communities and lead to moral decay. This attitude can be seen in a whole series of historical-cultural studies that link industrialisation with serious human and cultural loss and are basically pessimistic about modern society (Holm 1992). Hasslöf, Tunstall and Thompson agree in linking capitalism (fleet-owner capital and wage-earners onboard) with moral decline. In the same way, Thompson links capitalism with a distortion of the relations between men and women, whereas he describes women in the 'democratic' fishing communities as playing a central and respected role as the pivot of family life and enjoying a certain economic independence. Hasslöf and Thompson identify the communal ownership model with responsibility, community and democracy. At the same time, it should be pointed out that both Hasslöf and Thompson see the social constrictions of the communal model as an obstacle to the free development of the individual, and point out that these social restrictions can inhibit innovation. While Thompson finds social and political inspiration in the free and independent fishermen, Löfgren paints a resigned picture of a marginalised community in the process of dissolution.

The interaction of the human community with the natural environment is touched upon but not fully articulated by Hasslöf and Tunstall. To Hasslöf the environment is first and foremost a question of matching fishing technology to the species targeted, and by the use of detailed drawings he set a very high standard for understanding fishing operations. He provides a clear picture of how fishers are forced to pursue their catch in ever more distant waters but he does not analyse the movement as a possible case of serial depletion. Tunstall's work is primarily a work of sociological analysis but it may also be seen as an early example of an urban ecology although he did not claim the word. His study unites a perspective on human relations on board and at home with a sense of fraught relations with ever more distant fishing grounds. In this sense his study deserves to be read as an early example of marine environmental history. Löfgren finally takes the full step towards ecohistory. However, his environmental interest is not so much in the relations of fishermen with the sea but in understanding how the development of cash-crops created a sharp division of labour between propertied peasants and marginalised crofter-fishermen.

Recent European Studies: Communities and the Commons

In the 1990s, community studies and environmental history merged in a series of studies by the Dutch ethnographer Rob van Ginkel. His history of the oystermen of the island of Texel (van Ginkel 1996) introduced a theme which has resonated in many later studies: the problem of the commons. Today, open access fisheries often create problems of overfishing and management. Van Ginkel broke new ground by studying the historical roots of overfishing and community responses between 1700 and 1932, which he identified as an early instance of the Tragedy of the Commons (cf. Hardin 1968). In a later book he has revisited the island and taken its history up to the present (van Ginkel 2009) and published a volume of studies of European and American historical fishing and whaling communities *Coastal Cultures*: *An Anthropology of Fishing and Whaling Traditions* (van Ginkel 2007).

Similarly, Natalia Steins (1999) combined the study of commons and community in three case studies of the Isle of Wight (UK), Connemara (Ireland) and the Dutch Wadden Sea. Her study stressed the importance of actor-networks in processes involving multiple stakeholders pursuing rational but conflicting choices. She argued that actors may overcome the dilemmas inherent in rational choice models (Tragedy of the Commons, Prisoner's Dilemma) by collective action, involving the development of trust and a sense of community. While the study did include a century-deep perspective the focus of the study was the observation of contemporary processes. However, the study indicates some potential avenues for future analysis of historical fishing communities.

The focus point of much of contemporary sociological debate about fisheries management is the role of community and the potential of co-management by resource users. While most of this debate is a historical, the studies by van Ginkel and Steins indicate the potential contribution by a historical perspective. However, they also reveal that much lies in the eye of the beholder: Steins is very conscious that her study by itself contributed to the processes of co-management which she wanted to study, while van Ginkel is very clear that historical action did not just play out according to sociological rules; in fact, his analysis shows that the predictions of the Tragedy of the Commons do not adequately explain the decline. Actors did observe and tried to mitigate the consequences of their actions while negative attitudes to government intervention ruled out other actions. Van Ginkel concluded that the *homo economicus* of the Tragedy of the Commons is belied by historical analysis, and that "fishing practices are embedded within the historical, economic, social, and cultural context of communities."

In a recent review of recent sociological studies of fishing communities Urquhart et al. (2011) state that there is still only a "small, but informative, literature on the social impacts of fisheries." They call for future studies to break out of the narrow confines of isolated communities and to establish the importance of fisheries in other community settings. This seems like an open call for future collaboration with marine environmental historians. Steins et al. also echo the interests pursued by Steins as they would like to see "ecosystems approaches to management that incorporate the social and cultural dimensions alongside the ecological need". However, it seems that the basic problem is not much changed since van Ginkel's first study: on the one hand, managers seeks prescriptions based on ecological and sociological models, and on the other hand, historical analysis demonstrate the contingency of cultural and social communities.

American Studies of Fishing Communities

In a survey of North American marine environmental history, W. Jeffrey Bolster (2008) observed that "The very fact that humans' modification of near coastal ecosystems in much of the settled world has been on-going for centuries, and has been ignored for almost as long, provides tantalizing possibilities for scholars to explore how human maritime communities were embedded in non-human marine communities, and what that meant for the course of history." While previous American fisheries histories have primarily been dedicated to understanding legal and resource contexts (McEvoy 1986; Bogue 2000; Payne 2010; Bavington 2010). A notable exception to this pattern is the collection of fishing community histories by Newell and Ommer (1999). Recently, however, two studies have taken up the challenge of understanding human and marine communities as they interact.

Matt McKenzie's book *Clearing the Coastline* (McKenzie 2011) encapsulates the economic, ecological, and artistic drivers of change along the Rhode Island-Massachusetts coast from the seventeenth though the nineteenth centuries. In six chapters we get the story of how 'Wastelands' were managed and turned into 'Workspace' which generated 'Prosperity' but also precipitated environmental degradation. The final chapters investigate how public discourse eventually marginalised fishers as first scientists and later urban tourists took a hold on the coastline and thus cleared the inshore waters of not only fish but also of the local human population. The outcome was an impoverished sea as well as a deserted land which attracted a new generation of tourists who came in search of undisturbed nature. The conclusion is careful to apportion blame between the fishing population, scientists, politicians, and artists who helped both romanticise and eventually abstract the locals from the shoreline.

McKenzie writes in a tradition of American environmental history known as declensionism – his is a story of human degradation of the environment where everything gets worse step by step, and his pessimistic interpretation of nineteenth-century technological development is akin to many community studies of the past. He deplores the demise of the hand lining communities of the early nineteenth century as a loss of a more sustainable fishing practice and perhaps a better social life. McKenzie's careful analysis of the fishing technology of the first part of the nineteenth century is a close parallel to Hasslöf's study of West Swedish technologies of the same time, and there seems to be future potential for comparative analysis of technologies and communities around the Atlantic basin. Methodologically, the book also opens up new perspectives by using landscape paintings as a source of information on the public perceptions of the coast. No doubt such paintings impressed themselves on the urban American public and McKenzie shows how they inform us of actual developments on the shoreline.

As mentioned, Bolster (2008) alerted the American historical profession to the potential of marine environmental history, and Bolster (2012) is a full-blown interpretation of the historical fisheries of the Gulf of Maine and repercussions on maritime communities. Bolster argues that by the seventeenth century the waters of the Old World had been fished down and that New Englanders were right to rave about the richness of the waters of the New World. Here they found an abundance of fish and specimens of a size that they had never seen before. In the next couple of 100 years they enjoyed reaping the bounty of the sea, introducing wasteful practices such as damming the rivers and fishing out nursery seabeds, thus slowly depleting life in the sea. Bolster succeeds admirably in describing how over the centuries fishermen, advisors and decision makers were trapped in their minds by generational memory loss – the changing baseline syndrome; they suffered from the cumulative effect of bad decisions and each and every generation did not realise how much had been lost by the previous generation.

While Bolster's book sets a very high bar for future marine environmental history, it highlights a methodological dilemma in the uses of qualitative and quantitative evidence. Bolster largely tells his story of the fishing down of NW Atlantic waters by means of anecdote – the persuasive power of story after story of contemporary accounts of excessive catches and failure of the run of fish the following year. Occasionally, Bolster makes clear that contemporary claims are likely to have been alarmist such as when New Englanders believed that their few and small boats had an impact on the staggering but unpredictable abundance of mackerel in the seventeenth century. However, such is the flow of his narrative and the many stories we are told that it is difficult to fully assess the ecological impact of early modern fisheries.

Non-European/American Studies

Outside Europe and North America the field of marine environmental history is still only in the early stages. Many social-anthropological studies have analysed fishing communities but few have dealt seriously with historical change. For this review I shall restrict myself to some observations on Asian studies. Similar potential is evident for historical studies of African and Latin American fisheries communities.

In South Asia, the lack of research interest has been compounded by the fact that maritime communities are attributed a marginal position in society as 'impure' and 'untouchable'. Studies indicate that economic growth in recent decades has given rise to greater inequality and mobility in maritime communities, and with a growing role of the state and the global market maritime communities are becoming a recognised part of society. Problems of overfishing are evident but the role of communities in management and conservation are understudied. A review of the literature concluded that the "historical perspective is weak in most of these ethnographies" (Gupta 2003, 35).

In East Asia there is a similar lack of studies of historical fisheries communities, though a few monographs shine a light such as Arne Kalland's pioneering study of a Japanese whaling community (1981), Cynthia Neri Zayas' (1999) study of two Japanese fisheries communities, and David Luke Howell's (1995) study of nineteenth-century Japanese fisheries. In China, inroads into a vast unknown have been made by Chen's (2009) study of twentieth-century Taiwanese fisheries, and Muscolino's (2009) history of fishing wars in Imperial and modern China. Butcher (2004) provides a 150 year overview of South East Asian fisheries and deals with human communities to some extent. Christensen and Tull (2014) is a rich volume of studies of Asian and Indo-Pacific fishing communities which point to a promising future of this research field. There is a rich and rapidly growing body of Indian Ocean studies which highlight non-European contacts between littoral and fishing communities through the centuries between Africa, Arabia and South Asia (see for example Ray and Alpers 2007).

However, the rapid growth of Asian economies in the last couple of decades is changing the picture of neglect very fast. While pioneering studies in many countries have been made by European and American scholars, there is now a quickly growing body of locally-based historians, with appropriate language skills, who will soon rectify the skewed body of literature to give rich insights into Asian fishing communities. Much groundwork needs to be done, and it is important that environmental perspectives are brought into such studies. A very promising initiative has been taken recently by the launch of the *Journal of Marine and Island Cultures* by the South Korean Institution for Marine and Island Cultures (Hong and Pungetti 2012).

Asian coastal fishing communities depended on rich and highly diverse local resource bases well into the twentieth century and many still do to this day but environmental problems, in particular overfishing and bad management, increase the importance of understanding human resource use. The Asian colonial experience was crucial for problems of availability of capital, the role of the state and the slow development of scientific support for the fisheries. In recent decades globalization of fisheries have turned the seas of the world into one ocean in economic terms. Fisheries for tuna and sea cucumber have driven Asian vessels into the Atlantic just as earlier Atlantic whalers made the Pacific their home grounds. The global trade in marine foods is a vast and understudied field as indeed is the development of illegal and unregulated high-seas fisheries. The rise of aquaculture, not least in South East Asia, is a phenomenon of worldwide importance both as regards food security and changing urban life styles and has come at tremendous environmental cost but still lacks comprehensive historical treatment. The agenda for Asian marine environmental historians is vast and rapidly expanding.

Community and the Individual

In the twenty-first century, imagined and virtual communities may be more important to the individual than neighbours and colleagues. People living or working close to each other need not have much to do with each other. In a similar way we may assume that fishing communities are becoming deterritorialised as crews may be recruited from outside local communities. So to what extent do people of the present-day live in fishing communities and what effects is the deterritorialisation of fisheries having on the environment and governance of the sea?

These are huge research questions which hardly have been addressed as yet but we may find some possible clues in published research. A study of North Norwegian fishing communities found that even in these settlements with a strong sense of tradition and a state-subsidised residential pattern, communities seem to be breaking up (Jentoft 1993). Apart from the problem of recurrent scarcity of fish and thus losses of jobs on board fishing boats, women seem to be less attracted to stay on in villages where there is little job opportunity and their existence turns round the question of male employment. Enormous efforts are required simply to keep a community living; in Vesterålen islands north of Lofoten for instance, subsidies went towards a total remake on the industrial structure, from cleaning the harbour to providing day care facilities and establishing new jobs and managerial structures in the fish processing industry. Similar patterns of the dissolution of fishing communities have been identified in Denmark by means of in-depth repeat studies of all working fishing ports around 1990 and 2005 (Holm 1994; Byskov 2010).

A study of the geographical mobility of Danish fishermen in the twentieth century showed that habitational homogeneity among skippers and first mates broke up during this century, as more fishermen were born outside the parish and even the county of present residence (Vestergaard 1991). This quantitative evidence suggests that maritime communities have become less distinct during the twentieth century. On the other hand, occupational tradition was if anything reinforced. While 72 % of fishermen in 1935 were following in the footsteps of their fathers, the same was true of 76 % some 30 years later. In other words, fishermen seemed to converge on a national occupational pattern rather than on a local residential pattern. It would be of interest to see comparative studies in other countries.

With the tremendous increases in fishing power over the last century thanks to mechanisation and digitisation of operations, the traditional links between the home base of fishing operations and fishing grounds are breaking up. The selling and buying of fish quotas have established national and international markets of production capacity. One recent study identified the continuing relevance of community ties in the Shetland Islands, UK, where companies have bought most of the pelagic resources of the British seas. By 2012, the UK pelagic fleet numbered only 31 large-scale boats. Seven of these operated from the island of Whalsay in Shetland, which, with a population of approximately 1000 people (0.000016 % of the population of the UK), was entitled to land around 22 % of the UK pelagic catch. The huge price now attached to buying a quota prevents new entrants, thus putting severe strain on the survival of even this small nucleus of a fishing community (Cardwell and Gear

2013). Similar processes of concentration have dramatically impacted fishing communities in Iceland and New Zealand. In Denmark a recent study found that the introduction of transferable quotas in 2007 in the course of just 5 years caused the closure of no less than 50 fishing ports and the concentration of pelagic quotas in the hands of a few so called captains of finance (Høst 2013). The development is justified by the need to increase fishing management and undoubtedly it is easier to control a few dozen large trawlers than hundreds or thousands of smaller vessels. Such dramatic changes point to a future where fishing communities may be a phenomenon of the past as the number of vessels and crews will be so small as to no longer define a port community.

On the other hand, in developing countries millions of fishers depend on meagre returns in many developing nations. In the Philippines it is estimated that as many as 1.2 million people are engaged in fishing ever more depleted waters. A transition to a heavily capitalised and managed quota system, which maybe would be desirable from an environmental point-of-view, would create enormous social problems. Maritime communities across the globe are desperate for income and provide low-waged labour. International illegal and unreported fisheries have developed across the globe (see Christensen, this volume), and it would be of significant interest to understand the composition of crews and home bases of fishing operations which are alienated from traditional local, national and even international frameworks. In sum, community studies are of increasing importance to understand global change effects on humans and the environment.

Conclusion

In this essay I have touched on the theoretical inspiration to community studies and pointed to some basic assumptions and evaluations of maritime communities in their environmental and societal contexts. Analysing relations between 'community' and 'surrounding world' have led some fieldworkers to realise that the well-defined community they set out to analyse did not exist. Giving a name to a community is easy, the problems begin when the researcher defines criteria to distinguish community and surroundings. Community studies helped bring forth a 'thick' (or fuller) description than the tools normally employed by the historian would allow. The challenge in coming years is to integrate these insights into the normal practise of the historical discipline and to overcome the limitations of studying the small scale. The lack of comparative quantitative studies is a deficit but also points to the rich potential for reinvigorating marine environmental history by drawing on and redefining the study of fisheries communities. The study of fisheries communities has been dominated by social perspectives which have tended to neglect or not fully analyse the interaction between natural and social environments. Environmental historians bring an interdisciplinary vision and training which enable a dialogue across the natural and human sciences (Holm et al. 2013). By identifying fisheries communities as a key concept for marine environmental history we may have a meeting-point.

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Archaeology as a Tool for Understanding Past Marine Resource Use and Its Impact

David C. Orton

Introduction: The Unique Potential and Contribution of Archaeology

Archaeology refers to the recovery and analysis of any and all material traces of past human activity. This broad remit has resulted in a highly diverse discipline whose themes and methodologies straddle the sciences and humanities. Archaeology's most obvious advantage for historical ecology is potential time depth. While systematic scientific observations are typically only available for a matter of years or decades, and historical records become increasingly patchy beyond a few centuries, archaeology provides a more continuous record of resource use potentially going back thousands of years, albeit subject to its own set of biases and limitations. This ability to reach 'beyond' historical sources may be geographical as well as purely temporal: detailed records of early trade networks, for example, are often concentrated in core areas, making archaeological data from the periphery crucial for understanding the complete system. Even within the scope of written sources, archaeology may illuminate aspects of fisheries and other relevant activities that are rarely or unreliably documented.

Artefactual evidence from archaeological sites may have a bearing on past marine resource use, from fishhooks and tools to the remains of ships and processing facilities. This chapter, however, focuses on marine zooarchaeology – the study of marine animal remains found in archaeological contexts. Bones, teeth, shells, and other hard tissues typically preserve well and are often amongst the most abundant remains recovered from archaeological sites. Artefactual data on marine resource use is illuminating but sporadic; zooarchaeological remains constitute a more

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systematic record of the species exploited and – to an extent – the manner of their exploitation.

As a tool for understanding the history of marine animal populations, zooarchaeology arguably fills an intermediate position between palaeontology and history, not just in terms of typical time-frames but also of the nature of the evidence. On the one hand the ‘zooarchaeological record’ can be seen as a rich source of (relatively recent) palaeontological data, providing information on past animal populations that is unfortunately distorted by a filter of human activity. On the other, this very filter – the selective capture and use of organisms – constitutes direct evidence for human exploitation of those populations. The unique potential of archaeology to trace human impact on marine ecosystems over the long term depends on successfully exploiting this intersection between environmental and cultural evidence.

Beyond History: The Value of Time Depth

Although Pauly’s (1995) concept of a ‘shifting baseline syndrome’ – in which researchers erroneously take the situation they encounter at the beginning of their careers as a baseline against which to evaluate the effects of human exploitation – is now widely recognised, there typically remains little consensus regarding the time depth of significant human impact on a given population or ecosystem. There is therefore an ongoing need for studies aimed both at assessing the antiquity of intensive human exploitation of marine ecosystems and at reconstructing past states of those ecosystems.

With scientific stock assessments rarely reaching back beyond 100 years (Pinnegar and Engelhard 2008:4–5), the historical disciplines provide an alternative basis for such ‘baseline studies’. Apart from references to capture technology and past ranges, historical records kept for taxation and inventory purposes may represent quantitative data on effort, landings, and subsequent trade (Holm, chapter “Historical Fishing Communities”, in this volume). The time depth attainable varies widely, however: while the famous Danish Sound Toll Register reaches back to 1557 (www.soundtoll.nl), for example, and the earliest systematic customs records from England began in 1303 (Lloyd 1991:23–24), detailed historical coverage of fisheries and related trade typically extends to a few centuries at most. Moreover, where textual sources do exist they are not necessarily comprehensive. Where human use of marine species pre-dates available historical sources or falls outside their scope, archaeology constitutes an alternative source of data potentially reaching back millennia, albeit at reduced chronological resolution. Of course, one might question how useful this added time depth actually is. Taking the baseline paradigm at its simplest, this means asking at what point appreciable human impact began.

One intuitive answer involves the advent of industrialisation or mechanisation. For example, the introduction of the steam trawl in 1886 might be taken as the origin of ‘intensive’ North Sea demersal fishing (see Engelhard 2008). Since historical catch records in this case reach back to 1892 (Engelhard et al. 2011), there might seem little need for additional data sources. But did earlier fleets using less efficient technology necessarily have a negligible impact? While the total biomass removed was surely small by recent standards, concentration of effort in relatively coastal waters, for example, might have impacted upon stock structuring. If looking for a cut-off, one could alternatively point to earlier technological watersheds such as long-lining, or to economic and demographic events affecting demand. Archaeological data show that widespread consumption of gadids around the North Sea began suddenly at around AD 1000, providing the ultimate starting point for commercial-scale exploitation (Barrett et al. 2004a). In this as in any case, determining the true time depth of human impact on stocks is a difficult task, requiring empirical data. Globally, a persuasive case can be made for widespread pre-industrial – indeed prehistoric – human impact on marine ecosystems (Erlandson and Rick 2010:245–246; Pinnegar and Engelhard 2008).

Although a useful heuristic tool, the concept of a static, pristine, baseline state is limited given the dynamic nature of ecosystems. The further back one looks, the more likely it is that other factors, notably climate, would have driven changes with or without human action, and the less relevant the putative baseline becomes. This is particularly problematic in light of marked climate change over the last few centuries, and its continuing acceleration. Rather than rendering archaeological data irrelevant, however, this realisation plays into its greatest strength: time depth. The archaeological record presents a unique opportunity to trace changes across past episodes of climate change and/or human activity, and potentially to understand the interaction between the two, i.e. to provide ‘dynamic baselines’. In Europe, marked increases in average temperature since the eighteenth century may limit the utility of immediately pre-industrial data – for some purposes data from the generally warmer twelfth to thirteenth centuries may actually be more relevant. Time transects across warmer and cooler periods are potentially more useful still. In effect, the archaeological record can serve as a virtual laboratory for understanding past ecosystem changes and thus for predicting and managing developments. However, it must be recognised that some ecological changes – human-induced or otherwise – are irreversible: extinctions, loss of genetic diversity, and to some extent habitat destruction are one-way processes, and past events can only ever represent imperfect analogies for present and future changes.

The (Zoo)archaeological Resource

The ‘archaeological record’ refers to the totality of information that may be drawn from physical remains preserved on archaeological sites. The potential of this resource varies widely depending on numerous factors – from the discard and burial of remains, through soil chemistry and geological processes, to decisions made during excavation and subsequent analysis. The archaeological (and palaeontological) sub-discipline of taphonomy has developed to analyse and mitigate biases resulting from these processes (see Lyman 1994 for an overview).

Excavation has traditionally been driven by the interests of academics and/or the need to record known sites in imminent danger of destruction (‘rescue archaeology’), resulting in significant research biases. In recent decades, however, some countries (including much of North America and northwest Europe; see Webley et al. 2012) have instituted systematic development-led archaeology, in which construction projects are subject to routine archaeological oversight and/or prior excavation. This has generally resulted not only in a proliferation of data, with better coverage and less research bias, but also in increased standardisation of methodology and reporting – greatly increasing potential for meta-analyses of biological remains from multiple sites.

Since excavation is an inherently destructive process, documentation, publication, and archiving are critical. Unfortunately, much primary data is never published. Reports often remain as archived ‘grey literature’ or emerge in short print-run monographs, preventing easy access for non-archaeological researchers (Vander Linden and Webley 2012:6–7). Electronic publication is becoming more frequent, however, with the development of repositories for unpublished reports (e.g. the UK’s Archaeology Data Service) and of online databases (e.g. tDAR and Open Context; see Kansa 2010). Physical archives of ‘ecofacts’ (biological remains associated with human activity, c.f. artefacts) are now typically kept indefinitely, although discard after study was not uncommon in the past. In most territories these remains should ultimately be deposited with a local museum or statutory body, along with the site’s documentation, but in practice they may remain in the stores of excavation companies, university laboratories, or freelance analysts for many years. Contacting museums, excavators, and analysts directly is still often the best way to access both data and physical samples.

The methodology used to recover animal remains is critical. Failure to sieve excavated sediment – or to use sufficiently fine mesh – leads to many smaller bones being missed, seriously biasing results (Nagaoka 2005). Fish remains are ideally recovered by water-assisted sieving through fine mesh (Zohar and Belmaker 2005). Standard practice in UK development-led archaeology, for example, is to subject an ‘environmental sample’ of sediment from each promising stratigraphic unit (‘context’) to this treatment, while collecting bones by hand from the remainder. When assessing published results it is crucial to establish the methodology employed, and extreme caution should be exercised when comparing data resulting from differing recovery systems.

Once recovered, animal remains are studied by specialists, fish often separately from other vertebrates. Taxonomic and anatomical identifications are made with the aid of a physical reference collection, often supported by published guides and – increasingly – online resources (e.g. Nottingham’s Archaeological Fish Resource). Analysts vary regarding which anatomical elements are routinely recorded to which taxonomic level, introducing more potential biases. Information on age-at-death is also recorded where available, with size being the key proxy for age among fish (see also below regarding incremental growth structures). Standardised measurements (e.g. Morales and Rosenlund 1979) are taken where possible, with regression formulae for certain species and elements allowing estimation of individuals’ live lengths and weights (e.g. Thieren et al. 2012). Additional histological or biomolecular analyses may be carried out in specialist laboratories, including thin-sectioning of otoliths to analyse incremental growth rings, stable isotope analyses of bone collagen, and ancient DNA studies.

Dating is crucial to analysis of archaeological finds, but attainable resolution varies widely. For prehistory, radiocarbon dating (^{14}C) is the main technique. Individual dates (once 'calibrated') typically have ranges of a couple of centuries at 95 % confidence, but Bayesian modelling of multiple dates can increase precision from centuries to decades in some circumstances (Bayliss et al. 2007). Carbon dating can be applied directly to bone samples, rather than dating the context in which they were found, although an 'old carbon' effect in marine samples reduces precision (Russell et al. 2011). For more recent periods, dating based on associated material culture styles may allow finer resolution, in some cases down to a matter of a few decades. Higher precision still can be achieved through tree-ring dating (dendrochronology) of preserved timbers, potentially revealing the year in which a tree was felled. Sequences of such dates, e.g. in waterlogged urban deposits, can provide comparatively precise temporal brackets for contexts in which bones were found. Dating precision is typically highest in urban sites with complex stratigraphy.

Lines of Archaeological Evidence in Historical Ecology

Presence/Absence Data and Biogeography

The simplest data that can be derived from archaeological remains concern presence or absence of particular taxa in a given region and time period. In theory, the identification of species on archaeological sites can be used to trace range contractions and expansions over time. The mass of unpublished 'grey literature' in many countries represents a rich biogeographical resource just waiting for collation and analysis, held back principally by limited visibility across disciplinary boundaries. Sporadic published reviews (e.g. Enghoff 1999, 2000) are more accessible, but cannot keep pace with the accumulation of raw data. The Inventaires Archéozoologiques et Archéobotaniques de France (I2AF, Callou n.d.) project is a significant step in this direction, compiling data from more than 4700 French archaeological sites into an online database that can be searched by taxon and returns results by location and period (Fig. 1).

Given sufficient coverage, archaeological data could in theory be used to validate hindcasts from bioclimate envelope modelling, for example, and hence to refine predictive models. Systematic incorporation of archaeological results in this way remains to be undertaken, but past ranges have been assessed against climatic changes on a less formal level. Enghoff et al. (2007) demonstrated the widespread presence of anchovy in the Kattegat and western Baltic during the warm Atlantic period, juxtaposing this result with recent catch data indicating the species' return during the last two decades, presumably linked to rising temperatures. Interestingly,

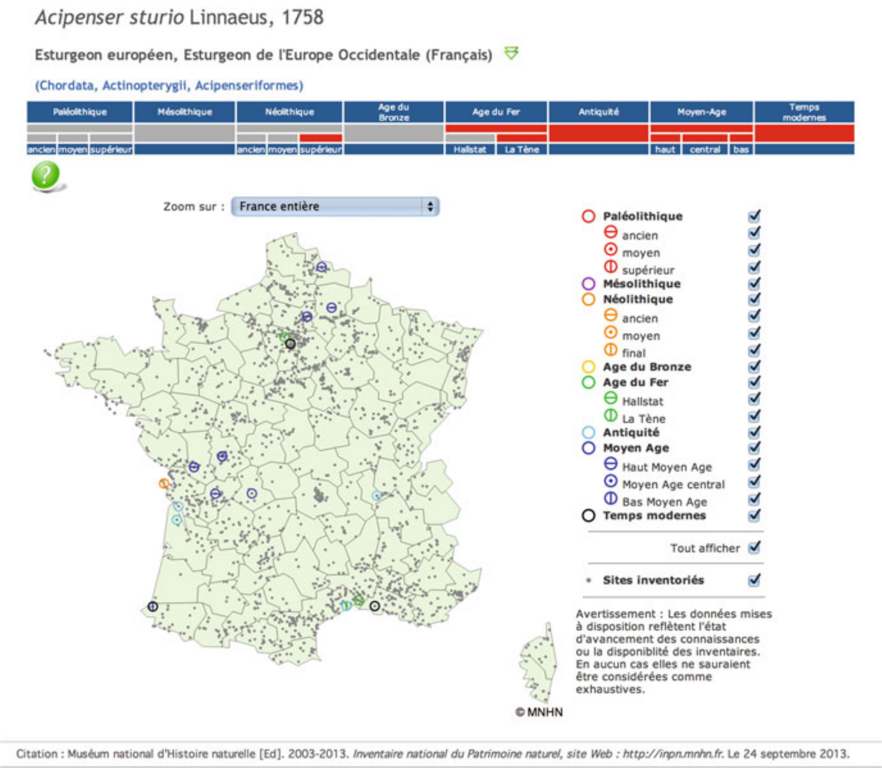

Fig. 1 Screenshot from the I2AF database in August 2013, showing results of a search for European sturgeon, *Acipenser sturio*. Archaeological occurrences are displayed by broad chronological groups, while small grey dots represent sites at which the species was not recorded (Copyright Muséum National d'Histoire Naturelle 2003–2013; Callou n.d.)

they also showed widespread exploitation in the same period of cod, *Gadus morhua*, a relatively cold-water species whose abundance one might expect to have been limited. Other studies have traced range changes or extirpations of species from the common eel, *Anguilla anguilla* (Kettle et al. 2008), to the great auk *Pinguinus impennis* (Serjeantson 2001).

The main limitation here concerns 'absence of evidence': it is impossible to demonstrate definitively that a species was not present in a given time and place. While confidence increases with intensity of research, there always remains the possibility that a species was present but simply not exploited. A meta-analysis of 107 bone studies from pre-European sites in New Zealand indicated that Maori communities generally harvested marine resources on the basis of availability, with limited selectivity (Smith 2013). Declines over time in the distribution (and relative abundance) of certain taxa – particularly seals and seabirds – could thus reasonably be attributed to harvesting pressure, but even in this case changes in taxonomic representation of fish on archaeological sites were argued to represent shifts in human settlement patterns and resource use, rather than availability.

Evidence for presence is more reliable, but nonetheless requires caution. Just as in the present, past human societies sometimes moved both living and dead individuals over considerable distances. Isolated or sporadic finds of surprising taxa are thus suspicious, particularly if they represent species or body parts potentially seen as exotic or valuable – the presence of a narwhal tusk certainly cannot be taken to indicate a local population – although in practice this is not always clear-cut. Archaeological context and prior knowledge of likely trade networks are important here. For example, barracuda (*Sphyraena sphyraena*) remains at a Roman site in the Netherlands (Enghoff 2000) should be interpreted in the context of considerable long-distance trade in food and commodities during this period (Pinnegar and Engelhard 2008:10). Likewise, specimens recovered from sites with a known trading role should be treated with caution.

Finally, archaeological biogeography is limited by the ability to identify remains to species, although the development of low-cost collagen fingerprinting (ZooMS – Richter et al. 2011) is likely to improve the situation dramatically in the near future.

Relative Taxonomic Abundances

Moving beyond presence and absence, the next most basic form of zooarchaeological data is the relative abundance of different taxa. Taxonomic abundance is most often reported as Number of Identified Specimens (NISP), i.e. straightforward specimen count. Minimum Numbers of Individuals represented (MNI) may also be calculated and used to estimate relative biomass, but have limited comparative potential (see Lyman 2008 for overview).

Since archaeological finds are the result of selective human activities, such data is not a direct proxy for relative abundance in the ecosystem. Moreover, estimates of relative abundance even in archaeological collections are subject to bias deriving from recovery methodology, differential identification rates, or survival in the ground (e.g. cartilaginous fishes will always be under-represented). Where such conditions can be controlled and/or corrected for, however, relative abundances are a key tool for reconstructing the history of exploitation of marine species. Their enumeration is a routine element of zooarchaeological reports, sometimes explicitly aimed at evaluating 'baseline' ecosystem states and/or sustainability of pre-industrial fisheries (e.g. Carder and Crock 2012).

Some studies have considered possible pre-industrial impacts of fishing pressure through the fishing-down-the-food-web phenomenon (Pauly et al. 1998), by tracing changes over time in mean trophic levels of marine species in archaeological assemblages (Bourque et al. 2008; Erlandson et al. 2009; Reitz 2004). The idea here is that an initial focus on large, high-level predators gives way to a gradual shift towards lower trophic level species if fishing pressure is sufficiently great to depress abundance of the former. This can be problematic when applied to the archaeological record for several reasons (Keegan 2009), not least the assumption that Optimal Foraging principles – favouring capture of larger species – outweigh variations in cultural preferences (not to mention changes in capture technology) when determining which taxa are targeted, an assumption called into doubt by ethnographic research (Jones 2011). Moreover, estimates of trophic level are based upon each species' position within modern food webs, which may not be analogous to their (pre)historic counterparts precisely because of the effect of fishing pressure over time (Morales and Roselló 2004:121). Nonetheless, broad long-term trends in trophic composition of (pre)historical catches can help to understand shifts in exploitation strategies and resultant fishing pressures.

Less directly, apparent abundance of one species may be taken as evidence for human exploitation of its predators, by analogy to present-day trophic cascades: Erlandson et al. (2005) take the frequency of red abalone on some sites in the Californian Channel Islands as evidence that prehistoric hunting had a significant depressing effect on sea otter populations.

Equally important is evidence for scale and specialisation of fisheries. Zooarchaeological abundance data can certainly detect shifts in the relative focus of fisheries, for example using diversity indices to assess specialisation (Carder and Crock 2012). Assessing changes in absolute catches is much more problematic. For example, marine species are almost absent from the archaeological record of England from the Neolithic to early medieval periods, but gadids suddenly become a major component of fish bone collections from approximately AD 1000 (and herring a little earlier at certain sites), with a concomitant decline in relative frequency of freshwater taxa (Barrett et al. 2004a, Fig. 2). In this case an interpretation in terms of an absolute increase in sea fishing – dubbed the 'Fish Event Horizon' – is reasonable given the near-total absence of marine species in earlier contexts. From relative frequencies alone, however, it is impossible to determine the initial scale of this new industry or the extent to which freshwater catches declined in absolute terms.

One solution would be to compare frequencies of both marine and freshwater species against terrestrial taxa – Barrett et al. (2004b) use this approach to demonstrate increased catches off northern Scotland in the same period – although preservation, recovery, and identification biases between fish and mammal remains must be overcome. Given reasonable estimates of (a) the relative dietary contribution of marine resources and (b) human population size, it may even be possible to estimate absolute biomass harvested – as demonstrated by Smith (2011) for pre-European New Zealand – although the possibility of trade between coastal and inland communities complicates such calculations. An alternative approach to assessing changes in scale is to assess the ubiquity of taxa – that is, the percentage of archaeological contexts from a given period in which they occur (e.g. Nicholson 1998).

Evidence for Production, Consumption, and Trade

The over-exploitation of marine resources in the present and recent past is underpinned by the development of consumer markets, commercial trade, and long-distance transport, allowing resource exploitation to be pushed well beyond local

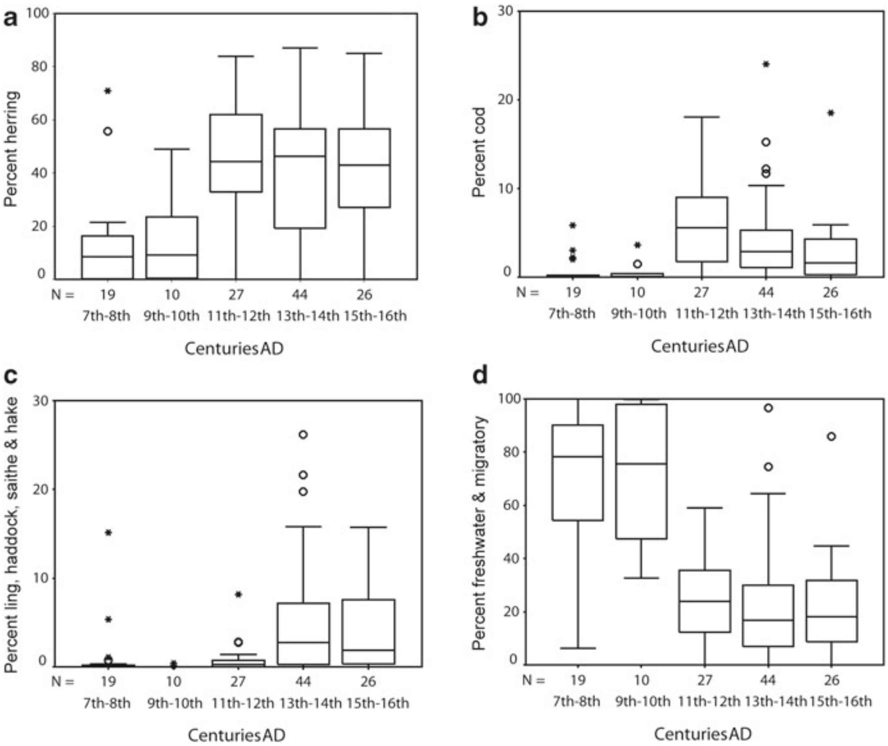

Fig. 2 Boxplots showing the relative frequency of different taxa in sieved English fish bone assemblages dated from AD 600–1600: (**a**) herring; (**b**) cod; (**c**) ling, haddock, saithe, hake; (**d**) freshwater and migratory species. Note the clear shift between the tenth and eleventh centuries, dubbed the 'Fish Event Horizon' (Reproduced from Barrett et al. 2004a by permission of the Royal Society)

ecosystems (Hoffmann 2001). Understanding the emergence of these phenomena is an important goal for marine historical ecology. Archaeology has shed considerable light on the early development of market economies and commercial trade in various times and places. With regard to the commercialisation of fisheries, zooarchaeology may contribute through evidence for industrial-scale production, for trends in mass consumption over time, or directly for trade.

The development of market trade in fish results in a distinction between producer sites – coastal locations where fish are landed and processed – and consumer sites, particularly urban settlements with a high concentration of demand. Production sites are potentially marked out by their focus on a narrow range of taxa and/or the sheer quantity of bones recovered relative to the size of the settlement (e.g. Barrett et al. 1999). Moreover, since these bones primarily represent processing waste, the anatomical distribution is likely to be distinctive. Prior to the invention of refrigeration, preservation of fish for storage or long-distance transport often involved removal of some body parts. In northern Europe, for example, cod were typically

Fig. 3 Cut marks to a cod caudal vertebra in transverse plane, suggesting removal of the anterior vertebrae for preservation as 'split fish' (*rotskjaer*) (Reproduced from Harland and Barrett 2012, with permission (Photo: J. Harland))

decapitated prior to drying for trade, with or without salting (Barrett 1997; Perdikaris and McGovern 2008); sites with cranial bones overrepresented are thus likely to represent processing for consumption elsewhere. Fourteenth to fifteenth century cod at the Teutonic Order castle of Mała Nieszawka – around 150 km upstream from the Polish coast on the river Vistula – are dominated by cranial bones and cleithra (an appendicular element just behind the head) with extremely few vertebrae, suggesting that fresh Baltic cod were shipped upriver to the castle before being processed for onward transport (Makowiecki et al. 2016). Anatomical data may be complemented by physical traces of butchery, i.e. cut marks on bone surfaces or elements chopped clean through (Fig. 3) – typically the cleithrum and/or anteriormost vertebrae in the case of cod (Barrett 1997).

By contrast, gutting and salting of herring in medieval Europe often followed the *kaken* method, with a knife inserted behind the head to remove the shoulder girdle, pectoral fin, and typically hyoid arch, along with part of the gut (Lauwerier and Laarman 2008). The origin of this mass-production technique – historically documented by the late medieval period – is obscure, but its signature processing waste was identified in a twelfth-century deposit from Selsø-Vestby, Denmark, dominated by bones of the shoulder girdle and to a lesser extent hyoid arch (Enghoff 1996).

Zooarchaeological remains from consumer sites represent the other half of the picture. Urban settlements in particular often produce rich, well-dated archaeological material that can be used both to trace consumption patterns and to shed light on

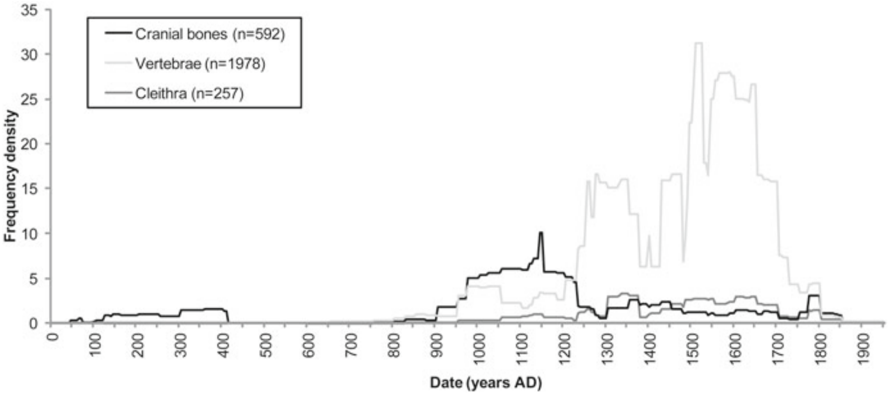

Fig. 4 Estimated frequency distributions for archaeological cod vertebrae, cleithra, and cranial bones from sites in London, showing sudden shift to vertebrae in thirteenth century (Taken from Orton et al. 2014 under CC-BY licence)

the provisioning networks that supported concentrations of agriculturally unproductive population. Waste disposal practices may present a problem here: as they become more organised in recent centuries, the chance of consumption waste ending up in well-dated urban contexts rather than peripheral waste dumps is diminished.

Some information on provisioning networks may be gleaned from the range of taxa alone. The presence of any sea fish remains at inland sites is evidence of trade on at least a local level, but even at relatively coastal sites imports may be apparent in the form of non-local taxa, as for example with cod bones in fifteenth-century deposits from a monastery in Seville (Morales et al. 1991). A distinction must be drawn here between long-range fishing expeditions and long-distance trade, albeit one of greater relevance to economic history than to historical ecology, and not entirely clear-cut. Early European fisheries off Newfoundland, for example – from which the Seville cod may have derived – could involve temporary shore camps at which cod were preserved before being transported back to Europe by the fishing fleets at the end of the season (Candow 2009).

In theory, anatomical profiles of imported species at consumer settlements should be complementary to those at the corresponding producer sites, presenting another line of evidence for trade routes. In practice this may be obscured by the presence of imports from multiple sources alongside locally caught fish, but crude import signatures may nonetheless sometimes be discerned at the settlement level. Comparison of cranial versus post-cranial cod bones across 95 Roman, medieval, and post-medieval sites in London, for example, reveals a sudden shift from local to imported fish during the thirteenth century (Orton et al. 2014, Fig. 4). Herring preserved as described above also have a distinctive anatomical signature that may be detected in archaeological deposits, as reported from Flanders by the fifteenth century (Ervynck and Van Neer 1992). Several Baltic sites dated well before conclusive evidence for the technique also show a suspicious absence of shoulder girdle elements, including eighth to tenth-century trading centres at Birka, Sweden (Lõugas 2001) and Truso, Poland (Makowiecki 2012), hinting at possible fish trade networks in the region earlier than otherwise documented.

'Direct' archaeological evidence for trade is much more limited. Sixteenth-century shipwrecks containing barrels of preserved herring more-or-less matching the *kaken* method have been excavated off Drogheda (Ireland) and in the Zuyder Zee (Harland 2009; Lauwerier and Laarman 2008), but while they constitute illuminating snapshots, wrecks are only ever likely to provide sporadic glimpses of wider trade patterns. On a more systematic level, it is potentially possible to trace individual archaeological specimens to their approximate catch regions using biomolecular indicators. Stable carbon and nitrogen isotope values ($\delta^{13}C$, $\delta^{15}N$) from cod cranial bones have been used to establish regional signatures with some success, allowing reasonably confident distinction between the North Sea, northeast Atlantic/Barents Sea, and Baltic (Barrett et al. 2011). Application to postcranial cod specimens from England and Flanders reveals that a significant northern import trade – probably mainly from Arctic Norway – emerged between the eleventh/twelfth and thirteenth/fourteenth centuries, matching the London anatomical data mentioned above. Artic Norwegian stockfish also seem to have supplied emerging towns around the eastern Baltic from the thirteenth century (Orton et al. 2011, Fig. 5). Pilot provenancing studies involving sulphur isotopes ($\delta^{34}S$) and ancient DNA (see also below) are currently underway.

Size, Age, and Seasonality Data

Since fish have indeterminate growth, the size of individuals within a given species is a proxy for their age. Given that fishing pressure tends to depress average age it is theoretically possible to detect past episodes of high fishing pressure through size declines over time in the archaeological record – or at least to provide a baseline for the modern era (Betts et al. 2014; Carder et al. 2007; Erlandson et al. 2008; Jackson et al. 2001; Limburg et al. 2008; Maschner et al. 2008). Caution is required here since various factors intervene between the size distributions of living populations and those ultimately observed in archaeological collections. Most obviously, the individuals caught by humans are a selective sample of the population. So long as the selection 'criteria' are constant it should be possible to detect size decline, or lack thereof, in the underlying population, but any change in fishing methods – developments in capture technology; geographical or seasonal shifts in fishing patterns – will undermine temporal comparison and potentially create spurious size shifts. Archaeologically speaking, such changes may be just as interesting as impacts on fish stocks, but distinguishing between the various possible factors presents a significant challenge. When using data from consumer sites, possible size-based selection of individuals for processing and trade further complicates matters. Discard at sea on grounds of size is probably a fairly recent phenomenon, however, making metrical distributions at producer sites more reliable. Finally,

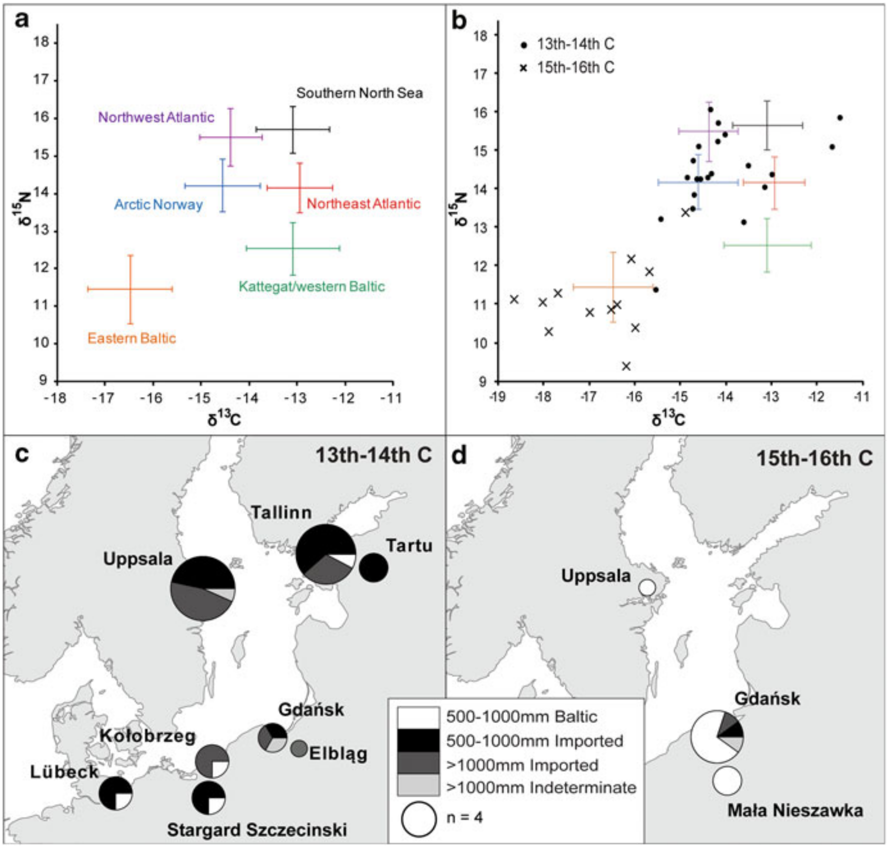

Fig. 5 Stable isotope evidence for long-range import of cod into the Baltic during the thirteenth to fourteenth centuries: (**a**) regional isotopic signatures based on 177 archaeological *cranial* bones from 25 settlements (*crosses* show one s.d. ranges); (**b**) isotopic values for *postcranial* medieval Baltic specimens; (**c**, **d**) summary of import statuses for sampled postcranial specimens, based on Discriminant Function Analysis (n.b. assignments are more tentative for fish >1000 mm due to limited control data) (Adapted from Orton et al. 2011 under CC-BY licence)

archaeological recovery methodology impacts on size distributions (Nagaoka 2005) and must be held constant for reliable comparison.

Sudden changes in observed size distributions should thus be treated with suspicion unless these factors can be ruled out or controlled for, and an understanding of archaeological/historical context is crucial (see e.g. Betts et al. 2014). Gradual shifts are perhaps more likely to be 'real', although there remains the possibility of ecological drivers such as climate (e.g. Maschner et al. 2008). By way of cautionary tale, fish bones from medieval Quoygrew, Orkney, reveal intensive offshore fishing of large cod in the eleventh to thirteenth centuries, followed by a decline in both size and frequency in the fourteenth to fifteenth centuries (Harland and Barrett 2012, Fig. 6). Rather than evidence for overfishing followed by a stock collapse, however,

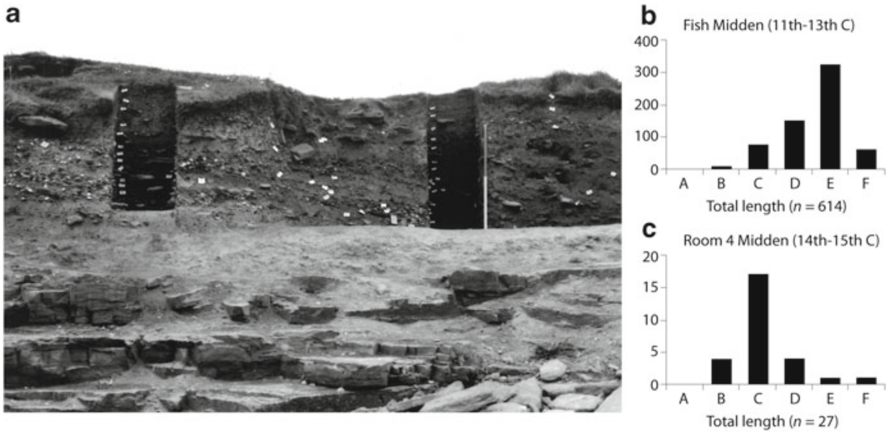

Fig. 6 Cod bones from medieval Quoygrew, Orkney: (**a**) the 'Fish Midden' area during excavation (photo: J. Barrett); (**b**) size distribution (estimated Total Length) of cod remains from the eleventh to thirteenth-century Fish Midden (**c**) size distribution of cod remains from fourteenth to fifteenth-century Quoygrew. The decrease in modal size does *not* appear to result from stock depletion. Key to size classes: *A*. <150 mm, *B*. 150–300 mm, *C*. 300–500 mm, *D*. 500–800 mm, *E*. 800–1000 mm *F*. >1000 mm (Reproduced from Barrett (2012) and Harland and Barrett (2012), with permission).

this appears to be a symptom of a wider economic crash, in which offshore fishing effectively ceased and a traditional onshore fishery for young saithe (*Pollachius virens*) resumed. The small cod from this period probably represent by-catch.

Archaeological size data may still be useful insofar as they reveal changes in size *ranges*, particularly at the upper end. Jackson et al. (2001, see also Betts et al. 2011) cite measurements on 3600-year-old cod vertebrae from the Turner Farm shell midden as a baseline for subsequent size declines in Gulf of Maine cod, giving an estimated average size of just over 1 m. A very low standard error suggests that fishing in this period specifically targeted cod of around 1 m, but the very fact that this was a viable strategy nonetheless puts recent mean length estimates of around 300 mm into striking perspective.

The impact of past fishing may also be detected through 'fisheries-induced juvenation' (Ottersen 2008): selective capture of larger individuals imposes evolutionary pressure on growth and maturation rates. This can potentially be approached from vertebrae and especially otoliths – heavily calcified inner-ear parts – found on archaeological sites (or archived by fisheries researchers) since they (a) show annual growth rings which can be counted microscopically to give ontological age, and (b) can be measured to provide an estimate of total length (Hales and Reitz 1992; van Neer et al. 1999). Limburg et al. (2008) used otoliths to estimate size, age, and size-at-age for both modern and Neolithic (c.4500 years before present) Baltic cod, and hence to compare mortality rates and growth rates between past and present populations. They found that Neolithic cod were, on average, both older and longer than modern catches. Moreover, the Neolithic fish exhibited faster growth in the first

2 years, suggesting that juvenile growth rate has been suppressed by fishing pressure in the modern population.

Growth rings may also reveal season of capture, potentially shedding light on past fishing strategies, although there are methodological problems (Van Neer et al. 2004). This same technique has helped understand the mechanism of the Bohuslän herring 'periods' – irregular events documented over at least the last five centuries, during which herring became temporarily superabundant on the Bohuslän coast (Sweden). Höglund (1972) excavated eighteenth-century 'train oil' factories, at which surplus fish were processed, specifically to find remains unequivocally associated with the 1747–1808/1809 herring period. Growth ring analysis indicated that these belonged to the autumn-spawning North Sea population rather than being Norwegian spring spawners, paving the way for explanatory mechanisms (e.g. Alheit and Hagen 1997).

Stable Isotopes as Ecological Indicators

Stable isotopic analysis of bone collagen from archaeological remains was mentioned above in the context of provenancing studies. Just as in contemporary ecology, however, stable isotopes are primarily ecological indicators and can theoretically be used to reconstruct aspects of climate, food web structure, and nutrient input to past marine ecosystems.

The well-established use of $\delta^{18}O$ from marine organisms – particularly shells – to estimate past temperature generally falls under paleoclimatology rather than archaeology. Collaboration between these disciplines can be fruitful, however, since anthropogenic deposits constitute a rich source of samples, potentially with good dating and direct links to evidence for human resource exploitation. Surge and Barrett (2012), for example, used oxygen isotopes from annual growth layers in limpet shells from tenth to twelfth-century Orkney to demonstrate high seasonal variations in temperature during the Medieval Climate Anomaly. Sequences of temperature estimates based on $\delta^{18}O$ in fish otoliths may also be used to infer season at capture, contributing to understanding of past fishing patterns (Hufthammer et al. 2010).

Carbon and nitrogen isotopic values, typically analysed in parallel, can be used to characterise past food webs (e.g. Grupe et al. 2009), to detect shifts in trophic levels over time, or to infer past foraging behaviour among populations that are now either extirpated or heavily influenced by human activity (Alter et al. 2012; Szpak et al. 2012). $\delta^{13}C$ and especially $\delta^{15}N$ are subject to fractionation through the food web, becoming enriched with successive trophic levels (Schoeninger and DeNiro 1984). At the same time, isotopic values reflect variations at the base of the food web: both $\delta^{13}C$ and $\delta^{15}N$ vary with primary producers and terrestrial nutrient input (Fredriksen 2003; Jennings and Warr 2003; Bergfur et al. 2009), while $\delta^{13}C$ is also sensitive to temperature and salinity (Weidman and Millner 2000; Robson et al. 2012). Szpak et al. (2013) suggest that a decline in $\delta^{13}C$ of archaeological rockfish bones from Haida Gwaii (British Colombia) following European contact represents a reduction in nearshore kelp forests, due to a trophic cascade resulting from local extirpation of sea otters by hunters supplying the eighteenth to nineteenth-century maritime fur trade. The isotopic composition of human bones can also be used to infer the contribution of marine protein to human diet (e.g. Richards et al. 2003; Salamon et al. 2008).

In theory, the fishing-down-the-food-web phenomenon might be detected through declining $\delta^{15}N$ in top predators, but attempts to demonstrate this have had limited success (Bailey et al. 2008). This may be partly due to elevated nutrient input in recent centuries, altering $\delta^{15}N$ at the base of the food web and hence obscuring fishing-related effects. Since nutrient input is of major significance to historical ecology in its own right, it would be very useful to be able to disentangle changes in isotopic values at the base of food webs from shifts in the structure of those food webs. One likely way forward is Compound-Specific Isotope Analysis (CSIA), which allows measurement of $\delta^{13}C$ and $\delta^{15}N$ in individual amino acids. Within collagen, non-essential amino acids such as glutamic acid are subject to considerable fractionation with each trophic level, while essential amino acids like phenylalanine are not. $\delta^{15}N$ in the latter thus reflects the food web base regardless of the organism sampled (after a small correction), while the $\delta^{15}N$ offset between the two amino acids in a given specimen is a good measure of trophic level, independent of any baseline effects (Naito et al. 2010). Unfortunately, CSIA is both expensive and technically demanding.

Sulphur isotope analysis ($\delta^{34}S$) is another recent development (Craig et al. 2006). Sulphur is barely fractionated with trophic level, instead providing information on the base of the food web: while there is a more-or-less constant global marine signature of around +20‰, freshwater signatures vary between −5‰ and +10‰ depending on local geology (Peterson et al. 1985). $\delta^{34}S$ in marine organisms therefore depends on the extent and source of freshwater input. Apart from potentially refining carbon- and nitrogen-based provenancing, $\delta^{34}S$ from archaeological samples may potentially be used to detect shifts between coastal and offshore fishing in the past (Nehlich et al. 2013), or to track increases in river outputs.

One of the main strengths of isotope analysis – the sheer range of potential ecological issues on which it can be brought to bear – is also a major weakness when applied to archaeology, as one must use a very small number of variables to characterise changes in a much more complex system. This is most acute for studies restricted to a small range of species; more holistic ecosystem studies provide greater control for changes in food web structure. CSIA may help to mitigate the problem in future. The destructive nature of isotopic analysis is also problematic for scarce, irreplaceable archaeological samples, although in some cases less than 0.5 g of bone may be sufficient. Since $\delta^{13}C$, $\delta^{15}N$, and $\delta^{34}S$ studies all rely on sufficient collagen being preserved, success rates vary from zero to virtually 100 % depending on antiquity, temperature, and pedological conditions. The basic technique is, however, relatively cheap.

Ancient DNA (aDNA)

The sheer complexity and rapid development of aDNA analyses preclude detailed discussion here, but it is worth outlining the main applications for historical ecology. Both mitochondrial and nuclear DNA have now been successfully extracted from archaeological specimens of various marine species, including even herring bones weighing under 10 mg (Speller et al. 2012). Considerable limitations remain, however: DNA analysis is expensive, destructive, and has variable but often limited success rates. As with isotope analysis and collagen, genetic studies depend upon the survival of sufficient DNA, which in turn depends on the antiquity and depositional environments of remains, not to mention handling and storage after excavation. Since DNA preservation is inversely related to temperature, this is particularly problematic in warmer climates. Contamination is also an issue, particularly where modern reference specimens have been used to identify the archaeological remains.

Perhaps the simplest application of aDNA is as an aid to identification, permitting finer taxonomic resolution than is possible from morphological analysis of remains, whether for biogeographic purposes or for understanding past marine resource use. Ancient DNA has shown, for example, that the sturgeon population extirpated from the Baltic during the 1960s was in fact the North American sturgeon *Acipenser oxyrinchus* – which apparently crossed the Atlantic and colonised the Baltic around AD 800–1200, replacing the native *A. sturio* (Ludwig et al. 2002) – a finding with implications for plans to re-establish the Baltic population using translocated individuals. Likewise, aDNA analysis of salmon remains from multiple prehistoric sites on the central coast of British Colombia revealed considerable local variation in the species exploited, rather than a homogeneous regional fishery (Cannon et al. 2011). The practicalities of aDNA analysis render it unlikely to become a routine identification tool, however, especially since collagen fingerprinting (Richter et al. 2011) is cheaper, less destructive, and typically has higher success rates.

At a finer scale, aDNA may reveal changes in population structuring over time within a species, potentially representing responses to climate and/or fishing pressure (e.g. Hutchinson et al. 2003). Apart from the implications for conservation genetics and fisheries management, the ability to distinguish between past populations of a given species also has potential applications for provenancing archaeological specimens and hence investigating trade (Hutchinson et al. 2015).

Finally, genetic diversity can be used to estimate past effective population sizes and hence provide approximate baselines for population declines. One study of grey whales, for example, used mitochondrial DNA from archaeological samples to estimate that population sizes prior to the onset of commercial whaling were three to five times higher than today (Alter et al. 2012), while work on Icelandic cod bones has shown a dramatic population crash around AD1500 (Ólafsdóttir et al. 2014). This is one of the most exciting uses of archaeological material for historical ecology, but unfortunately very large samples are required to achieve acceptable confidence intervals. Improvements in cost and success rates will mitigate this in future, but the availability of sufficiently large collections of more-or-less contemporaneous archaeological specimens will remain a limiting factor, especially since it is necessary to avoid multiple specimens that might represent the same individual.

Future Prospects

Considerable technical advances are likely to be made in the near future regarding biomolecular analysis of archaeological marine animal remains. Collagen fingerprinting is likely to become more routine, with particular implications for biogeography; applications of $\delta^{34}S$ will surely be refined; CSIA may see more widespread implementation; and constant improvements in cost and reliability of aDNA are likely to continue, 'next-generation' sequencing having recently opened up the possibility of full-genome research on archaeological material even in deep time (see Hofreiter et al. 2015). The emergence of novel approaches to historical ecology that draw upon archaeological material in innovative ways is thus to be expected.

For all that, however, the greatest potential for improved exploitation of the archaeological resource probably lies not in laboratory advances but in improved data accessibility, awareness, and communication. Archaeologists will continue to generate vast amounts of data relevant to historical ecology, along with physical archives of remains from past marine ecosystems, and it is crucial that visibility of this resource is improved. Individual programs of inter-disciplinary collaboration are welcome but, ultimately, realising the full potential of the archaeological resource will require a concerted drive within (zoo)archaeology towards systematic, open, and accessible publication of data in formats amenable to meta-analyses and data-mining.

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Human Archives: Historians' Methodologies and Past Marine Resource Use

Bo Poulsen

Where shall I fasten my mind's eye,
as over oceans skimming
I peer below but only spy
how many mouths come swimming?

(Brorson 1734)

Introduction

The above citation stems from a Danish psalm by Hans Adolph Brorson, who lived most of his life in the Waddensea area along the eastern parts of the North Sea. From the top of one of the dikes typical of this area he would have seen a constantly changing marine ecosystem overlooking what is one of the worlds' largest tidal flats. He could go to any fishing village in the area and observe the multitude of species being brought ashore, and if in doubt as to the name of the species, it was possible to look it up in one of the volumes on natural history being published in the first half of the eighteenth century, the time of the enlightenment. Nonetheless, many of the how's and why's of life in the World's oceans were yet to be addressed, let alone explored in a meaningful scientific way. Obviously great advances have been made since then, over the past almost 300 years. Not least following intensified research over the last century, we now know infinitely more about the so-called life history of fish species, that is questions revolving around their fecundity, growth rates, migration patterns, preferred habitats, and during recent decades genetic studies based on microbiology, while ecosystem based studies have greatly advanced the state of knowledge on marine ecosystems as dynamic entities.

To a large extent, the increase in knowledge has gone hand in hand with a gradual intensification of human exploitation of the marine resources around the world. Not least since the mid-1800s, fisheries have expanded greatly both spatially and in terms

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of the amount of fish, and the variety of fish species being targeted. Throughout the World human population soared, and following the expansion of the network of railroads across continents an unprecedented demand for fish spurred the process of industrialization in the World's fisheries. With the new speedy modes of transportation and industrial ways of production, fresh fish and canned fish added to the existing varieties of salted, dried, pickled and smoked fish in the stalls of any decent fish monger.

The fishing industries foremost in Great Britain, soon after in other countries, were able to meet the improved market situation through the implementation of new vessels and new types of fishing gear and fishing methods. Cotton nets replaced nets made from hemp, steam propulsion and from around the turn of the twentieth century also motor propulsion replaced the use of wind, which greatly multiplied the fishing power of each fishing vessel. Towards the end of the nineteenth century other countries invested heavily in their fishing sectors to further their share of the harvest of the seas. Gradually countries like Japan, Germany, Norway, France, The Netherlands and Denmark joined this leap into modern industrial fishing practices and industries (Poulsen 2012a).

Today it is fair to say that the World's oceans are encircled by highly sophisticated fishing practices, where strong and thin nylon gear, echo sounding, helicopters and GPS facilitated mapping makes it very difficult for any targeted fish species, and their marine habitats as well, to escape the attention of human hunters. A similarly striking development in the last c. 50 years is the tremendous increase in aquaculture output. Thus in the most recent decades the global amount of fish produced via aquaculture has surpassed the quantity of fish caught wild in the world's oceans. This growth in harvests of the sea, has led to countless examples of decimation and depletion of fish stocks and habitats around the world, but assessing the precise causes of this is far from easy.

The deep impact of human harvesting has been inductive for one of the great challenges in today's fisheries management, which is to distinguish between what is naturally fluctuating and what is humanly induced, when it comes to changes in the marine composition of marine ecosystems around the globe.

Meanwhile, society's attitudes towards the ocean have undergone a tremendous proliferation in the past centuries, since Brorson pondered over 'oceans skimmings.' These attitudes interplay directly and indirectly with the way the sea is being thought about, explored, exploited and preserved. In all of this, marine environmental history has a significant role to play.

Situating Marine Environmental History

Over the past c. 20 years marine environmental history have come of age as a distinct scientific approach, drawing on the expertise of a range of disciplines. This chapter outlines some the advancements in marine environmental history, where the historians' approaches – theories, methods and techniques – have been particularly fruitful. However, these approaches vary significantly with what type of research question is being asked.

It is a common trait in marine environmental history that the object of investigation is the dynamic relationship over time between two dynamic systems, the marine environment and human society. Nonetheless, in the following, it is worth distinguishing between three types of historical research. This follows an article by American environmental historian, John McNeill, who in 2003 located environmental history at large, as an entity consisting of at least three different categories, cultural, intellectual and material environmental history (McNeill 2003).

The first, cultural environmental history can be seen as trying to assess issues of how human society has addressed environmental concerns over time in various political and social fora. Much of this research sprung out of the environmental movement of the 1960s and 1970s. Secondly, intellectual environmental history is another important path, where much research and many researchers have emerged out of a history of science tradition, centring on the development of scientific disciplines, not least with life sciences. Work for instance on the historical spread of Darwinism would fall into this category. Finally, material environmental history is occupied with reconstructing past human resource use, and past environmental impact on human society. Prime examples of such history is the reconstruction of timing of the Burgundy wine harvest over 700 years based on ancient account books, knowledge which has since funnelled into climate history reconstructions. According to McNeill, material environmental history can been seen as particularly demanding in terms of engaging in an interdisciplinary manner with the natural sciences.

When McNeill wrote up his paper more than a decade ago, marine environmental history was visible only to a lesser extent. Since then, there has been a significant take off of marine studies, to the extent that this chapter can only go into details with small portion of the accomplishments of the past couple of decades.

Assessing past patterns of human exploitation of marine environments as an interdisciplinary endeavour is at the heart of this volume. Therefore, the following assessment of historians' contributions to marine environmental history will focus slightly more so on material marine environmental history than what might be termed cultural and intellectual marine environmental history. In any case, other important aspects of cultural marine environmental history are covered by the chapter "Acknowledging Long-Term Ecological Change: The Problem of Shifting Baselines" on Fishing Communities, chapter "Ecological Indicators and Food-Web Models as Tools to Study Historical Changes in Marine Ecosystems" on illegal, unreported and unregulated fisheries as well as chapter "Oral Histories: Informing Natural Resource Management Using Perceptions of the Past" on marine gender studies.

Reconstructing Species Abundance

One of the ways in which historians' methods and techniques of working up paper documents from past centuries is in terms of reconstructing data to infer on past catch rates, species abundance and spatial distribution patterns of fish stocks. In this way historical work has addressed the challenge of the shifting baselines syndrome (see chapters "Of Seascapes and People: Multiple Perspectives on Oceans Past", "On the Need to Study Fishing Power Change: Challenges and Perspectives" and "Illegal, Unreported and Unregulated Fishing in Historical Perspective"). By now this has been carried out in a number of cases, while the section below highlights just two such examples, where the historical contribution funnels into a scholarly discourse which is relevant in a science context as well as in an historical humanities and social science context.

Within marine historical ecology, one of the most cited papers is the reconstructing of the abundance of cod in the 1850s–1860s on the Nova Scotian Shelf in Atlantic Canada. Modern data had suggested that the peak total biomass of cod in the post 1970s was 300,000 metric tons. The historical reconstruction however, revealed that in the 1850s, total biomass had extended beyond the 1,200,000 metric tons barriers. In contemporary debates over target numbers for reconstructing the resident cod stock, it has been suggested that a return to the peak 1980 level, would create a return to a healthy state. Nonetheless, the historical numbers suggested that four times as much cod thrived in this part of the North Atlantic as what was previously perceived to be a top abundance level from a contemporary point of view (Rosenberg et al. 2005).

Unsurprisingly, this investigation stirred much attention, as it would be much more difficult, if at all possible, to return to the state of affairs of the mid-nineteenth century. Yet, the way in which these historical figures were reconstructed is a fascinating story in its own right. While, historical biomass reconstructions as such are dealt with in the chapter "On the Need to Study Fishing Power Change: Challenges and Perspectives", the historians' work creating the dataset is worth dwelling at here.

As part of the research program, History of Marine Animal Populations (HMAP), a team of researchers banded together in New England, United States, to investigate historical documents as a potential source of information for how nineteenth century fisheries related to the natural marine resources in the Gulf of Maine and the wider Northwest Atlantic Ocean (Holm et al 2010). Through this effort, an American history student came across a number of archival boxes containing several hundred logbooks kept on board American fishing vessels based in Beverly, Massachusetts between 1852 and 1866. During this time frame the local Collector of Customs were responsible for paying a bounty to each fisherman operating a vessel over 5 tons, according to how much cod they had caught during a fishing season of at least 180 days. The fishermen in return were expected to document their entitlement through the delivery of seasonal logbooks to the customs house. The logbooks consisted of printed booklets with pre-formatted with space to indicate the name of the fishermen, their homeport, which fishing bank they targeted during the fishing season as well as the amount of cod caught. Now in many modern settings the quality of information contained in fishermen's landings data can be jeopardized by incentives to fish beyond a certain quota or similar catch limit. In most historical setting however, such as this one, this was rarely the case.

The research team then paid close attention to the context of these logbooks. Close scrutiny, or source criticism as historians label it revealed that the fishermen had little incentive to deliberately give out false numbers on their catches or their encounters with other vessels for that matter. In the logbooks these encounters were frequently noted down, including information on how much fish had been caught by the vessel that they had communicated with. Cross checking this information with information presented in the fishermen's own logbooks indicated that this communication had a high degree of credibility. One reason for this was the fact that it was socially important to maintain a high level of credibility in the logbooks. In the event that the boat sank or went missing, it was of great importance to the relatives of the crew back home to receive as much information as possible on the circumstances of the last sighting of a missing vessel (Bolster et al. 2011).

Having established a pattern of credibility concerning the information contained in the logbooks, the data were used to estimate the catch per boat per season (CPUE) over the available number of years. The result of this was that of a waning catch rate. The decline in CPUE was related to the total catch of the entire fleet fishing on the Scotian Shelf. The research team then added knowledge of the assumed rate of natural mortality of the cod and the rate of recruitment (that is the annual number of offspring maturing into the adult population). This finally enabled them to fit the data into an index of abundance, resulting in the above staggering number of cod thriving on the Scotian Shelf in the mid-nineteenth century (Bolster et al. 2011).

Thus, the historians' methodological contribution to this research result has been twofold. First of all, from an anthropogenic point of view, much new knowledge on concrete past fishing practices was inferred from engaging in a large scale archival research such as the one described above. Secondly, the historian's 'craft' or technical skills of diligently delivering the documentary based data was a vital key for unlocking the door to a past marine ecosystem, which had otherwise been irretrievably hidden behind time gone by.

Estimating Long-Term Catch Rates

Catch rates can also be used to reflect on the relative abundance of fish, when the time series is long enough, and when it is being standardized, so that any given year's catch rate is a reflection of a specific unit of effort. This is important for two reasons. First of all, the relative catch rate over centuries in a lightly sampled fish stock gives an indication about how the total abundance fluctuated over a long time span. Secondly, the catch rates also reflect on the potential economic output of the fisheries operation. In this way it is possible to estimate earnings not just as a reflection of price fluctuations, which is the way economic historians typically assess the dynamics between supply and demand in a pre-modern economic activity. Instead, the ecological dimension of the supply mechanism is added to the range of explanations.

The baseline of a certain area of observation is often framed by the beginning of a time series, within historical marine resource exploitation typically as a series covering landings or catches of one or more fish species divided by a unit of effort, such as the number of vessels, nets or hooks deployed in a given fishing activity. In most modern fisheries it is very difficult to reconstruct a standardized unit of effort over a longer time span of more than a decade due to the continuous technological improvements in the fishing sector. For instance, on modern fishing vessel of a given tonnage, rarely changes in size during its period of service for the owner. However, the tackle on board can change substantially due to improvements in the quality and size of nets or the improvement the way winches are functioning. As we observe in the chapter "On the Need to Study Fishing Power Change: Challenges and Perspectives", the so-called technological creep is an inherent part of contemporary fishing. When it comes to historical times, the situation is somewhat different. A study of the Dutch herring fisheries of the sixteenth to nineteenth centuries for instance revealed that over a tremendously long period of more than 300 years, there was hardly any technological innovation taking place. Each new fishing vessel was being modelled on its predecessor, and the drift nets employed in the industry were sown according to enforced customs, including the mesh size and size of the total gear remained unchanged over centuries (Poulsen 2008a).

The Dutch model of producing herring was characterised by (i) a rigorous set of fishing laws designed to promote a top quality product and minimize internal competition, (ii) independence of geographical restraints due to the use of factory ships, busses and hookers, (iii) a continuous privileged position in Dutch society for 300 years including off shore military protection and (iv) a large vertical integration in the herring industry. Apart from the size of the Dutch fishing industry, the fishery was extremely well organized for its time, and definitely the most regulated high seas fishery anywhere in the world prior to the twentieth century. In the 1560s a number of Dutch towns had formed a body, College van de Grote Visserij, which during the last decades of the sixteenth century was inaugurated by privilege from the Dutch government. The college was thereby given jurisdiction over the entire Dutch herring industry with respect to the catch, processing, distribution and marketing of salted herring. The main purpose of the College van de Grote Visserij was to uphold the quality of the top brand of salted herring in Europe, while the state of monopoly gave a large degree of protection to the industry.

Sometime in the latter half of the fourteenth century Dutch and Flemish fishermen started to process the herring aboard their fishing vessels. They would bring along salt, and barrels, so the herring could be cured and salted immediately after being caught, thereby preparing a high quality product, and making the fisheries almost independent of geography. This was also about the time, when the herring buss was introduced as a fishing vessel with large storage capacity. So, provided the fishermen had enough provision aboard, they could focus on following the fish round the North Sea rather than waiting for it near the shores of the continent. This extended the fishing season compared to the other herring fisheries in Northern Europe. Over the course of the fifteenth and sixteenth centuries this production method developed into a major enterprise, with large investments, not only in shipbuilding and fishing but also in developing a widespread distribution network for the finished product throughout Europe. All products except hemp for nets coming from the Rhineland area and salt, which had to be of Portuguese or Spanish origin, was manufactured in Holland, giving a strong economic interdependence between shipyards, coopers, seaman, net makers etc. The whole industry was the envy of foreign nations and privateers, so each year naval vessels were designated to patrol the fishing waters in the North Sea at the expense of the Dutch government. Usually the Dutch fisheries were operated through a large number of smaller fishing companies. Sometimes the skipper would own his own boat and a few others, more often a number of shareholders invested in one or more ships as way of spreading the financial risk.

All of these pieces of information, contingent upon a variety of aspects of early modern society are important to recognize when assessing the catch rates over more than two and a half centuries. Results showed in this case that the annual catch rates per boat remained very stable throughout the seventeenth and eighteenth centuries. This outcome though, was influenced by the fact that the duration of the season expanded during the course of the eighteenth century. When instead of the annual catch rate, the catch rate per day at sea was estimated then the result revealed a vivid fluctuation in between years, and also in between subsequent decades. Thus, the inter-annual fluctuation on the one hand was a testimony to the volatility of a pelagic species such as herring. On the other hand though, the annual catch rates reflects how the fishermen over centuries were able to cope with and mitigate the inter-annual fluctuations, by way of extending or minimizing the length of each fishing trip and each fishing season (Poulsen 2008a). As in the case above, of the New England fisheries of the nineteenth century, this research points in multidisciplinary directions. Here, historical methodology functioned not as a stand-alone methodology, rather as an entangled approach, where cultural history and natural science questions were given equal attention.

Past Marine Science, Politics and Individual Choices

A sizeable portion of historical research into marine environmental history is occupied with what one might call cultural environmental history or intellectual environmental history, which is equally important for the prospects of the sub-discipline of marine environmental history. Historicizing contemporary problems can be tremendously helpful in terms of properly assessing the dynamics of contemporary marine resource management. A fine example of this type of scholarship is American historian Carmel Finley's recent monograph, *All the Fish in The Sea*, which deals with the development of modern fisheries management, in which the concept of the so-called Maximum Sustainable Yield has been central.

Maximum Sustainable Yield (MSY) is a well-known concept in fisheries management. The concept covers the idea that fish stocks produce a surplus, which can be fished without damaging the stock's reproduction. In many cases this is widened to include the notion that it is in fact a healthy act on behalf of the fish stock, if it is being fished well. In this way the older and slower growing fish are removed from the food chain to leave more room for the younger fish with a bigger growth potential. Fishermen and the marine environment therefore will both benefit from a fishing intensity set at the right level so as to maximize the output sustainably, hence the name of the concept. This prospect was so appealing to the modern fisheries nations that it became central to international negotiations on how to share the fruits of the sea in the post-WWII Atlantic and Pacific Oceans, where virtually all nations wanted a bigger share of the World's fisheries to land in their own fishing ports.

While the concept as such is simple, its implementation has proved disastrous in many cases when it comes to sustainability of fish stocks. Since the 1940s marine science has been enlisted to come up with viable solutions using ever more sophisticated mathematical models inferred onto ever larger collections of fisheries statistics derived from scientific surveys and commercial catch data. However, while ideally the models can predict the future scenarios with great precision, in reality most marine ecosystems are so complex that inter-annual stock size fluctuations are contingent upon an almost infinite range of dynamic factors.

What then sets Finley's work apart is the idea that we are treated to an in-depth analysis of the historical context of how MSY came to dominate international fisheries management from the 1950s until well into the 1990s. Using government documents mainly from the US fisheries service, various government agencies and contemporary newspapers, as well as a background knowledge of the fisheries and fisheries science from the mid-twentieth century, Finley gives the reader a rare insight into what might be termed a black box of decision making, where marine science often played a legitimizing role more than anything else (Finley 2011).

An equally important study is Jacob Hamblin's *Oceanographers and the Cold War*, where the author shows marine science practices in the post WWII period were engulfed in the high politics of the Cold War. Here the focus is not so much in between the way fisheries management interacts with fisheries science, as it deals with the ways in which international marine science as such was funded and organized in this era of tense political entanglement throughout the world. In some scientific arenas it might be possible to uphold an idea that science is a politically neutral activity completely separated from more worldly affairs. On the organizational level marine science is far from being such an enterprise (Hamblin 2005).

This is also one of the main findings in Helen Rozwadowski's *The Sea Knows No Boundaries* (ICES/University of Washington Press, 2002). Here, the reader is treated to a story of how international marine science cooperation was crafted into one of the World's oldest remaining intergovernmental organizations, the International Council of the Exploration of the Sea (ICES). Again, the methodologies used are from the realm of historians, as the author compare information from protocols of official meetings alongside official and private letters, and various scientific recommendations and trends in the development of modern marine science. By the same token, but from a more national angle, Jennifer Hubbard (Canada) and Vera Schwach (Norway) have produced interesting volumes on the twentieth century history of marine science situated in the context of the socio-economic climate of these countries, both among the most important fisheries nations globally (Hubbard 2005; Schwach 2000).

The actual marine science history is considered in its paradigmatic context, in books such as, Smith, Tim D., *Scaling Fisheries*, *the Science of measuring the effects of fishing*, *1855–1955*, (Smith 2007) and Mills, E., *Biological Oceanography – An Early history*, *1870–1960*, (Mills 2012). In both cases, the author is a keen observer of the development of the science of studying the living oceans. For this type of research it is critical for the researcher to have an in-depth knowledge of marine science practices, even more so than in the history books mentioned just above. On the other hand, the societal context of marine science is not prominent in these works.

Photographic Analyses

The list of techniques one could readily deploy in marine environmental history is literally endless. Yet, a few rarer, but interesting ways of extracting information from past documents deserve mentioning. One of the – literally – most iconic examples of marine environmental history from recent years has been Loren McClenachan's study of changes in the post-1950 species composition off the coast of Key West in Florida, USA (McClenachan 2009). Ingeniously, McClenachan looked for, and found, thousands of photographs of anglers showing off their catches at the end of a daytrip to sea, pictures taken by the company operating the angling cruises. Over the decades from the 1950s onwards the fish taken gradually became smaller and smaller, and there was a marked change in species composition, showing that in the most recent couple of decades, angler caught fish from a lower trophic level than before. To adequately measure the size of each specimen taken, McClenachan travelled to Key West and measured the height of the poles and crossbars used for displaying the anglers' catches. The same wooden frame had been used throughout the decades. This in turn enabled her to estimate the actual size of each fish, based on how far the fish stretched down from the crossbar.

While this technique was revealing for answering an historical ecology question; did the size and species composition change over time? – Then a follow-up paper used the same material and historical context to address an anthropogenic question: In the recent 60 years, how did anglers' interest groups respond to the gradual depletion of local fishing resources? Here, McClenachan, using more classical historical text reading as a methodology found that indeed there was a gradual realisation that the marine ecosystem surrounding Key West became more and more heavily exploited over the decades In river systems anglers would typically advocate a rather restrained conservationist approach to marine stewardship. Nonetheless in this open sea case, they lobbied heavily in 11 different US states that anglers should have free and unlimited right to fish. They would only agree to restrain their own fishing effort if it became scientifically proven that it was indeed the anglers who had jeopardized the state of resident fish stocks (McClenachan 2013).

Assessing Fishermen's Status and Skills

Another issue of relevance to studying the intersection between fisheries and the marine ecosystem is the role of the fishermen's skills, not least the captain, who is typically in charge of fish finding. The hardware, fishing gear and vessel sizes are tremendously important factors for the success of any fishing operation, as it is dealt with in the chapter "On the Need to Study Fishing Power Change: Challenges and Perspectives". Within the last 100 years or so, there are usually statistics available for assessing the size of vessels and gear, at least within the context of industrialized fisheries. For the pre-industrial era, the size of vessels et cetera can be harder to come by. In the case of Dutch herring fisheries of the early modern era it was possible to come by information on the size of the fishing vessel through records from an old shipyard, where vessels were continuously built for more than 300 years, but this is exceptional. In other cases material objects can reveal important information along this line. This is the case for instance in René Taudal Poulsen's study of the Swedish North Sea ling and cod fisheries in the nineteenth century. Here the author visited a local museum to measure the size of the hooks being deployed for the demersal fish species. The size of the hooks has an important bearing on the size of fish being caught, and one of the interesting historical findings turned out to be the discovery of nineteenth century catch levels much higher than what have been caught in the past three decades, even though the hooks used in the nineteenth century hook and line fisheries were larger than the modern hooks (Poulsen et al. 2007).

Nonetheless, the software of fishing, the fishermen's skills, is equally important for at least two reasons. First of all, several studies on the so-called 'skipper effect' have pointed out that not only technology and environmental factors, but also the skills of individual skippers is a significant determinant for the size of his catch (Bjarnason and Thorlindsson 1993; Barth 1966). Within modern fisheries the actual existence of a notable skipper effect has been hard to prove, since the technological creep is difficult to separate from more intangible human skills. Secondly, what is beyond doubt is that in many fishing communities it is of vital importance that the skipper creates a self-image as someone with special skills in finding fish, which gives the 'lucky' skipper a very high status on and off his vessel. Some skippers reportedly, were able to dream of where to fish, thereby attracting the best crew. Secondly, a high status would be beneficial for conducting other businesses in a tightly knit fishing community (Pálsson and Durrenberger 1982, 1990; Durrenberger and Pálsson 1983; Gatewood 1983). The idea of a 'lucky skipper' was found in the 19th century Dutch herring fisheries (Drossaart 1868). Modern studies of the education, skills and status of Icelandic skippers suggested that the formal training of an Icelandic skipper hardly had any impact on his future job as a fisherman. The Icelandic case emphasizes that the critical skills required for locating and catching fish are acquired through the everyday practice of fishing rather than formal schooling (Pálsson and Helgason 1998).

The abovementioned case studies are the result of modern social anthropological fieldwork, where data is largely derived from interviews and scholarly observation of social practices. Trying to assess the human factor in fisheries from a more distant past, these ways of gathering data are no longer available. Nonetheless, a recent study of the eighteenth century New England cod fisheries, has pointed towards kinship and fraternity as highly formative for the composition of crews on commercial fishing vessels. To a large extent family members fished together on separate vessels, as well as operating on board the same vessels (Magra 2010). This is echoed in a study of the Dutch North Sea herring fisheries, where a well-developed co-operative behaviour at sea seems to have been particularly strong when vessels from the same town fished together (Poulsen 2008b). Thus, the human factor played significant roles, but did it also spill over to the actual or perceived skill levels of fishermen?

Indeed, a couple of examples exist, where the human factor in pre-industrial fisheries have been assessed.

In the North Sea herring fisheries multiple states and enterprises around the North Sea tried copying the Dutch model of fishing (see above). The most successful of these copycat operations was the one set up in the town of Emden from 1769, in present day northwest Germany. The initiative came from the mighty King of Prussia, Frederick the Great, ruler also of Emden since 1744. Frederick and the Prussian government with him sought to promote trade and economic growth in the newly acquired territories, and setting up a herring company was one aspect of a general economic policy. After a full year of negotiations and planning, the *Emder Heringsfischerei-Kompagnie* was established by royal charter in 1769. Part of the argument for setting up a herring industry was that it was beneficiary for a variety of economic sectors, and the herring vessels as well as fishing gear were to be produced locally in the region, and the herring vessels were to be maintained in the towns of Emden and Leer. The quality was to be ensured with proper branding, and manufacture of barrels and curing techniques similar to the Dutch neighbours. Over the course of the next 87 years the Emden herring fishery operated exactly in the same way as the Dutch. In both cases there was hardly any technological innovation took place, at least none that was exclusive for the Germans or the Dutch. The mesh sizes were the same, the timing of the start of the season and the size of barrels and quality of the salt (Hahn 1941).

Thus to a large extent it is possible to compare the two operations, one a replicate of the other. For 23 years between 1770 and 1857 the yearly results per buss can be measured for Emden as well as for Holland, which makes it possible to compare their performance at sea against each other. Plotted against each other, a strong correlation (r^2: 0.72) between the performance of the two areas is an indication that they were fishing in the same waters. Making the fair assumption that the Emden vessels were almost identical to the Dutch, and that they did fish in the same way with the same type of gear, the end results were on average poorer for the Emden fishermen than for the Dutch. Per season an Emden buss caught about 14.5 metric tonnes less than a Dutch vessel. This implies that in spite of the complete transfer of technology, the necessary skills are something, which was not easily acquired by a relative newcomer such as Emden. In other words, in this case the human factor in fishing power alone accounted for c. one third of the catch (Poulsen 2012b).

Prospects of Archival Material

One of the main practical challenges in historical document based research is the time consuming search for and transcription of archival material. Historical archives usually are registered on basis of the so-called, principle of provenance. This means that the documents are sorted on the basis of where the documents originate from. Typically paper documents from before c. 1900 originate from public institutions such as local court rolls, diplomatic correspondence from governments, ledgers from custom houses or tax, probate and marriage registers. For the fisheries historians court cases revolving around fisheries related controversy are particularly interesting for highlighting the otherwise hidden everyday practices of fishermen or fish mongers. Serial records such as custom rolls are more relevant in quantitative assessments of the size of fish trade and fish consumption over time. Firstly, such imprints of financial transaction are fairly reliable statements with regards quantities. Secondly, the unchangeable nature of many such bureaucratic practices facilitates the construction of time series spanning decades, even centuries of serial data.

While fraud is an eternal threat to the credibility of any bureaucratic entity, there is no evidence to believe that people of the past should have provided less care in pecuniary matters. On the contrary, in a study by Dutch historian, van Bochove, less than 1 % deviation was found between the amount of herring landed in the Netherlands and the amount that was declared in separate registers for tax purposes (Bochove 2008).

It should also be noted that the state penalties for violating fisheries regulations frequently were quite draconian. The great Dutch herring fisheries for instance, operated under a set of regulations originating in the fifteenth centuries. Here, paragraphs spanning several hundred pages stipulated everything from codes of conduct at high seas when more vessels where fishing next to each other. Cutting the nets of fellow fishermen for instance, could be penalized with a fine equivalent to the total value of a fully equipped fishing vessel (Poulsen 2008b). The threat of individual fishermen exporting know-how and fishing gear to foreign countries were taken equally serious, and cases exist, where along fishermen with their entire family, were outlawed in Dutch society when convicted for selling such assets to Sweden or neighbouring Flanders (Poulsen 2012b). In fact, the ill reputation for credibility associated with many contemporary fisheries statistics, mainly landing statistics, is a particular modern phenomenon associated with the incentives to mis-report caches arising from quota legislation etc. Before the twentieth century there was no maximum allowable catches, hence there was a lot less incentive to misreport.

Private institutions creating masses of paper for archives typically range from manorial accounts, craftsmen's guilds, diaries and personal letters from individuals and accounts of major corporations such as colonial enterprises. Here, the fortunate researcher of fisheries may be able to find registers of land lease to shore based fisheries, and fishing licenses along rivers. Individually kept records such as ship logs, diaries from sea voyages or the note books from naturalists operating in the field are equally wonderful material to dig out from heaps of old papers in archives.

Finally, at the intersection of published and unpublished documents an item such as pamphlet literature deserves mentioning, as they can be found in archives as well as in major library holdings. Newspapers became common during the nineteenth century in the industrialising parts of the world, but alongside with them, and in particular before newspapers became common, the distribution of pamphlets was a way of reaching a larger audience with advertisement and outright propaganda in a fairly inexpensive way. For the investigator of fisheries, ideas on how to promote fisheries were communicated in this way in seventeenth and eighteenth century Britain (Grant 1734). In urban areas, news on where to dine out when in the mood for seafood could be propagated in similar ways, as was the case with an early nineteenth century guide to Copenhagen restaurant menus (Arboe 1805).

From an archivist's point of view it makes a lot of sense to organize historical data on the principle of provenance. When taking in archival material, there are limits to how much the archivist can foresee future use of historical documents. Twenty years ago for instance, marine environmental history did not exist, so how should one have been able to catalogue archival entries for this noble purpose back in the 1950s for instance?

Wishing to investigate an historical archive, the marine environmental historian then needs to be aware of the historical context of the type of historical marine resource exploitation under investigation. The key questions to ask is akin to the investigate strategy of Sherlock Holmes: Who might have provided a written testimony under such and such circumstances? What was the motive of the producer of documents, and why has some material been preserved for posterity, while other documents have disappeared?

The archival entry point from the user's perspective then becomes the inventory, where one can look up the archival holdings from various institutions, but simple queries on the topic "fish" or similar will only provide a superficial result of the potential in most historical archives. Contextualised understanding of the geographical area and peculiarities of the historical period in question is a necessity.

Digital Data Mining and Resources

Presently, digitization of data is the order of the day, also among major archival institutions, but it is a daunting, if not impossible, task to expect full digitization of past paper records. The state archives in a small country like Denmark consists of hundreds of kilometres of shelves stacked with bundled documents from the past. Yet, increasingly, large data mining projects are making use of the potentials of modern search engines and searchable digital database platforms. The potential for marine environmental history is huge, just when looking at a few digital history projects and portals coming out of the past decade of research.

Within marine environmental history per se, one of the largest databases in the one coming out of the History of Marine Animal Populations (HMAP) project of the Census of Marine Life programme (2000–2010), where data was submitted to a standardized flat file spreadsheet format. Incorporated into the HMAP database is also the data arising from the INCOFISH Specific Targeted Research Project of the European Community (2005–2008). Today, these datasets are archived at the University of Hull England, and are freely accessible online at: (http://www.hull.ac.uk/hmap/index.htm). The Sea Around Us Project of the University of British Columbia is mainly concerned with fisheries developments since 1950, but also has strong components stretching back hundreds of years (http://www.seaaroundus.org/), and this project also sports an online database of historical fisheries records. The International Council for the Exploration of the Sea (ICES) is one of the most important proponents for facilitating international fisheries research, although mainly within the framework of the North Atlantic Ocean. Established as early as 1902, ICES has been the most important collector of cross-national fisheries statistics seen over the past century. Recently, ICES has initiated that many species and country specific statistics have been digitized and made publicly available in an open access format (http://ices.dk/marine-data/dataset-collections/Pages/Fish-catch-and-stock-assessment.aspx). ICES is also backing the so-called Study Group for the History of Fish and Fisheries (SGHIST), whose terms of reference include providing a platform for the presentation of marine environmental case studies, supporting the ongoing effort to digitize historical datasets as well as promoting the use of historical data, when establishing reference points for restauration goals in the EU Marine Strategic Framework Directive (http://www.ices.dk/community/groups/Pages/WGHIST.aspx).

Looking at the larger umbrella of digital history, important digitization efforts equally deserve mentioning. Mainly within the last c. 400 years, the use of paper for documentation has been of such volume that commercially derived documents have been preserved in parts of the world such as Europe, and in the context of tracking information form the high seas the European colonial expansion has generated enormous amounts of ocean transport and trade as well as a legacy of archival and printed material. None were more successful than the British Empire, and the English-Canadian led 'Trading Consequences' project has exploited this in novel ways. Here, online text mining is possible from a full body of digitized texts encompassing no less than seven billion word tokens. More than 2000 commodities, including products of marine origin are searchable through this online database, which is global in scope – covering the global span of the former British Empire in the nineteenth century (http://tradingconsequences.blogs.edina.ac.uk/).

Another huge effort in digital history, which has left a promising online database is the Dutch led consortium, Sound Toll Registers Online, which has been instrumental in digitizing the so-called Sound Toll Registers. For more than 300 years until 1857, all ships passing through The Sound between Denmark and Sweden were obliged to pay a toll depending on, which products they carried in and out of the Baltic Sea, and in which quantity. This has left a body of archival material recording 1.7 million ship passages through the Sound (Gøbel 2010). Now, all entries in the registers from 1635 onwards are digitized and searchable online through this webpage: (www.soundtoll.nl). Currently a volunteer based effort seeks to complete then entries for the years preceding 1635. Hundreds of many marine products were listed in this multi-centennial bureaucratic endeavour.

Some of the pioneers in digitizing historical data have been scientists with an interest in environmental forcing, mainly climate variability, which is also of interest to marine environmental history/historical marine ecology. One the features of pre-modern fisheries exploitation, at least in open sea is the fact that the harvest of the sea was fairly light compared to industrial quantities. Therefore, inter annual variability in catches may be attributable to environmental variability in salinity and or temperature and ocean currents, and it is of great interest to be able to compare long term developments in fisheries as well as environmental forcing. Assessing temperature and salinity etc. is feasible through scientific measurements such as thermometer based records for the past 100–200 years. Yet, if one wants to go further back in time, environmental approximations can be created from amongst other sources, document based records. Before c. 1800 seamen and a very few naturalists were the only literate people present on the World's oceans, and their recordings of various weather phenomena are relatively scarce and valuable records of past ocean climate. Logbooks especially, have been tapped for information on weather, and quite often supplemented with data originating from tree rings or ice cores. This includes portals such as: CLIVAR, Climate variability and Predictability (http://www.clivar.org/). The Royal Dutch Meteorological Institute (KNMI), among other resources, provides access to the global CLIWOC project trying to reconstruct the global weather from 1750 to 1850 (http://climexp.knmi.nl/). The NOAA Satellite and Information Service is hosting a large amount of temperature proxies (http://www.ncdc.noaa.gov/paleo/data.html). Another large collection of datasets can be extracted from NASA at (http://gcmd.nasa.gov/index.html) (Poulsen 2010). There are also a number of ongoing research projects such as the Australia based, 'Weather Detective', (http://www.weatherdetective.net.au/). In an effort to reconstruct sea surface temperatures, The Weather Detective seeks to uncover weather records hidden in the log books of ships sailing the Southern Ocean around the turn of the twentieth century. Here volunteers are successfully recruited to transcribe scanned images from numerous old vessels.

Conclusion

We are fundamentally separated from the seas of the past. As Brorson mentioned in 1734, we may 'peer below, but only spy.' The chapter has assessed a number of ways in which historians using their methodological 'spyware' can peer below the surface of the present as a way of assessing the leftover documents from the past.

The above chapter shows how historians' methodologies and approaches have been used to reconstruct marine ecological phenomena of the past. With regards the use of history in historical marine ecology, a number of examples are presented of how past species abundance and spatial aggregation as well as long term catch rates has been investigated through the use of past paper documents, including photographs.

Equally important, and more frequently, historians are answering anthropogenic questions evolving around individual fishermen, fishing fleets, consumers, managers and scientists. Listing all relevant historical scholarship, which can be termed marine environmental history have been beyond the scope of this chapter. What is mainly in focus here, is historical research, where the methodologies have been used to infer knowledge on past marine resource use, while marine environmental history as a sub-discipline of environmental history has a wider range of topical interests.

Central to reconstructing past marine resource use is the practices of past agents in relation to the dynamics of the marine ecosystems they have interacted with. Here, examples are provided as to how in the age of sail, fishermen frequently organized themselves in ways that were opportune only their specific context, but not in a modern one. The Dutch herring fishery from the 1500s until the late 1800s is one such example, where regulations for fishing were extremely elaborate and far ranging. The status and skills of fishermen in more modern times have also been investigated through a combination of interviews and archival studies.

Modern marine fisheries management is based on science, and scientific advice. However, a number of historical accounts have told a story of how the construction of marine science and scientific advice is more often than not engulfed in a whole range of political agendas, locally, nationally, and internationally. In this type of historical research, the 'craft of the historian' is frequently centered on assessing motivations and conditions for policy makers, as they evolve over time in an ever changing political atmosphere.

The final parts of this chapter explored some of the prospects for including historical archival material further in future research in marine environmental history. Accessing these types of data can be a rewarding but labour intensive adventure. Nonetheless, the ongoing process of digitization is a welcome proliferation of the accessibility of such data, where a number of examples were presented.

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On the Need to Study Fishing Power Change: Challenges and Perspectives

Georg H. Engelhard

Introduction

Fishing power expresses the efficiency by which vessels have the potential to catch fish. It is well known that fishing power has improved steadily over the past century, but there is very little quantitative information about the speed at which this has happened. Researchers have tried to address this question since the early days of fisheries science: see, for example, Garstang (1900) on the dramatic increase in fishing power when the era of steam-powered trawling followed that of wind-powered vessels. The continual improvement in fishing power is also a phenomenon that will intrigue any fisherman, and not the least those senior fishers who have witnessed technological improvements themselves (and who may not always have seen these reflected in better catches, e.g. if stocks began to dwindle).

There is general agreement that substantial changes in fishing power have occurred, however, quantitative information on the amount and rates of change is limited, especially over multidecadal time-scales (but see Engelhard 2008; Pauly and Palomares 2010). This is surprising given the obvious benefits of research on fishing power change. This section is a plea for more research on the subject, in the following sub-sections: (1) why study fishing power change? (2) how to define fishing power? (3) a case study: long-term fishing power change in North Sea trawlers; (4) how to analyse fishing power change; and (5) some limitations and potential pitfalls with studying and applying fishing power data, to be borne in mind to avoid drawing false conclusions.

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Although the focus of the chapter is on North Sea fisheries, studies on fishing power have been carried out elsewhere. See, for example, Gascuel et al. (1993) on fishing power in eastern Atlantic tuna fisheries; Holst et al. (2002) on cod gill netters in the Baltic; Damalas et al. (2014) on Greek demersal trawlers; O'Neill et al. (2003) and O'Neill and Leigh (2007) on demersal trawlers off Queensland, Australia; Kimura (1981) on ocean perch trawlers in the north-east Pacific; Brown et al. (1995) on the Western Australian rock lobster fishery; and Robichaud et al. (1999) on coral reef fish traps in the Caribbean.

Why Study Fishing Power Change?

There are at least two important, applied motivations for studying fishing power change:

– To understand change in the *capacity* (or overcapacity) of fishing fleets, and their potential to exploit (or overexploit) fish stocks; such knowledge can be brought to use for effective management and sustainable exploitation of stocks.
– To help interpret (calibrate) catch and cpue from commercial fisheries data if these are to be used as an *index of stock abundance* over medium to long time-scales, where changes in fishing power (and hence catchability) are likely to have occurred; such knowledge is important for assessing long-term stock dynamics.

How to Define Fishing Power?

Definitions of fishing power, sometimes referred to as catching power, differ slightly amongst authors. All have the key question in mind: how efficient are different fishing vessels or fishing fleets in catching fish? In principle, fishing power expresses *differences in catch-per-unit-effort* (*cpue*) between fishing vessels if they would be fishing at the same time and at the same location. Fishing power can be calculated by comparing the cpue of a 'base vessel' or 'base fleet' with data available for a number of years, with the cpue of other vessel(s) or fleet(s) that are newly developing (Beverton and Holt 1957). For calculations, a spatio-temporal overlap between these fleets is required. The base vessel or base fleet usually represents a conventional fishing method that is remaining, or has remained, relatively unchanged for a reasonable stretch of time; the study vessel or study fleet may represent a new or different fishing methodology that is being introduced. The cpue can either refer to a particular fish species, or to the catch of all or a number of species combined.

Garstang (1900), to my knowledge, was the first to apply the fishing power concept. He compared the fishing power of the first steam trawlers, fishing in the North Sea during the late nineteenth century, with that of conventional sailing trawlers or 'smacks', and hence expressed steam trawler fishing power in terms of 'smack units' (Fig. 1). Later on, Beverton and Holt (1957) compared the fishing power of steam and motor trawlers, at a time when steam trawling was gradually giving way

Fig. 1 Two sailing trawlers (smacks) leaving the port of Lowestoft (Photo: Crown Copyright)

to motor (diesel-driven) trawling. Whereas sailing trawlers comprised the base fleet in Garstang's (1900) study, the steam trawl fleet did so in Beverton and Holt (1957).

Case Study: Long-Term Fishing Power Change in North Sea Trawlers

A few years ago, using the principles of Garstang (1900) and Beverton and Holt (1957), an attempt was made to reconstruct the development of fishing power in English North Sea trawlers from the 1880s to 2000s (Engelhard 2008), by combining a range of catch, effort, and cpue data for various periods, where possible taking spatial information into account. The study looked at fishing power for cod and plaice specifically, and it attempted to express the whole change in fishing power as original 'smack units' (but see below for an increasing potential for errors in the estimates once the 'base fleet' of sailing trawlers became extinct during WWII). The three, arguably most important changes in fishing technology that have taken place in the North Sea UK (demersal) trawling fleet are highlighted here.

During the late eighteenth and most of the nineteenth centuries, demersal fish were typically caught by sailing trawlers or smacks (Fig. 1), where a wooden beam trawl was towed behind the vessel, manually lowered and taken in. The first major 'leap' in fishing power occurred in the 1880s with the introduction of the first purpose-built steam trawlers (e.g., Robinson 1996, 2000). Garstang (1900) estimated that these first steam trawlers, still using a beam trawl, had a fishing power for total demersal fish that was four times higher than that of conventional sailing smacks (i.e., four 'smack units'). By 1898, steam trawlers had adopted the use of otter trawls, and by then their fishing power for total demersal fish had improved to eight smack

Fig. 2 SS *George Bligh*, Lowestoft steam trawler, which also served as Cefas research vessel from 1921 to 1939. Characteristic of steam trawlers built during the first half of the twentieth century (Photo: Crown Copyright)

units. The sailing trawl fleet declined rapidly after the introduction of steam trawling and by the 1920s–1930s was restricted to the southern North Sea (Engelhard 2005). Here, steam trawlers had about 4× higher plaice fishing power, and about 10–20× higher cod fishing power than sailing trawlers during this period (Engelhard 2008).

Steam trawlers soon came to dominate the trawling fleets of the UK and many other countries (e.g., Fig. 2). Already in 1900 the English fleet numbered over 1000 steam trawlers, and the first half of the twentieth century may be considered the 'Golden Age' of steam trawlers (Fig. 3). Throughout this period, steam trawlers landed at least 80 % of Britain's entire demersal catch (Engelhard 2005).

The second major technological change came in the 1940s–1960s when steam trawlers became gradually out-competed by motor trawlers (diesel-driven) (Fig. 3). However, the change from steam to diesel was more subtle than that from sail to steam. Motor (diesel) trawlers had about equal, or only marginally higher, cod and plaice fishing power when compared to contemporary steam trawlers in the North Sea (Gulland 1956; Engelhard 2008), but this was in spite of on average much smaller vessel size. This related to the far greater compactness of the diesel motor compared to the steam engine. Thus, corrected for vessel size, motor trawlers had considerably higher fishing power (see also Beverton and Holt [1957] for similar results on British steam and motor trawlers fishing around Iceland).

Thirdly, the introduction of modern (twin-)beam trawlers had profound implications for North Sea trawl fisheries (Figs. 4 and 5). This method involves two large beam trawls lowered mechanically from the side of the ship, often with tickler chains, and is particularly effective for catching sole, plaice and other flatfish. 'Modern' beam trawling was especially developed by the Netherlands and Belgium

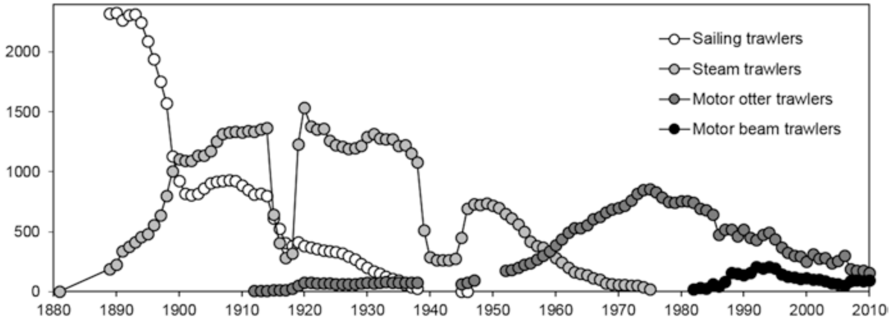

Fig. 3 Dynamics of the trawling fleet of England and Wales. Trends in the numbers of sailing (beam) trawlers, steam (otter) trawlers, motor otter trawlers, and modern beam trawlers registered in England and Wales

Fig. 4 Lowestoft trawler *Mincarlo*, built in 1960–1961 and characteristic of side-winding diesel trawlers built during the 1950s–1960s. Currently a museum vessel stationed in Lowestoft harbour (Photo: Crown Copyright)

during the 1960s–1970s, with the UK following relatively late in the mid-1980s–1990s. A comparison of Dutch beam trawlers with English otter trawlers fishing the southern North Sea in the 1960s–1970s, revealed that the former initially had ~2×, later ~8× higher plaice fishing power; and initially lower, later on about equal cod fishing power (Engelhard 2008). This was in spite of the fact that the Dutch beam trawlers were actually targeting sole (de Veen 1979). During later decades, the fishing power of beam trawlers for flatfish, but possibly not roundfish, increased further (Large and Bannister 1986; Rijnsdorp et al. 2006; Engelhard 2008).

Although fishing power of English North Sea trawlers, with introduction of new technologies, has several times 'leapt' forward within periods of a few years, there

Fig. 5 Dutch trawler in action, characteristic of mechanised twin-beam trawlers (Photo: Georg Engelhard)

have also been long periods of stagnation in fishing power change (Engelhard 2008). During both World Wars the majority, and generally the best and most modern, of UK trawling vessels were converted to mine sweepers, and many vessels were destroyed by enemy action (e.g., Robinson 2000; MAFF 1946). After the war, many newly built vessels were sent to distant waters with the older vessels remaining active in the North Sea (Robinson 2000). It is therefore likely that within the North Sea, little change in fishing power of steam trawlers occurred between the 1910s and 1950s, and possibly a temporary decrease from the 1930s to 1950s. From the 1960s to 1980s, rapid technological developments occurred that must have significantly increased fishing power, including introduction of Decca navigation and sonar fish finding techniques, the expansion of twin-beam trawling, and gradually the replacement of side-winding otter trawlers by stern trawlers (Thompson 1987; Robinson 2000). Unfortunately, it is for this crucial period in North Sea fisheries history that essential data allowing fishing power comparisons are actually relatively scarce, possibly owing to the fast developments themselves and the absence of a constant, unchanging 'base fleet'. It may be considered likely that the European Union's fleet capacity reduction programme of the 1990s–2000s has halted this trend to some extent. Further research is needed to reveal whether this really is the case (cf. Villasante and Sumaila 2010).

How to Analyse Fishing Power Change?

The most direct approach for quantifying differences in fishing power is through conducting "parallel fishing" experiments, using chartered commercial vessels or, if available, research vessels that are in fact derived from commercial vessels (Holt 2010). Unfortunately, comparatively few parallel fishing experiments have been done partly due to the associated cost. Side-by-side trawling experiments are sometimes carried out when a new research vessel is introduced to take over an ongoing, long-term fisheries monitoring survey from another research vessel (e.g. Wilderbuer et al. 1998; von Szalay and Brown 2001). Already Garstang (1905) carried out parallel fishing experiments when testing the relative efficiencies of beam and otter trawls used in early scientific surveys in 1903–1904.

Alternatively, fishing power change can be estimated from available, long-term fisheries datasets, and three approaches are highlighted here. Each of these requires a calibration time-series of cpue or fish abundance: (1) cpue obtained from a commercial base fleet or vessel; (2) cpue from a scientific survey; (3) fish abundance or fishing mortality estimates from stock assessment models.

Approach (1) can be used if a time-series of cpue data can be identified for a conventional, relatively unchanging *base fleet with presumably constant catchability*; or if one or several vessels can be identified that applied the same fishing method over a reasonable length of time (Gulland 1956). Cpue data for a study fleet, matching in space and time, are compared with those for the base fleet (Fig. 6). Ideally, cpue data matched at least at the spatial detail of ICES rectangles are to be used; comparisons of commercial cpue aggregated over large geographic areas (such as ICES sub-areas or divisions) might give misleading results since fleets tend to differ widely in the grounds fished. See Box 1 for an example of how this approach can be modelled statistically using the open-access R package.

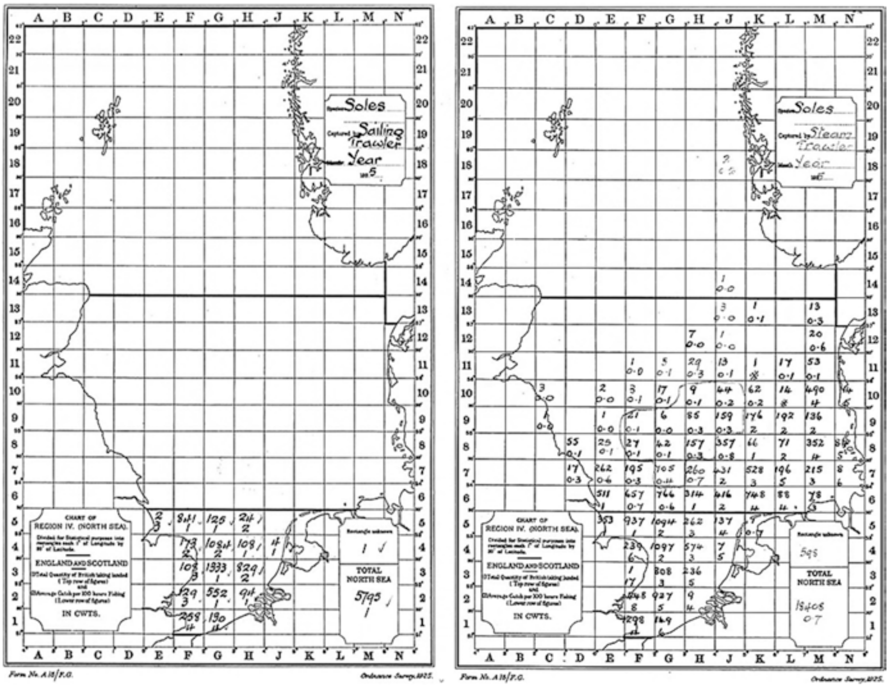

Fig. 6 Example of spatially and temporally matched sole cpue data for British sailing (*left*) and steam (*right*) trawlers in 1925, allowing a fishing power comparison between the two fleets. In the analysis, only spatio-temporally matched cpue data are included (i.e., data for the southern North Sea, ICES Division IVc). Within each rectangle, the *top figure* shows the total landings (in cwt), and the *lower figure* shows cpue (catch [cwt] per 100 h of fishing) (Crown Copyright)

Box 1: Modelling Fishing Power Change: An Example Using R

Using spatio-temporally matched cpue data for the base and study fleet (such as illustrated in Fig. 4, for sailing and steam trawlers), differences in fishing power can be modelled using generalised linear models (GLM) or linear mixed-effects models. As cpue and fishing power data tend to be multiplicative, they may be modelled using log-transformed data (or e.g. log(x + 1) if the data contain many zero cpue values), or using an log link function in GLM. One relatively simple way is, first, to calculate for each spatial unit, the local ratio of study fleet cpue to base fleet cpue. Thus in our example, for each rectangle *r* the ratio P_r steam: sailing trawler cpue is calculated:

$$P_r = \text{cpue}_{steam,r} \,/\, \text{cpue}_{sail,r} \tag{1}$$

These can then be averaged over all rectangles as a crude estimate of average steam trawler fishing power (expressed as sailing trawler units).

However, it is more appropriate to use a linear mixed-effects model to estimate fishing power. The advantage is that the 'rectangle effect' can be accounted for, by including it as a random factor. This is especially recommended in case of time-series data, where the same rectangles were fished repeatedly in multiple years. In the widely used, open-access statistical package R, the form of the model is:

$$\texttt{lme}\left(\texttt{log(Pr)\textasciitilde 1, random=\textasciitilde 1}\,\middle|\,\texttt{factor(rect), data=data}\right) \tag{2}$$

where the resulting estimate of the intercept gives an estimate of ln(steam trawl fishing power); Pr are ratios of study: base fleet cpue by rectangle (rect), i.e. $\text{cpue}_{steam,r}/\text{cpue}_{sail,r}$; and data is the name of the dataset. Next, yearly estimates of fishing power can be estimated by including year as a factor:

$$\texttt{lme}\left(\begin{array}{l}\texttt{log(Pr)\textasciitilde as.factor(year),random}\\ \texttt{=\textasciitilde 1|factor(rect),data=data}\end{array}\right) \tag{3}$$

A linear temporal trend in fishing power can be estimated by including year as a covariate (rather than as categorical factor):

$$\texttt{lme}\left(\begin{array}{l}\texttt{log(Pr)\textasciitilde year,random}\\ \texttt{=\textasciitilde 1|factor(rect),data=data}\end{array}\right) \tag{4}$$

The above method (yearly estimates of fishing power) has been applied, e.g., in Engelhard (2008), and for an example of a fishing power time-series see Fig. 7.

(continued)

Box 1: (continued)

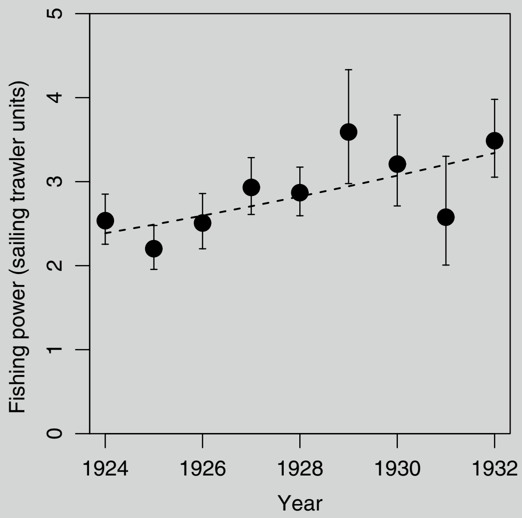

Fig. 7 Time-series of fishing power for British steam trawlers fishing for plaice in the southern North Sea (cf. Fig. 6), expressed in 'sailing trawler units'. *Symbols* show annual fishing power estimates (with *bars* indicating the standards errors; calculated using Eq. 3). *Dotted line* highlights increasing trend of steam trawl fishing power over time (estimated using Eq. 4)

Approach (2) can be used if a contemporary cpue time-series from a *standardised scientific survey* covering the same locations as the study fleet is available. Survey cpue are compared with the cpue for the study fleet. Notice that surveys are typically carried out during one or few specific months of the year. By contrast, commercial cpue data are often aggregated over an entire year. In order to allow a comparison matching in time and space, it is suggested only to include commercial cpue data that are collected during the same month(s) as when the scientific survey took place. This approach was used, amongst others, by Marchal et al. (2002, 2007).

In approach (3), the cpue of the fleet where fishing power needs to be investigated, is compared against estimates of fishing mortality or fish (spawning) stock biomass, based on stock assessments (such as those produced by ICES Working groups, e.g. ICES 2013). This approach was applied by Millischer et al. (1999) who modelled fishing power for the Brittany offshore fleets based on estimates of annual fishing mortality (F) from virtual population analysis (VPA). The calibration cpue time-series is now not provided by a constant base fleet or a standardised survey cpue, but by an abundance time-series from a stock assessment. Notice that in stock assessments, fish abundance or biomass is typically estimated on a per-stock basis, i.e. for an entire sea or fishing region, without the spatial detail of localised presence within the region. Lack of spatial detail might sometimes compromise this method as being less suitable in providing calibration cpue data matched in space and time with the study fleet. On the other hand, there is no need to rely on an assumption of constancy of base fleet or survey catchability.

Limitations and Potential Pitfalls with Fishing Power Data

A number of limitations and potential pitfalls with fishing power calculations and fishing power estimates are highlighted here, that should be borne in mind to avoid drawing incorrect conclusions when such techniques are applied.

- Fishing power should not be equated with *engine power*. Although fishing power is generally improved with engine power, this does not necessarily scale in a proportionate way (de Boer 1975; de Boer and de veen 1975); i.e. doubling of the engine power does not equate to twice higher catch rates – this can be more, also less (Large and Bannister 1986).
- Fishing power is influenced by a variety of factors other than engine power and vessel size; these include targeting ability as well as the desire to target particular species, the size and material of nets, skipper skills, familiarity with grounds, fish finding devices, global positioning systems, and so on (Sichone and de Veen 1973; Holst et al. 2002; Robins et al. 1998).
- Fishing power is *species-specific*. If the fishing power for one particular fish species is doubled this is not necessarily the case for other species. Fish species differ widely in behaviour, size, shape, swimming speed, depth, habitat, etc., and each of these affect catchability (e.g. Main and Sangster 1983). Fishing power is also species-specific because it relates to fishers' ability to target particular desired species, and/or to avoid targeting other, undesired species (such as those with low market value, or over-quota species). Therefore, the extrapolation of fishing power data from one species to any other species requires caution and where possible, should be avoided. For example, in Queensland east coast trawl fishery, the increases in fishing power from 1989 to 2004 ranged from 6 to 46 % depending on the particular fish or shellfish species (O'Neill and Leigh 2007)
- Fishing power change can be *area-specific*. Specialisation of a fleet to particular fishing grounds might actually reduce its fishing power on a different ground.
- In fishing power calculations, it is worth to question the assumption of *constancy of the base fleet*, if this is used to calibrate the fishing power of a new developing study fleet. Also old, conventional fishing methods might undergo changes, and these are not always recorded. In the case where a conventional fishing method is gradually outcompeted by a novel technology, the disappearance of the fleet is unlikely to be random, and within the old fleet, the best-performing of vessels will be those clinging longest to existence. This implies that fishing power of the base fleet is expected to increase (and not a good baseline for calibration anymore). For example, in the 1990s when North Sea beam trawlers had largely outcompeted otter trawlers in plaice fisheries, some conventional side-winding trawlers steered by experienced skippers remained successful for many years, aided by very low running costs and fuel consumption compared to beam trawlers (Engelhard 2008).
- Where fishing power data are used to 'calibrate' cpue time-series to estimate a fish biomass trend (Bishop 2006; Thurstan et al. 2010), any spatial changes in the fishing grounds of a fleet over the study period should be properly accounted for.

If lpue data from different fishing grounds are 'lumped', this could lead to misleading interpretations of fish biomass trends. The interpretation of long-term commercial cpue data, even if corrected for fishing power change, as a proxy for biomass trends requires considerable caution, and is, wherever possible, best done in combination with other indices of stock abundance (such as survey cpue time-series).

- Where an attempt is made to express long-term fishing power change as a single historical unit (such as the 'sailing smack unit' in Engelhard 2008), several calculation steps may be needed where a technology change was introduced. It should be noted that with each calculation step, an added uncertainty is introduced.
- Ideally, fishing power or cpue calibrations should be attempted using a combination of approaches.

Perspectives

Change in fishing power is an essential aspect of the dynamics of fishing fleets (Marchal et al. 2013) – whether it is caused by general progress in technology, is the direct result of competition between fishers, or of depleting fish resources requiring ever improving technologies to find and catch fish. Improvements in fishing power may not necessarily lead to more profitable fisheries. Owing to the so-called 'race for fish', fishers may feel forced to enter into more advanced but also more expensive new technologies. These might be more fuel-intensive, and larger vessels do not necessarily lead to better profitability margins. With biomass declines in many commercial fish stocks, the total allowable catches (TACs) will necessarily have to be adjusted, and cuts in fishing quotas required to sustain fish stocks may be sudden. The ability of a fleet to adapt successfully, however, is likely to require more time.

Studies on fishing power change may also support our understanding of the past and current state of the marine environment (e.g., Mackinson 2001). Fishing power 'creep' often goes hand in hand with greater anthropogenic pressures. On the other hand, more vessels are now beginning to use more selective fishing methods aimed at reducing bycatches and discards (Catchpole et al. 2005), or at reducing impact on the ground (review: Linnane et al. 2000), developments that might either increase or decrease fishing power. Because fishing power is linked with fishing pressure, its changes are relevant when studying the historical, environmental footprint of fisheries, and in understanding long-term change in fish and shellfish populations.

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Ecological Indicators and Food-Web Models as Tools to Study Historical Changes in Marine Ecosystems

Marta Coll and Heike K. Lotze

Introduction

Humans have used natural marine resources extensively throughout history (Jackson et al. 2001; Pandolfi et al.; Lotze et al. 2006; Rick and Erlandson 2008). As human populations grew and evolved, the amount of natural resources used and the impacts human activities had on the ocean's ecosystems and resources intensified and diversified. Today, marine resources contribute on average more than 16 % of animal protein to human diets worldwide, total fisheries catches have exceeded 90 million tonnes of marine organisms, and fishing effort as well as marine aquaculture are exponentially growing (Anticamara et al. 2011; FAO 2012). The impacts of human activities can now be found everywhere in the ocean (Halpern et al. 2008).

This growing use of marine resources by humans, as well as the rise in habitat alteration, water pollution and species invasion from diverse human activities, has greatly influenced marine organisms and ecosystems over historical time scales. But how can we reconstruct and analyse those past changes that happened decades, centuries or millennia ago? Several chapters in this volume address the question of how we can gain information on the ocean's past from different research disciplines and data sources (e.g., Orton 2015; Thurstan and Buckley 2015). In this chapter, we focus on the use of ecological indicators and food-web models as tools to analyse historical changes in marine species and ecosystems.

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Ecological indicators are characteristics of a population or ecosystem that can be measured and used to track changes over time and across species or regions. Because ecosystems are inherently complex, the use of ecological indicators can help describe them and their changes in simpler terms. In this chapter, we focus on commonly used ecological indicators to describe changes in populations and ecosystems, such as species abundance and occurrence, changes in functional groups and species traits. We then describe how we can use food-web models to analyse more complex changes in marine ecosystems in the past, such as changes in food-web structure or stability.

Marine ecosystems are composed of many different species that directly or indirectly interact with each other through, for example, predator-prey relationships, competition, or facilitation. Through these interactions, the species become linked in a "web" of connections that can create complex marine food webs. However, the way that species interact within a food web depends on a series of parameters, such as how many species there are (species richness and biodiversity), how abundant they are (numbers and biomass), where they are (distribution), and what their biological and ecological traits are (e.g., their body size and feeding behaviour). If these parameters change, the nature of food-web interactions may change as well (Bascompte et al. 2005). Thus, changes in the underlying structure of marine food webs can yield changes in the way marine ecosystems function and provide essential services to human well-being (Worm et al. 2006; Hooper et al. 2005).

Over the past decades, the new field of marine environmental history has made great progress in understanding past changes in marine species and communities and their consequences on the structure and functions of marine ecosystems. This enterprise is challenging due to the need to recover and combine data from different scientific disciplines such as palaeontology, archaeology, history, fisheries, ecology and climatology (Jackson et al. 2001; Lotze et al. 2006, 2011a; Pandolfi et al. 2003). However, by adapting techniques that are widely used to study present-day ecosystems and by developing new methods to extract, analyse and model such diverse data, truly innovative ways of studying the ocean's past have emerged.

This chapter provides an overview on ways to document and analyse such past changes, from marine populations to communities, food webs and entire ecosystems. Specifically, through examples in the literature, we describe (i) how to measure changes in past abundance and occurrence of species and functional groups (sections "Species occurrence and abundance as ecological indicators" and "Functional groups as indicators for ecosystem change"), (ii) how to quantify past changes in species traits (section "Changes in species traits: body size and trophic ecology"), and (iii) how to describe past changes in marine food webs (section "Historical food-webs: qualitative and quantitative food-web models"). The availability of methods to integrate what can be learned from the past is essential to understand the present state and contribute to a sustainable future of the ocean and human societies (MacKenzie et al. 2010).

Species Occurrence and Abundance as Ecological Indicators

Magnitude of Population Changes Across Different Taxonomic Groups

One of the most fundamental ecological indicators of historical change is a change in population abundance. This can be measured as a decrease or increase in the number of individuals, their biomass, average size or age, as well as an expansion or contraction of their distribution range over time. These indicators have been applied to a variety of records from the past. For example, archaeological records from shell middens revealed declines in the relative abundance, size and age of white sturgeon from 2,600 to 700 years ago based on their bone frequency and dentary width (Broughton 1997, 2002). Historical whaling maps and log books have been used to reconstruct the rapid depletion of right whales in the North Pacific by nineteenth-century whalers (Josephson et al. 2008). Fisheries catch and effort data throughout the Mediterranean have been used to analyse declines in the catch-per-unit-effort (CPUE) of sharks since the nineteenth century (Ferretti et al. 2008). Some researchers have combined records across different disciplines to gain insight into longer-term changes. For example, Eddy and co-authors (2010) used archival information, fishers' ecological knowledge and underwater surveys to reconstruct a 400-year timeline of lobster (*Jasus frontalis*) in Chile (Fig. 1), suggesting modern lobster biomass is only 15 % of historical abundance from 1550 to 1750.

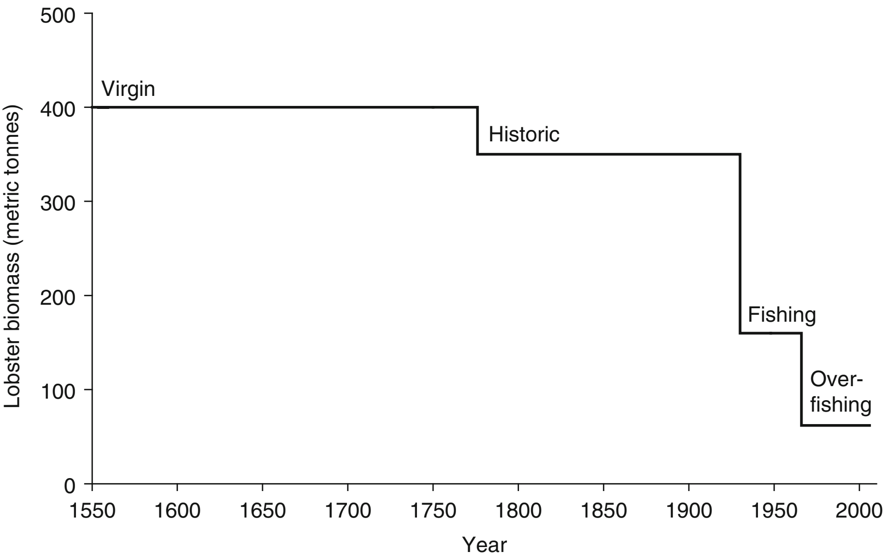

Fig. 1 Reconstruction of lobster (*Jasus frontalis*) biomass in Chile over the past 400 years (Eddy et al. 2010)

Using similar approaches, an increasing number of case studies have documented severe depletions in many marine populations over past centuries or millennia, often earlier and more severe than previously thought (Jackson et al. 2001; Pandolfi et al. 2003; Sáenz-Arroyo et al. 2005; McClenachan et al. 2006; McClenachan and Cooper 2008; Rick and Erlandson 2008; Smith 2005). Generally, those species that have been of value to humans as resources for food, fuel, fashion or other products, and could be easily accessed, caught and processed, have been most affected (Lotze et al. 2006). In some cases, depletions occurred early on through the influence of hunters and gatherers; however, human pressures generally increased over time with growing populations and demands, as well as the commercialization and industrialization of resource use. Thus, the depletion of marine species intensified over the past two to three centuries (Pandolfi et al. 2003; Lotze et al. 2006).

In a case study on the Adriatic Sea, Lotze and co-authors (2011a) compiled a variety of records on the abundance, distribution and size of 90 species or groups of marine mammals, birds, reptiles, fishes, invertebrates and plants from pre-human to modern times (Fig. 2a). The authors used a combination of quantitative and qualitative records to estimate the relative level of population abundance through time as pristine (100–90 %), abundant (90–50 %), depleted (50–10 %), rare (10–1 %), and extinct (0 %). Their results indicated a first wave of depletions during Roman times, particularly for birds and fish, followed by some stabilization during medieval times and then severe depletions across all species groups in the nineteenth to twentieth centuries. By the late twentieth century, 98 % of the recorded species were depleted, 37 % rare, and 11 % locally extirpated (Fig. 2b). Such synthetic studies provide insight into trajectories of change in individual species and entire ecosystems throughout history.

In an effort to quantify the overall magnitude of historical depletions across a range of large marine animals, Lotze and Worm (2009) synthesized 256 case studies with numerical records of historical and modern population size. On average, populations were depleted by 89 % from their historical baseline. Not all populations, however, have remained depleted. Due to growing management and conservation efforts in the twentieth century, several species are recovering (Lotze et al. 2006, 2011b; Kittinger et al. 2011). A recent review suggests that 10–50 % of depleted populations show some recovery, but so far rarely to former levels of abundance (Lotze et al. 2011b). For example, only 40 of 256 historically depleted populations experienced some recovery, mostly marine mammals and birds, with an average increase from 13 to 39 % of their historical abundance (Lotze and Worm 2009). In many cases, the level of former depletion strongly influences the magnitude of subsequent recovery (Hutchings and Reynolds 2004; Magera et al. 2013; Neubauer et al. 2013).

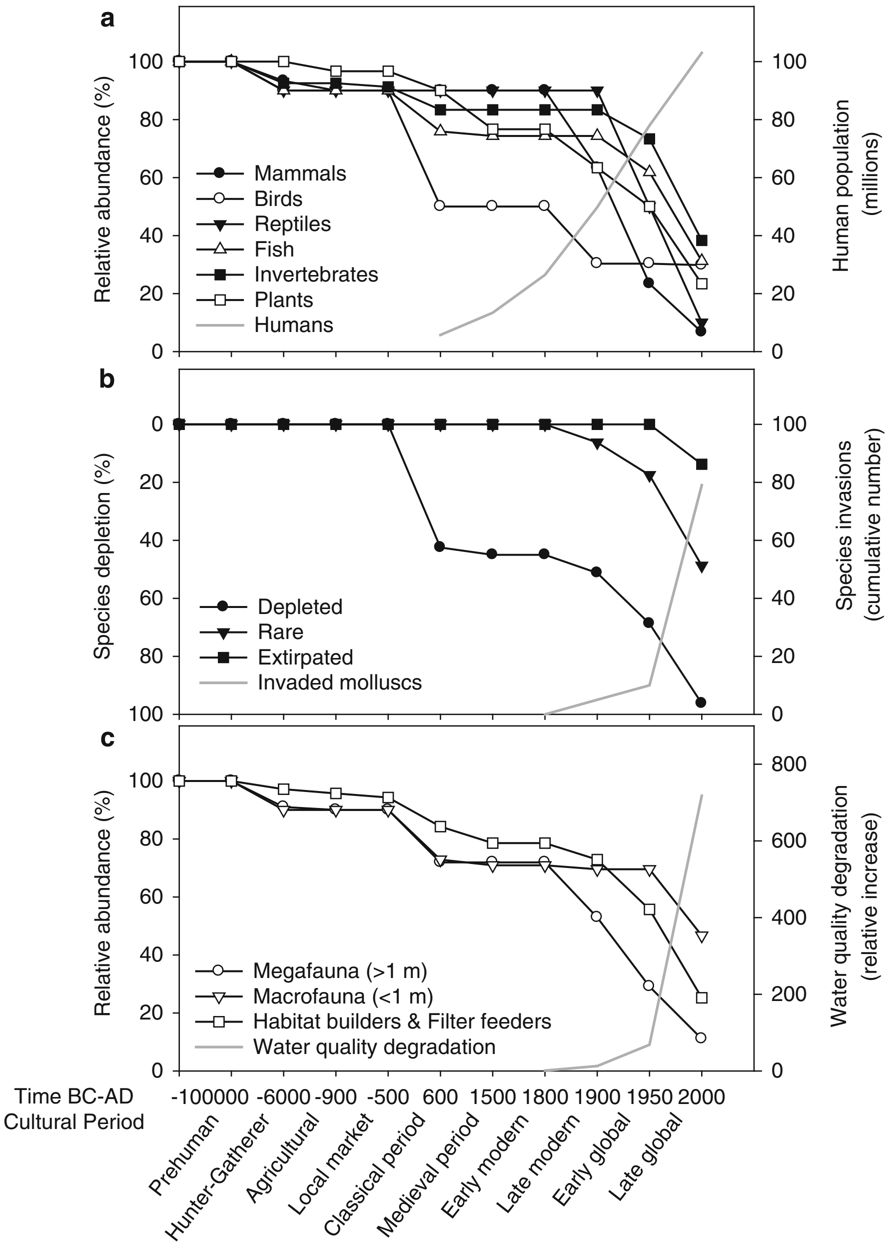

Fig. 2 Synthesis of the historical trajectories of change in marine species and ecosystem structure of the Adriatic Sea: (**a**) relative abundance of different taxonomic groups and the human population, (**b**) species diversity expressed as the cumulative percent of species depletions and number of invasions, and (**c**) relative abundance of different ecosystem components over historical time BC–AD and cultural periods. Axes for *thin black lines* with symbols are on the *left*, axes for *thick gray lines* on the *right*. The timeline for species invasions refers to mollusk invasions in the Mediterranean as a whole; all other data refer to the Adriatic Sea (Adapted from Lotze et al. 2011a)

Changes in Species Occurrence: Extinctions Versus Invasions

Another fundamental ecological indicator is the basic presence or absence of a species in an ecosystem. Summed up, all species occurrences provide an estimate of a region's species richness or biodiversity. Yet severe population depletion can lead to the disappearance of a species through local, regional or global extinction. In the case of the Adriatic Sea, 11 species became locally extirpated (Fig. 2b), including the Mediterranean monk seal (*Monachus monachus*), the Dalmatian pelican (*Pelecanus crispus*), and several species of sharks, rays and other fish (Lotze et al. 2011a). On a global scale, Dulvy and co-authors (2003) reported 133 marine extinctions on local or regional scales during the nineteenth and twentieth centuries. Moreover, since AD 1500 at least 20 marine species have become globally extinct, including the Caribbean monk seal (*Monachus tropicalis*), Steller's sea cow (*Hydrodamalis gigas*) and the Great auk (*Pinguinus impennis*) (Dulvy et al. 2009; Harnik et al. 2012). For most of the recorded species depletions and extinctions, overexploitation was the primary human driver and habitat loss the second most important factor followed by pollution (Fig. 3a, Dulvy et al. 2003; Lotze et al. 2006).

There have not only been losses to local species richness but also gains through the intentional or unintentional introduction of exotic species. The first identified marine invasion occurred through Norse voyagers who brought the soft-shelled clam (*Mya arenaria*) from North America into the Baltic and North Seas before AD 1245 (Petersen et al. 1992). In the following centuries, marine species invasions gradually increased with the expansion of global navigation, trade and commerce (Ruiz et al. 1997; Lotze et al. 2006). In Chesapeake Bay, for example, at least 150 marine and brackish invasions have been recorded since 1609 (Fofonoff et al. 2003) and 164 in San Francisco Bay since 1853 (Cohen and Carlton 1998). In the Northern Adriatic Sea, 41 invasions were recorded via ships, including 13 macro-algae, 27 invertebrates, and 1 fish (Occhipinti-Ambrogi 2002), and at least 79 molluscs alone have invaded the Mediterranean Sea since 1877 (Fig. 2b, Zenetos et al. 2004). In many coastal ecosystems the number of species invasions actually outnumbers the number of species extinctions resulting in a net gain of biodiversity (Lotze et al. 2006, 2011a; Lotze 2005; Byrnes et al. 2007). Yet most invasions consist of invertebrates, algae, plankton, bacteria and viruses; whereas extinctions consider vertebrates such as marine mammals, birds, reptiles and fishes (Fig. 3b). Such fundamental shifts in species occurrence and composition not only change local and regional biodiversity, but have also strong consequences on ecosystem structure and functioning (Byrnes et al. 2007, and see sections "Functional groups as indicators for ecosystem change" and "Historical food-webs: qualitative and quantitative food-web models").

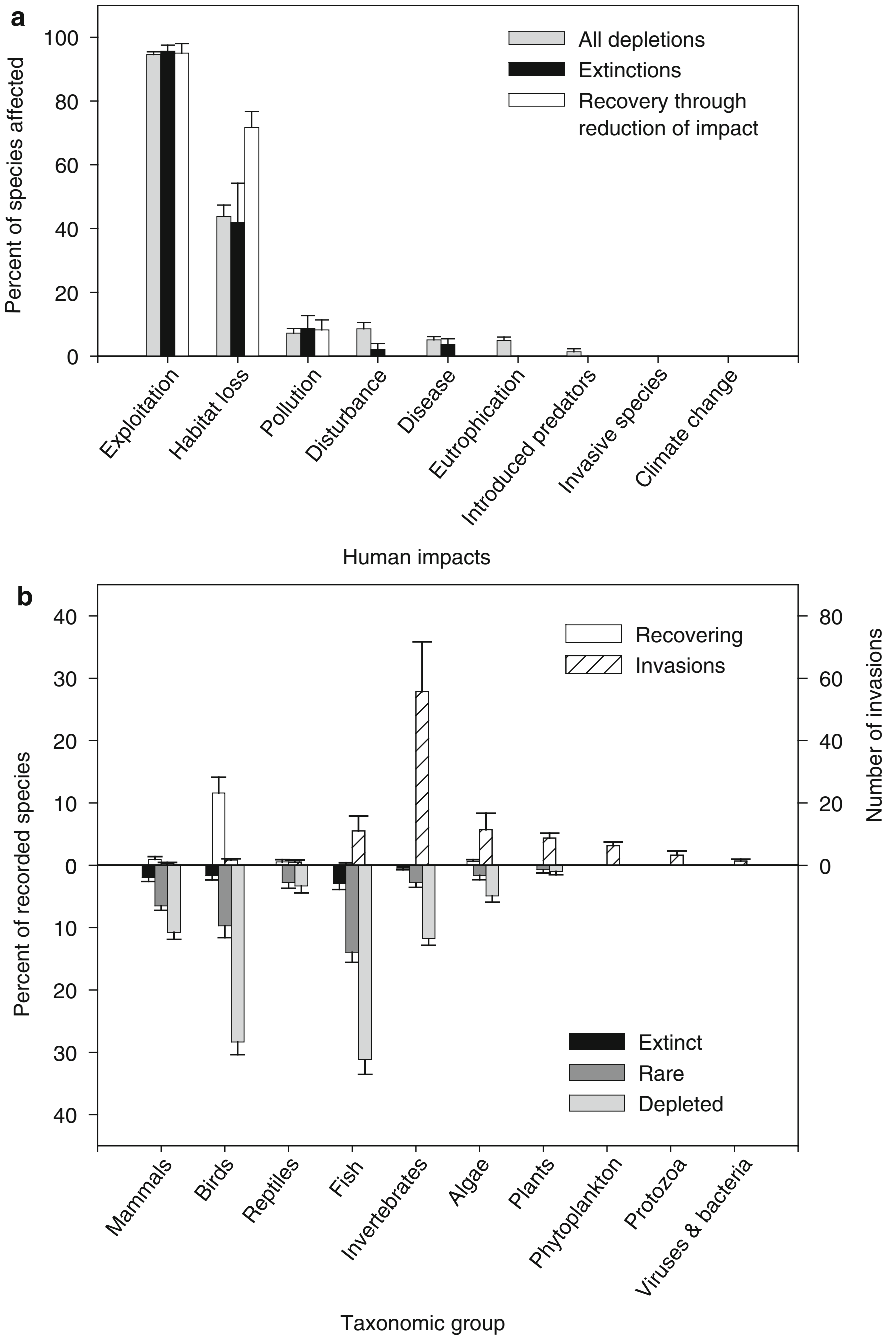

Fig. 3 Reconstruction of (**a**) the human drivers of species depletions (*grey*), extirpations (*black*) and recoveries (*white bars*); and (**b**) shifts in species diversity due to species losses and species gains through recovery (*white*) and invasions (*hatched bars*) (Adapted from Lotze et al. 2006)

Functional Groups as Indicators for Ecosystem Change

Every species fulfils certain ecological roles. To study historical changes in an ecosystem context it is therefore informative to group species not only by their taxonomic connections but also their ecological functions. In the following, we present historical trends in three well-studied functional groups, consumers, filter feeders and habitat-providers, and then summarize changes in overall ecosystem structure and function.

Trends in Feeding Guilds

Most species exploited by humans are consumers in marine ecosystems, either preying upon other animals (carnivores or predators), plants (herbivores), or dead organic matter (detritivores). Throughout history, humans generally preferred targeting species that were large, nutritious and easy to catch. Consequently, large carnivores (e.g., seals and sturgeons) and large herbivores (e.g., manatees and green turtles) have been strongly depleted early on (Broughton 1997, 2002; Lotze 2005; Smith 2005; McClenachan et al. 2006; McClenachan and Cooper 2008; Rick and Erlandson 2008). As highly valued species declined, they were successively replaced by smaller, less valued and harder to catch species (Lotze et al. 2006; Lotze and McClenachan 2013). This phenomenon has been called "Fishing down the food web" (Pauly et al. 1998) if accompanied by a decline in the average trophic level, or "Fishing through the food web" (Essington et al. 2006) if lower-trophic level species have been added to the catch of higher ones.. In both cases it describes a serial depletion from higher- to lesser-valued species.

In the Adriatic Sea, large megafauna (>1 m body length) became much more depleted in the nineteenth to twentieth centuries compared to smaller macrofauna (<1 m) (Fig. 2c, Lotze et al. 2011a). Similarly, across 14 coral reef ecosystems worldwide large carnivores and herbivores became much more depleted since European colonization compared to small carnivores and herbivores, as well as suspension feeders, corals and seagrasses (Fig. 4, Pandolfi et al. 2003). In some cases, large carnivores and herbivores became so depleted in the last 50–100 years that they were deemed ecologically extinct. Similar historical trends in feeding guilds occurred across 12 estuarine and coastal ecosystems in Europe, North America and Australia (Lotze et al. 2006). Interestingly, a more recent study on Hawaii's coral reef ecosystems found that several groups show some recovery in recent decades, especially in the more remote and protected northwest Hawaiian Islands (Kittinger et al. 2011). While ecological functions of individual species can sometimes be fulfilled by other species, the loss of entire feeding guilds has severe effects on overall food-web and ecosystem functioning (see sections "Changes in ecosystem structure and function" and "Historical food-webs: qualitative and quantitative food-web models").

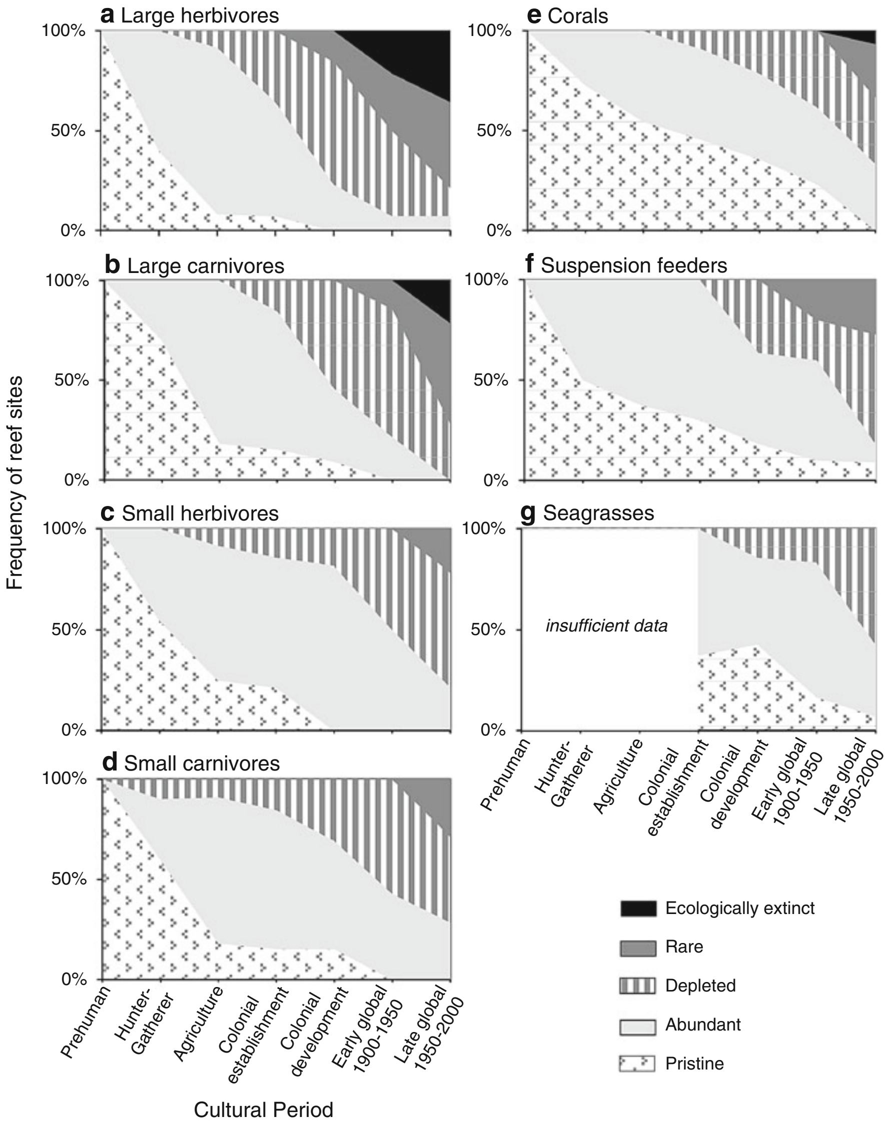

Fig. 4 Reconstruction of historical changes in different functional groups (panels **a**–**g**) across 14 coral reef ecosystems worldwide. Shown are the percent of reef sites where the functional group has been pristine, abundant, depleted, rare or ecologically extinct from prehuman to recent times (Adapted from Pandolfi et al. 2003)

Changes in Habitat-Providing Species

Some species provide three-dimensional habitat for a wide range of associated species searching for food, refuge, settlement substrate, nursery or breeding grounds (Beck et al. 2001). For example, corals and oysters build reef structures that are home to numerous algae, invertebrates, fish and sea turtles. Mussel beds are less complex but still provide a solid settlement surface and three-dimensional structure. Along soft-sediment shores, saltmarshes and mangroves cover the intertidal and seagrass beds the subtidal seafloor, whereas rooting plants are replaced by intertidal rockweeds and subtidal kelps along rocky shores. These different vegetation types provide meadow- or forest-like habitats that support numerous animals and plants (Lotze et al. 2006; Schmidt 2012).

Historically, some habitats have been directly exploited (e.g., oysters and mussels for food, mangroves for firewood), while some oyster and coral reefs were mined for road construction. Many saltmarshes and mangroves were transformed into farmland, settlement or industrial areas, while seagrass and mussel beds were destroyed by dredging and trawling. Increased sediment loads from land clearing and nutrient loads and pollution from agriculture, sewage or industrial activities have affected many coral reefs and seagrass beds. Consequently, many coastal habitats have been depleted or lost over past centuries. For example, in Chesapeake Bay, 111,600 ha of natural oyster reefs on the Maryland side declined by >50 % between 1907 and 1982, with local losses of 95 % (Rothschild et al. 1994). In the Adriatic Sea, oyster reefs were already heavily affected during Roman Times (Lotze et al. 2011a), and in many other coastal ecosystems since industrial exploitation in the eighteenth to nineteenth centuries (Kirby 2004; Lotze et al. 2006, 2011a). Across 14 coral reef ecosystems, corals, suspension feeders and seagrasses strongly declined since the 1950s, although some corals were already affected before European colonization (Fig. 4, Pandolfi et al. 2003). Average loss of wetlands amounts to >50 % of their historical area in Europe and the United States, with highs of >80 % in many regions (Airoldi and Beck 2007) and 94 % in San Francisco Bay (Lotze 2010). Rockweed beds and kelp forests have generally been less affected by human activities, although strong declines have occurred in some regions (Airoldi and Beck 2007; Lotze et al. 2011a).

Since many species directly or indirectly depend on habitat availability, historical habitat losses had severe consequences for associated species. Globally, habitat loss has been ranked as the second most important driver for species depletions and extinctions after exploitation (Fig. 3a, Lotze et al. 2006; Dulvy et al. 2003; Harnik et al. 2012). In addition, many coastal habitats play important roles in the retention and cycling of nutrients, sediments and organic matter, and are therefore important natural filters and buffer zones between land and sea (Costanza et al. 1997; Lotze et al. 2006; Schmidt 2012).

Changes in Filter Feeders and Water Quality

Filter feeders, including oysters and mussels actively filter large amounts of water to extract phytoplankton, detritus and other food particles, thereby enhancing water clarity. In Chesapeake Bay, the pre-1870 oyster population could have filtered the entire water column in 3–6 days during the summer (Newell 1988). Reduced by >90 % current oyster stocks may need 244–325 days to filter Chesapeake Bay's water (Newell 1988). Similar losses of filter feeders and filtration capacity have been documented in many estuaries worldwide (Lotze 2005, 2010; Lotze et al. 2011a; zu Ermgassen et al. 2012). Wetlands, seagrass beds and other aquatic vegetation also retain nutrients, trap sediments, and take up pollutants; therefore, historical declines of these habitats have contributed to water quality degradation (Lotze et al. 2006).

Historical changes in water quality have been reconstructed by palaeontologists based on records from sediment cores, including sedimentation rate, trace elements, biochemical markers, and phytoplankton shells. Such studies revealed that first changes in water quality occurred in the course of land clearing for agriculture or human settlements. This has increased erosion and sediment loading into coastal waters, such as in Chesapeake Bay and the Inner Great Barrier Reef in the course of European colonization (Cooper and Brush 1993; McCulloch et al. 2003). The increased sediment run-off has also enhanced nutrient loading and consequently primary productivity (Lotze et al. 2006, 2011a). Over the past centuries, increased sewage production, municipal and industrial wastewater, agricultural and aquaculture run-off further enhanced nutrient and chemical pollution. Nutrient loading commonly leads to increased phytoplankton growth and shifts in species composition, such as from benthic to planktonic species (Cooper and Brush 1993). It further increases water turbidity and shading, causing declines in seagrasses and other benthic vegetation. This can be reconstructed from sediment cores based on epiphytic diatoms (*Cocconeis* spp.), which decline with their hosts (Cooper et al. 2004). Finally, the decomposition of enhanced algal biomass leads to oxygen depletion causing hypoxia or anoxia, which can be traced in sediment cores based on the amounts of sulphur or pyrite (Cooper et al. 2004). Combining these different measures, water quality in the Adriatic Sea started to degrade in the nineteenth century and exponentially worsened in the twentieth century (Fig. 3c, Lotze et al. 2011a). Similar historical trends in water quality degradation have been found in estuarine and coastal waters around the world (Lotze et al. 2006, 2011b; Lotze 2010).

Many more pollutants have been added to the marine environment since the industrial revolution, including organic wastes, heavy metals, pesticides, and pharmaceutics. Some have caused acute toxicity or chronic illnesses, such as DDT causing strong declines in many birds in the 1960s and 1970s (Lotze 2010). Overall, pollution ranked third after overexploitation and habitat loss in causing historical species depletions and extinctions (Dulvy et al. 2003; Lotze et al. 2006; Harnik et al. 2012).

Changes in Ecosystem Structure and Function

Together, all changes in the occurrence and abundance of species, populations and functional groups have altered the fundamental structure of marine ecosystems. This includes declines in species richness and diversity, increased species invasions, and shifts in the composition of taxonomic and functional groups (Figs. 2 and 3, Lotze 2005; Lotze et al. 2006). Such changes affect species interactions, community dynamics, food-web processes and ecosystem functions. For example, the taxonomic mismatch between species losses and gains has shifted species composition from larger, long-lived, and slow-growing species to smaller, fast-growing ones (Byrnes et al. 2007). Such high-turnover species are more sensitive to environmental changes, and render the community less stable and more variable to external drivers (Planque et al. 2010).

The decline of large predators has often caused increases in their prey and competitors. In some cases this has triggered trophic cascades, whereby several lower trophic levels were affected (Myers et al. 2007; Ferretti et al. 2010). Thus, in many marine ecosystems actual top-down control has decreased, while nutrient loading has increased bottom-up control. Changing the strength of these basic ecological drivers affects ecosystem productivity and functioning (Worm et al. 2002; Worm and Duffy 2003). Moreover, the loss of essential habitat and the degradation of water quality may have altered the carrying capacity for many species. Finally, impoverished food webs are also more prone to species extinctions following perturbations (Dunne et al. 2004; Lotze et al. 2011a) and to the establishment of invasive species (Stachowicz et al. 2002).

Structural changes in marine ecosystems that translate into changes in functions end up affecting ecosystem services provided to humans (Worm et al. 2006; Lotze et al. 2006). For example, the depletion and loss of species in coastal ecosystems over past centuries has affected the provision of viable commercial fisheries and seafood, spawning and nursery habitats and filtration capacity. The decline of these essential services has resulted in rising health risks and costs to society, such as increasing beach closures, harmful algal blooms, fish kills, shellfish closures, and coastal flooding (Worm et al. 2006; Lotze et al. 2006).

Changes in Species Traits: Body Size and Trophic Ecology

In addition to changes in the occurrence and abundance of marine species, historical data also suggest changes in their intrinsic traits. Recent studies show how specific traits are modified as species abundance changes due to human activities. Several traits are known to change with high fishing pressure, including species' body size, total length and length at maturity, and their trophic ecology (Rochet and Trenkel 2003). Historical ecologists have adopted these metrics to be calculated from past data to set historical baselines against which the life-history characteristics of current species can be compared.

Changes in Body Size

Paleontological and archaeological studies provide information on changes in fish and invertebrate taxa and sizes (Rick and Erlandson 2008; Morales et al. 2007). The size of past organisms can be determined by broad comparison with modern specimens, or by detailed analyses of fish remains (Collins et al. 2010). For example, an archaeological study in the Black Sea using fish bones documented a size reduction in some species from the Archaic period (seventh to sixth century BC) to Roman times (one to fifth century AD) (Morales et al. 2007). In southern Polynesia, archaeological studies compared species remains across shell middens and found strong human impacts on coastal resources from AD 1100–2000, including changes in the length of crayfish tails (Anderson 2008).

In places that have been inhabited since ancient times, such as the Mediterranean Sea, other information can be used to set species trait baselines. For example, artistic information such as pictorial remains was used to assess the maximum size and length at maturity of fishes in the Mediterranean Sea (Stergiou 2010). Using information provided in the Minoic fresco at Akrotiri, in Satorini ('the little fisher of Santorini') (Fig. 5), Stergiou (2010) calculated the length frequency of the common dolphinfish, *Coryphaena hippurus*, held by the fisher in the fresco. These were much larger than present-day length frequencies of the species, and this decline in average length over the past 3600 years is probably due to overfishing (Stergiou 2010).

From the recent past, the recovery of traditional knowledge through interviews enables the collection of information on species traits (Huntington 2000; Sáenz–Arroyo et al. 2005). This information is valuable since fisheries statistics in many regions are quite recent and do not necessarily cover the time periods when important ecological changes occurred. For example, in the Gulf of California, Mexico, results from interviews with fishermen documented a drop in abundance but also in the weight of the largest fish ever found of a species at risk, the Gulf grouper (*Mycteroperca jordani*), from the 1940 to 1950s to the present (Sáenz–Arroyo et al. 2005). Similar changes in the weight of the largest fish ever caught in demersal fisheries and the composition of the catch were documented in the Western Mediterranean Sea from 1940s to date (Coll et al. 2014) (Fig. 6).

In cases where the available data is less abundant, other methods can be used to predict the structure of marine communities and changes in species traits, such as the one based on macro-ecological theory and modelling techniques applied in the North Sea (Jennings and Blanchard 2004).

Changes in Trophic Habits and Positions

Other traits of marine species that are highly studied are the trophic habits and positions. The trophic habits provide information on the feeding preferences of marine organisms, while the trophic positions represent where the organisms are placed in

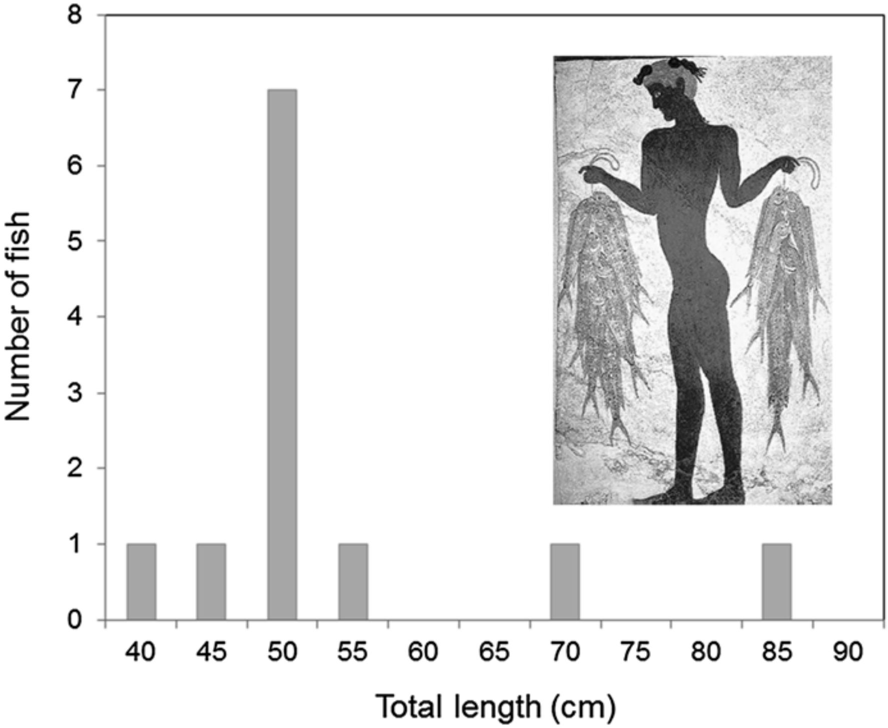

Fig. 5 Using information provided in the Minoic fresco at Akrotiri, in Satorini ('the little fisher of Santorini') it is possible to calculate the length frequency of the common dolphinfish, *Coryphaena hippurus*, that are held by the fisher in the fresco, and compared it to the one that is common nowadays in the Mediterranean Sea (Adapted from Stergiou 2010)

relation to others in the food web based on what they eat. For example, organisms feeding on plants are herbivores and have a lower trophic position than those mainly feeding on animals (such as crustaceans and fish). The trophic position can be expressed in terms of trophic level (TL) (Lindeman 1942). Algae, higher plants and detritus have a TL = 1. Therefore, the organisms that feed on them, herbivores, have a TL = 2 and the organisms that feed on herbivores have a TL = 3, and so on. Since marine organisms feed on a range of organisms at different trophic positions, their trophic levels are expressed as fractional numbers (such as TL = 3.25 or 4.5).

Aside from traditional stomach content analysis, which pose serious problems to use on individuals from the past, one way of studying trophic ecology is using stable isotopic markers (Post 2002). This technique is applied to fish muscle, bones and other tissues (Michener and Kaufman 2007; Layman et al. 2011). Stable isotopic markers (mainly nitrogen $\delta^{15}N$, carbon $\delta^{13}C$ and oxygen $\delta^{18}O$) have been used successfully to analyze changes in trophic habits of species from ancient times in comparison with recent ones. In particular, $\delta^{15}N$ has been useful for tracking changes in the diet of marine predators (Wainright et al. 1993) and thus comparing prehistoric, historic and modern $\delta^{15}N$ values could provide insights into temporal trends in

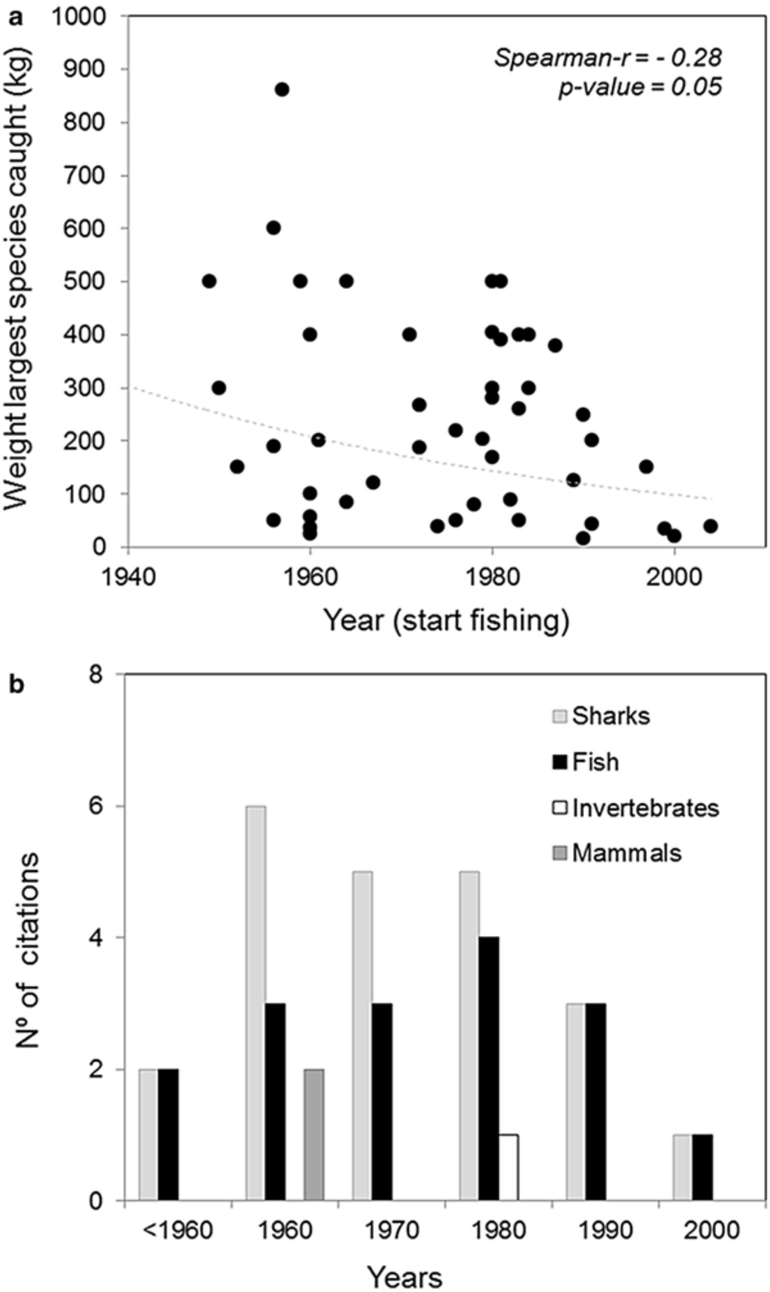

Fig. 6 Weight (**a**) and composition (**b**) of the largest species ever caught by fishers in the N-Western Mediterranean Sea estimated using fishers interviews (Adapted from Coll et al. 2014)

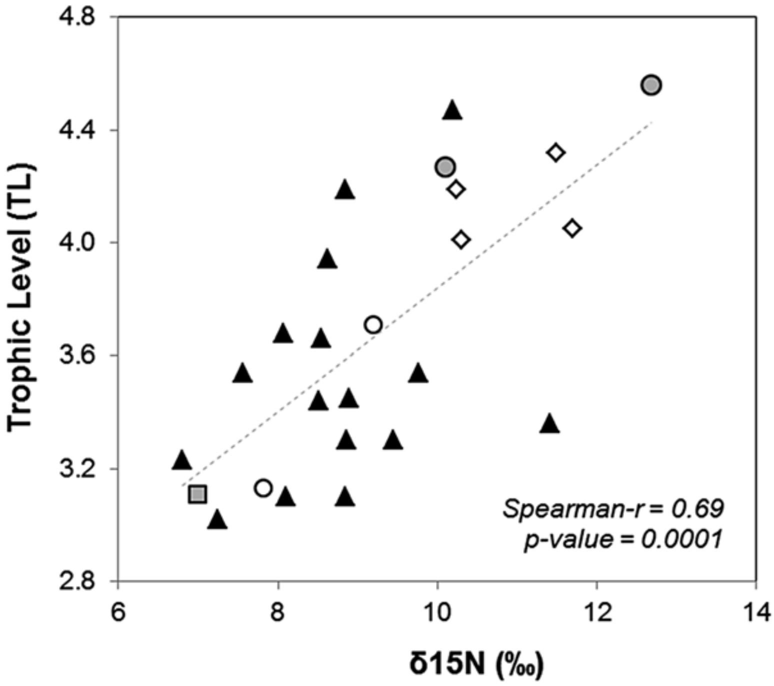

Fig. 7 Relationships between the trophic level (mean) calculated with the Ecopath model and the δ15N values (*mean*), calculated with the isotopic values, for fish (*black triangles*), cephalopods (*white circles*), seabirds (*white diamonds*), cetaceans (*grey circles*), and marine turtles (*grey squares*) from the NW Mediterranean Sea (Adapted from Navarro et al. 2011)

ecosystem structure in relation to human impacts. An example comes from the Aleutian islands in Alaska (Corbett et al. 2008), were the diet of an extinct species, the Steller's sea cow (*Hydrodamalis gigas*), was analysed from archaeological remains, indicating that it was highly specialized on kelp. Therefore, human over-hunting of sea otters and following decline of kelp forests may have limited the habitat and food available for sea cows, contributing to its demise.

The $\delta^{15}N$ isotopic composition of bones can be also used to assess the tropic level of marine organisms, and potentially track changes in the ecosystem structure (Collins et al. 2010), since $\delta^{15}N$ and trophic levels are known to be correlated (Navarro et al. 2010) (Fig. 7). However, this method has limitations because in order to document changes of the food web due to human activity, rather than environmental variability, it is essential to compare $\delta^{15}N$ measurement of organisms at different trophic levels, at different time periods and in different geographic locations. Therefore, although the concept of the trophic position and trophic level has been used recently to characterize past marine ecosystems (Rick and Erlandson 2008; Steneck et al. 2004), the implementation of stable isotope analyses to measure change in trophic positions of marine species in the past is still challenging. One interesting example is the study of the prehistoric fishing effects on the coastal food webs in the Gulf of Maine (Bourque et al. 2008), where $\delta^{15}N$ and $\delta^{13}C$ signatures of cod (*Gadus morhua*), sculpin, (*Myoxocephalus* spp.), and flounder (*Pleuronectes* sp.) of prehistoric and modern bone collagen showed important changes in diets and trophic position of these organisms through time. Another interesting study highlights changes in the trophic position of a generalist oceanic predator, the Hawaiian petrel (*Pterodoma sandwichensis*) (Wiley et al. 2013). In this study, the comparison of modern and ancient radiocarbon-dated bones showed a stable diet of this species over 3000 years followed by a decline of 1.8 ‰ in $\delta^{15}N$ over the last 100 years, attributed to fishing impacts.

Historical Food-Webs: Qualitative and Quantitative Food-Web Models

Information on species diversity, abundance, distribution and traits are used to depict the food-web structure of marine ecosystems. Different methodologies exist, from qualitative to quantitative techniques with different degrees of capabilities to simulate ecosystem dynamics, include human activities and environmental drivers, and capture different technical and biological complexities (Dambacher et al. 2003; Williams and Martinez 2000; Christensen and Walters 2004; Fulton 2010; Plagányi et al. 2012). These techniques have been adapted or modified to model marine food webs in the past.

Qualitative Food-Web Representations

Qualitative food-web modelling includes a broad array of techniques, from simple drawn-by-hand conceptual diagrams of the food webs to more complex analyses of matrices of positive and negative species linkages. One of its utilities is to identify and interpret community-level indicators (Dambacher et al. 2009). Using qualitative modelling, a food web can be represented by a graph known as a signed diagram graph (Levins 1974) and different techniques are available to formally implement these analyses (Dambacher et al. 2002).

An interesting early application of simple conceptual diagrams was used to depict the structure of marine ecosystems prior to fishing posing alternative hypotheses (Steele 1996). The authors were puzzled by the fact that data from early fisheries in several ecosystems suggested that catch rates of demersal species were very high despite primitive fishing methods. Therefore, they used food-web diagrams to hypothesize the structure of the ecosystem and the main energy flow channels in past marine food webs that supported high past abundance and productivity. Simple conceptual diagrams of kelp forest, coral reef and estuarine ecosystems were also used to depict the structure of food webs before and after fishing (Jackson et al. 2001) (Fig. 8). These diagrams clearly helped to highlight major changes in

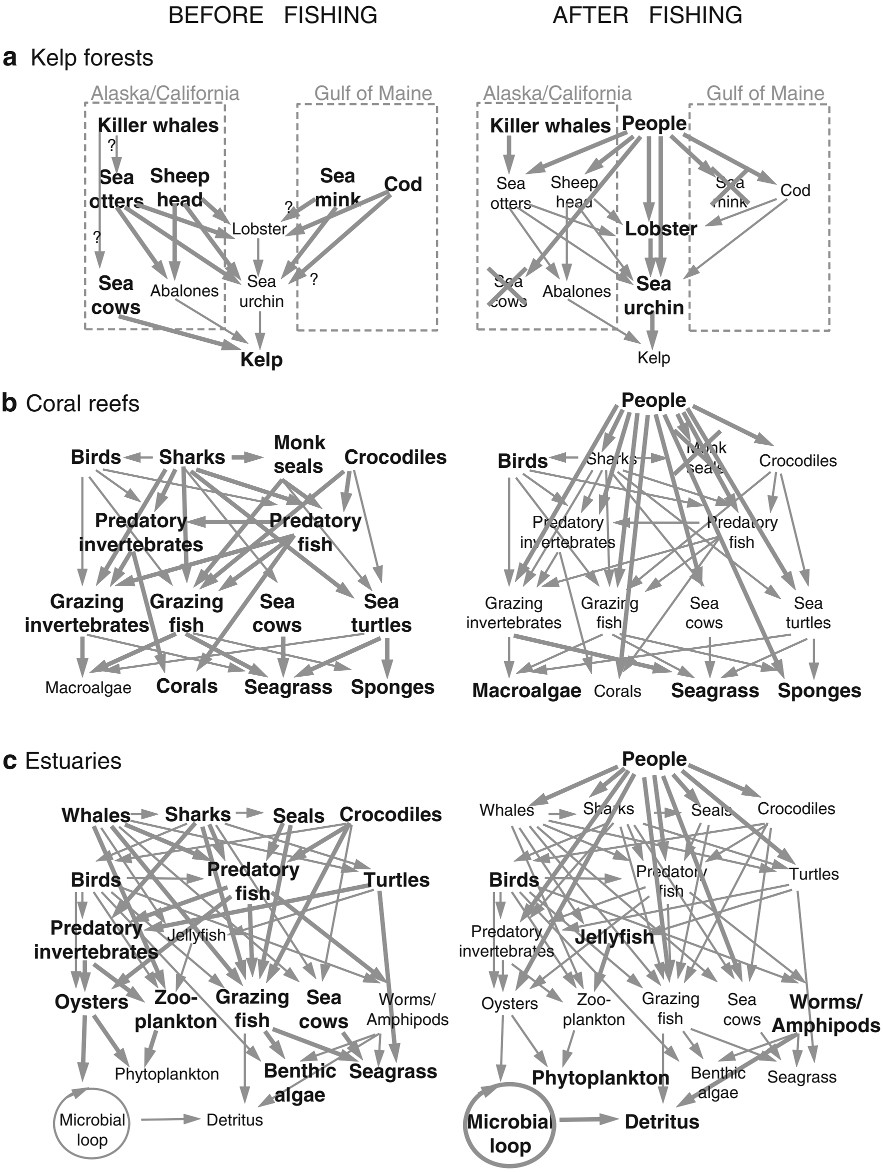

Fig. 8 Conceptual food-web models depicting historical changes in (**a**) kelp forests, (**b**) coral reefs, and (**c**) estuaries due to the impacts of fishing. Abundant species are indicated in *bold*, low-abundant or rare species in *smaller regular font*, and extinct species are *crossed out*. Strong interaction links are depicted with *thick arrows*, while weaker ones with *thin arrows* (Adapted from Jackson et al. 2001)

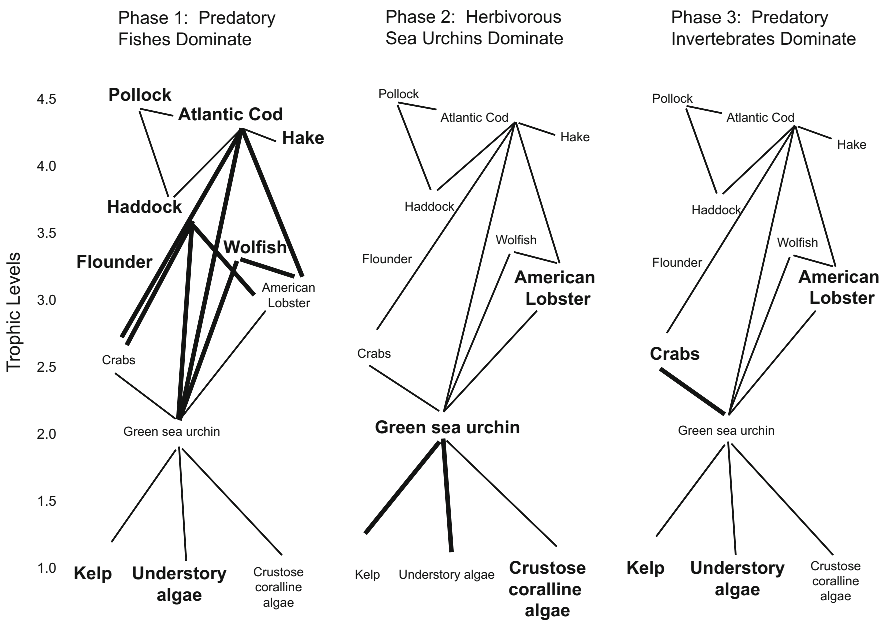

Fig. 9 Food webs of coastal zones of Maine. All species determined to have been abundant at one time were plotted with their assigned trophic level. Abundant species are shown in *bold*, rare or low-abundant species in *smaller regular font*. Most trophic linkages have been demonstrated with ecological studies. Interaction strengths correspond to the width of trophic linkages lines (Adapted from Steneck et al. 2004)

marine food webs as human impacts lead to the loss of biodiversity, the removal of large predators, the degradation and loss of special habitats and water quality. They illustrated the simplification and homogenization of coastal food webs over time.

Qualitative modelling was also used in the Gulf of Maine to identify distinct and sequential phases in the trophic structure of kelp forests (Steneck et al. 2004) (Fig. 9). The authors used archaeological, historical, ecological, and fisheries data to document a serial targeting and depletion of abundant top consumers that led to functional loss of trophic levels, creating trophic cascades that changed the structure and function of the ecosystem. They concluded that humans had disrupted the ecosystem by fishing it down (Pauly et al. 1998) for millennia. Another qualitative modelling application using prey-predator links established from available historical data was used to depict a typical coastal food web of the North-western Mediterranean Sea in the past (Sala 2004). The study highlighted that ecologically extinct megafauna accounted for 24 % of the identified trophic interactions in the past suggesting that their removal may have had large ecological consequences that are still partially unknown.

Network Models

Several simple models are used to explain the structure of food webs observed in nature. They hypothesize a structure of the data based on theoretical ecology and data on species presence/absence and their feeding links ("who-eats-whom") (Williams and Martinez 2000; Allesina et al. 2008). Their application to ancient datasets is rare due to a lack of detailed data. Generally, we only know little about those few species that have left traces, thus there is high uncertainty about trophic links. However, a few interesting examples exist.

One study explored structural properties of marine food webs of the Cambrian Period based on fossil assemblages of the Chengjiang and Burgess Shale assemblages in China and Canada, respectively (Dunne et al. 2008). The authors used network analyses including a sensitivity analysis of the effects of uncertainty in diet links. Results highlighted that Cambrian communities had remarkably similar structure to modern food webs and concluded that more research is needed to explore the generality of food-web structure through deep time and the potential mechanisms that could give rise to similar structures.

Another example was developed in the Adriatic Sea to describe the historical change of marine food webs using ten historical periods that started in the prehumen period before ~100,000 BC to the global expansion of humans in AD 1950–2000 (Lotze et al. 2011a). Binary food web models were used to depict the different historical periods and analysed possible changes in food-web structure and functioning over time (Fig. 10). Results showed that increased exploitation and functional extinctions altered and simplified the food-web structure over time, especially by changing the proportions of top predators and intermediate consumers.

Network models applied to more recent datasets are more abundant. An example studied the structure of marine food webs in two exploited Mediterranean ecosystems during the 1970s and 1990s and evaluated how changes in species composition and biomass have affected food-web properties (Coll et al. 2008b). Results showed strong similarities in structural food-web properties between the two food webs analyzed indicating similar ecosystem structure between regions and time periods in the Mediterranean Sea. A comparison with other published marine food webs suggested that both Mediterranean webs were in an advanced state of ecological degradation.

Quantitative Food-Web Modelling Techniques

Quantitative food-web modelling approaches are frequently used to study marine ecosystems and a diverse toolkit exists (Christensen and Walters 2004; Fulton 2010; Plagányi et al. 2012). These analyses include abundance/biomass data and energy flow information instead of just presence/absence, and they allow considering human activities and environmental variability. As in the case of qualitative

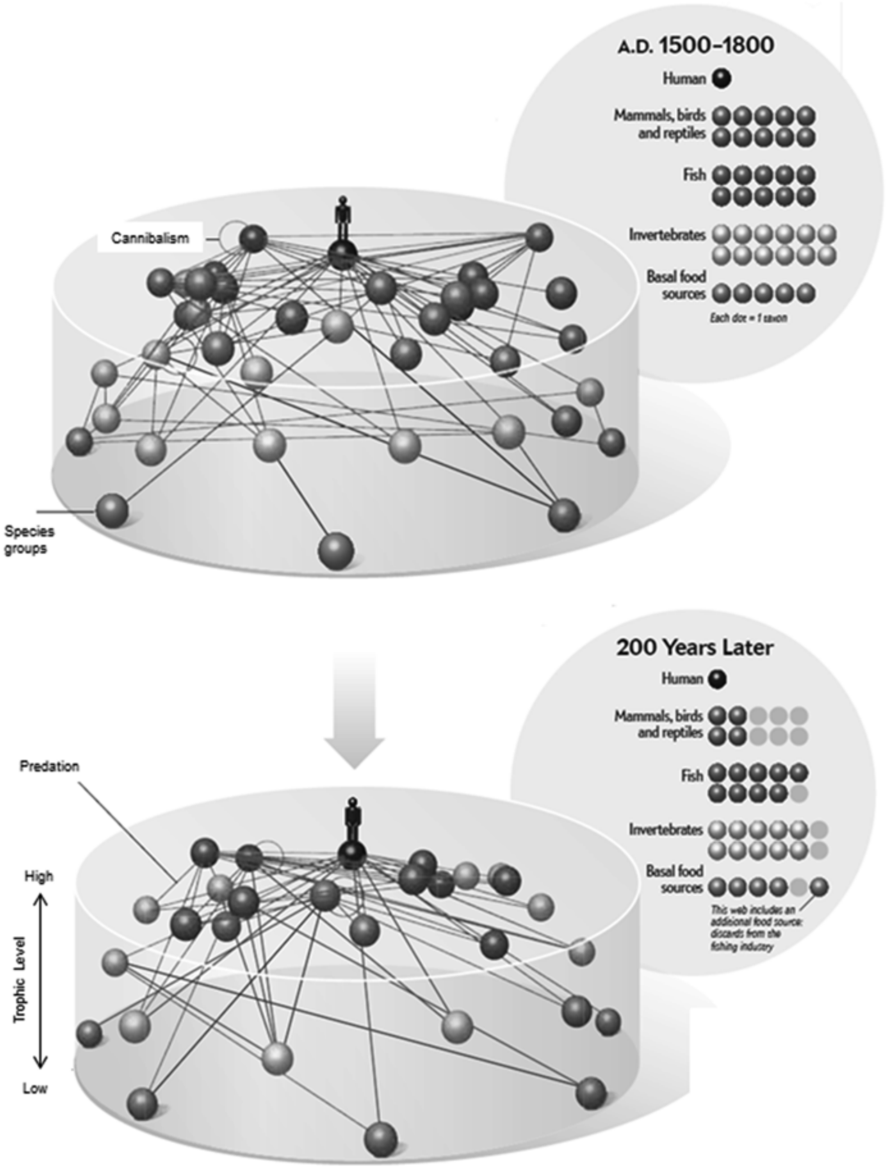

Fig. 10 Binary food web models used to depict different historical periods in the Adriatic Sea. They show predatory relationships among marine species and include humans (Adapted from Matson 2012; Lotze et al. 2011a)

modelling, the application of these techniques to model past ecosystems is challenging due to data availability and data quality. However, some applications to past ecosystems show smart ways to overcome the difficulties.

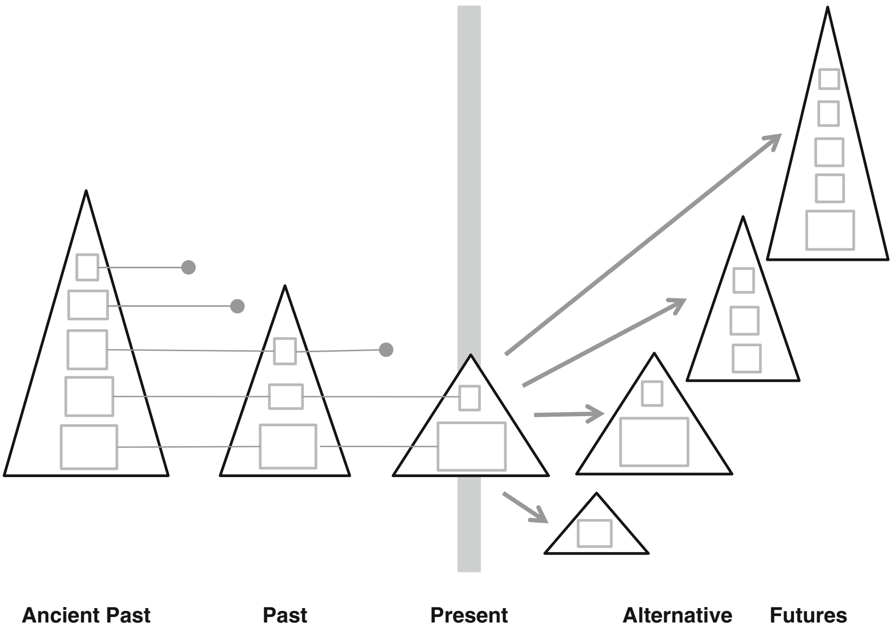

Fig. 11 The "Back to the Future" approach to marine ecosystems restoration using historical documents, data archives, archaeological data and traditional and local knowledge. *Triangles* represent trophic pyramids and height is directly related to biomass and internal connectance. Internal *boxes* show biomasses of representative species through time, with *closed circles* indicating extirpations (Adapted from Pitcher 2005)

At present, the *Ecopath with Ecosim* approach (EwE, Christensen and Walters 2004, www.ecopath.org) is the model that has been mostly applied to marine food webs (Coll et al. 2008a). The *EwE* modelling capabilities can be used to build food-web models by describing the ecosystem by means of functional groups, each representing a species, a sub-group of a species (e.g. juveniles) or a group of species that have functional and ecological similarities. *EwE* modelling has been extensively used to model marine ecosystems in the past.

An interesting application of *EwE* to model past ecosystems is develop under the "Back to the Future" approach (Pitcher 2005). This approach aims at evaluating historic ecosystems as tools to define possible restoration goals and to design rebuilding strategies for the ecosystems (Fig. 11). Two remarkable applications of this approach were developed in Canadian marine ecosystems of Newfoundland (Pitcher et al. 2002), covering the periods of 1450, 1900, 1985 and 1995, and of British Columbia (Ainsworth et al. 2008), covering the periods of 1750, 1900, 1950 and 2000. These studies highlighted the general depletion of marine resources since the first European contact and the important changes in the structure and functioning of the food webs through time.

Another interesting application of *EwE* to depict past food webs can be found in the upwelling ecosystems of the Northern and Southern Benguela. Here, *EwE* was used to construct and compare quantitative food-web models of the ecosystems representing different eras of human influence: aboriginal, pre-industrial, industrial, and post-industrial (Watermeyer et al. 2008a, b). These applications yielded interesting results about major changes in the structure and function of one of the most productive marine ecosystems in the world. Results evidenced the different role that fishing and environmental factors may have played in the North and the South Benguela, which were harvested at different intensities. Other applications of *EwE* to hind-cast past dynamics of marine ecosystems exist using the capability of the temporal module to fit models to past data (Coll et al. 2008c).

Changes in Food-Web Properties and Comparative Approaches

Food-web model applications can be used to compare structural and functional properties of marine food webs (Dunne et al. 2004; Coll et al. 2008a). Quantitative and qualitative techniques are envisioned as a complementary approach to model marine food webs. This is due to the fact that model structure and uncertainties in available data are reduced when modelling studies are compared using different levels of model complexity. If different models deliver similar results of food-web traits, these can be considered more robust.

One study that analysed two marine food webs in Mediterranean ecosystems during the 1970s and 1990s is a good example of this comparative qualitative/quantitative approach (Coll et al. 2008b). The study used two modelling approaches, the stochastic structural *Niche* model (Williams and Martinez 2000), and the deterministic mass-balance *Ecopath* model (Christensen and Walters 2004). Both applications, although very different with respect to their configuration, input parameters and assumptions, delivered comparable results, suggesting that they both capture fundamental information about how food webs are structured. Moreover, both approaches highlighted similar patterns of degradation of the structure of Mediterranean food webs over time (Table 1).

Potentials for Future Research

This chapter provides an overview on ways to document and analyse past changes in marine populations and ecosystems using ecological indicators and food-web models. We have highlighted studies that developed new methods to extract, analyse and model heterogenic and diverse data from the past, illustrating that truly innovative ways of studying the ocean's past have emerged in the last decades.

Some important lessons arise from this new field of research. First, it becomes clear that multidisciplinary studies are essential and possible to study past marine

Table 1 Qualitative comparison of 22 network properties from Mediterranean and non-Mediterranean models and descriptions of directions suggesting a more degraded state for overexploitation of high trophic level species, simplification of the food web and decrease of productivity and biomass

Network properties		Mediterranean versus non-Mediterranean areas		
		Niche	Ecopath	Direction
(a) Overexploitation of high TL				
1	%T	↑	↑	Improvement
2	%I	↓	↓	Degradation
3	%B	↑	↑	Degradation
4	GenSD	↑	–	Degradation
5	VulSD	↑		Improvement
6	SWTL&mTLco	↓	↓	Degradation
7	maxTLi	x	x	Non clear
(b) Simplification of food web				
8	L/S	↓	↓	Degradation
9	C&C′	↓	↓	Degradation
10	%Omn&SOI	↓	↓	Degradation
11	%Can	↓	↓	Improvement
12	%Loop	↓		Degradation
13	ChLen	↓		Degradation
14	Path&Fpath	↑	x	Non clear
(c) Changes in productivity and biomass				
15	Bt		↓	Degradation
16	%BTP		↓	Degradation
17	%BI		↓	Degradation
18	%BB		↑	Degradation
19	B/P		↓	Degradation
20	TST		↓	Degradation
21	FD/TST		↑	Degradation
22	TE		x	Non clear

Adapted from Coll et al. (2008b)

%T Fraction of species with prey but no predators, *%I* Fraction of species with both prey and predators, *%B* Fraction of species with predators but no preys, *Gen & GenSD* N° of prey items by species and standard deviation, *Vul & VulSD* N° of predators by species and standard deviation, *SWTL* Short-weighted trophic level (SWTL) or the average of prey trophic level, *mTLco* Mean trophic level taking into account biomass of preys and predators and diet composition (calculated from all TL and from TL>1), *maxTLi* Maximum trophic level of the top predator in the food web, *L/S* All trophic link in the web (L) divided by S (species or ecological groups), *C* Proportion of actual trophic links to all possible links (L/S2), 0 = no species preys on any species, 1 = every species preys on every other species including itself, *C′* Ratio of numbers of actual links to the number of possible links (L/(S-1)2), where S is the number of living groups, *%Omn* Fraction of species that feed directly on more than one trophic level and have food chains of different lengths, *SOI* The average omnivory index of all consumers weighted by the logarithm of each consumer's food intake, *%Can* Fraction of species that feed directly on its own species, *%Loop* Fraction of species involved in looping by appearing in a food chain twice, *ChLen* Mean number of links in every

(continued)

Table 1 (continued)

possible food chain or sequence of links connecting top to basal species, *Path* Characteristic path length or the mean shortest path length between species pairs, *Fpath* Finn's path length or the average number of groups that an inflow or outflow passes through, *Bt* Total biomass (calculated as t. km^{-2} from all Tl and from TL>I), *%BTP* Percentage of biomass of species with prey but no predators, *%BI* Percentage of biomass of species with both prey and predators, *%BB* Percentage of biomass of species with predators but no preys, *B/P* Ratio between total biomass and total production, *TST* Sum of all trophic flows in the system (t. km^{-2}), *FD/TST* Ratio of sum of all trophic flows to detritus over TST, *TE* Ratio of efficiency of energy transfer from lower to higher trophic levels

ecosystems, and we envision an increase in case studies that integrate multiple data and disciplines using novel methodologies. Second, the future will likely bring large developments in modelling the past, thereby increasing the capability to hindcast ecosystem dynamics and ensure forecasting possibilities. Third, we also expect that more comparative analysis of qualitative and quantitative models will be developed since the ability to model past marine ecosystems is crucial to understand the present, and predict the future. These analyses will be challenged by the urgent need to consider ecological, economic and social dimensions of change.

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Illegal, Unreported and Unregulated Fishing in Historical Perspective

Joseph Christensen

Introduction

The condition of marine capture fisheries globally is one of the most urgent environmental problems of the early twenty-first century. Many experts now believe that the world's marine capture harvest peaked in the late 1980s, and although this peak was masked for some years by over-reporting of landings along the Chinese coast, the undeniable legacy is that key stocks around the world are overfished and declining in abundance (Pauly et al. 2002; Worm and Branch 2013). According to the Food and Agriculture Organization of the United Nations (FAO), in 2011, 28.8 % of global fish stocks were over-fished, 61.3 % were fully-fished, and only 9.9 % were under-fished and able to support increased exploitation. But the true picture may even be worse than these figures indicate. As much as 80 % of the world's catch may come from fisheries that are not formally assessed, and two-thirds of these may be depleted below a level that provides for maximum sustainable yields (Costello et al. 2012). Such figures highlight an emerging division in the status and prospects of marine fisheries globally, where Europe, North America and Oceania have comparatively well-assessed and sustainably-managed fisheries, in which exploited populations are most likely to be rebuilding, and the comparatively data-poor and poorly-managed fisheries of Asia and Africa, where too many populations remain over-exploited and continue to decline (Worm and Branch 2013; Mora et al. 2009; Pitcher et al. 2009). These developing regions, which depend heavily upon the marine environment for food security and employment and where the impediments to effective fisheries governance are often acute, represent the greatest challenges to fisheries scientists, managers, and conservationists today. At stake is the potential to

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rebuild and sustain marine capture harvests that, if managed properly, can underpin the food security and employment for many millions of people.

Among the most pressing of these challenges confronting global fisheries is the phenomenon of 'Illegal, Unreported and Unregulated fishing', or simply 'IUU fishing'. According to the FAO, IUU fishing 'remains a major global threat to the long-term sustainable management of fisheries and the maintenance of productive and healthy ecosystems as well as to the stable socio-economic condition of many of the world's small-scale and artisanal fishing communities' (FAO 2014). A joint statement by European Union and United States of America describes the phenomenon in similar terms, stating that 'IUU fishing is a global phenomenon with devastating environmental and socio-economic consequences, particularly for coastal communities in developing countries who rely on fisheries for their livelihoods or for protein' (Damanaki and Lubchenco 2011). These statements, made barely a decade after the FAO had first committed to tackle illegal fishing, reveal the depth of concern that has developed over the threat posed by such activities to the long-term conservation and socio-economic goals of fisheries governance. What is the scale of the problem? By its very definition, IUU fishing is an activity which seeks to avoid official monitoring and for which a deficient of reliable knowledge can be presumed to exist. Yet in 2009 one team of scientists produced the first baseline estimate of the global scale of IUU fishing. Their study found that, at the start of the twenty-first century, losses attributed to IUU fishing accounted for between US$10 billion and US$23.5 billion annually, representing between 11 and 26 million tons of wild-caught fish. Moreover, between 1980 and 2003, IUU fishing may have accounted for as much as 20 % of the world's marine capture harvest. The study also pointed towards a correlation between governance and the incidence of IUU fishing, with developing nations being also most at risk from illegal fishing activity (Agnew et al. 2009).

Producing a global estimate of IUU fishing is no straightforward matter. To arrive at their estimate, the authors of this landmark study examined a vast array of information; catch statistics, trade data, stock assessments, surveillance reports, specialist studies and expert opinions were all analysed to produce figures of the likely extent of illegal fishing globally. Such evidence was sufficient not only to produce estimates of the extent of IUU fishing, but also to gauge how it may have developed across time (Agnew et al. 2009). This raises an interesting point. The range of data sources that can be marshalled as evidence, and the temporal range of IUU fishing, suggests that it is phenomenon that is relevant not only to fisheries scientists, managers and conservationists – it suggests that it is also a concept that is relevant to environmental historians and historical ecologists concerned with changes in human-environment interaction across time. Can IUU be examined in historical perspective? This chapter addresses this question. It begins by outlining a short history of IUU fishing, locating the phenomenon in a wider context shaped by the global expansion of marine capture fisheries in the twentieth century and the changes to the regulation of fishing industries and control over maritime space and marine living resources that took place during this period. The chapter then looks closely at three historical case-studies of IUU fishing in the Indo-Pacific, one of the world's principal marine realms. The chapter concludes with a discussion of the potential for further investigations of IUU fishing from an historical perspective.

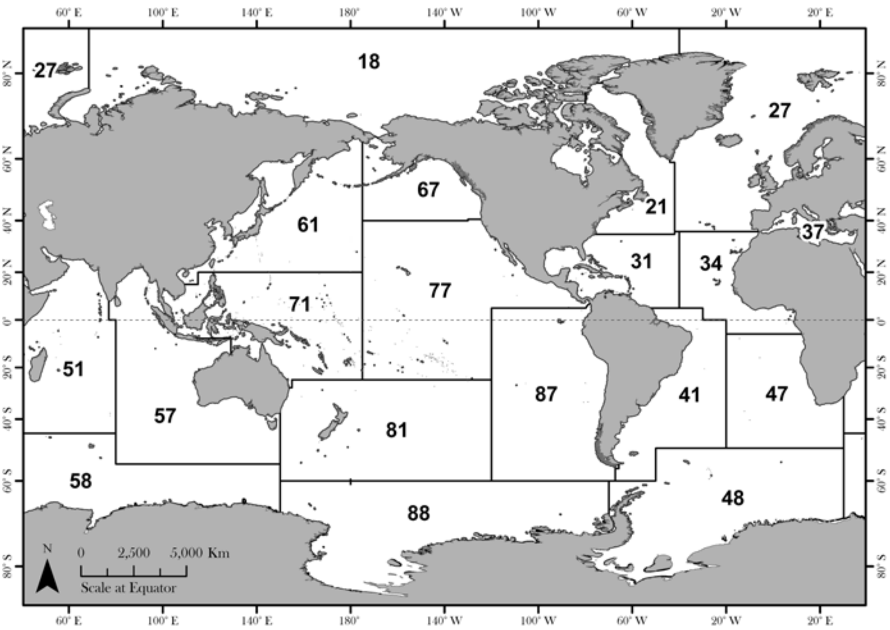
A Short History of IUU Fishing

The first use of the term 'Illegal, Unreported and Unregulated fishing' was made by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) in a 1997 report that documented unauthorised fishing taking place within the Exclusive Economic Zones (EEZs) of the Southern Ocean (discussed later in this chapter). In 1999, as pressure mounted for a comprehensive response to illegal fishing, the FAO committed to the development of a global strategy that culminated 2 years later in the *International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing* (FAO 2001). This blueprint outlined the first comprehensive definition of IUU fishing: 'Illegal Fishing' referred to fishing carried out in a state's territorial waters without state permission or in contravention of its laws, and to fishing on the high seas by a state-flagged vessel in contravention of laws and obligations agreed to between two or more states through a Regional Fisheries Management Organisation (RFMO); 'Unreported Fishing' covered the non-reporting or misreporting of catches in contravention to national or regional regulations and procedures; and 'Unregulated Fishing' covered fishing by vessels without nationality or by state-flagged vessels in waters where the state is not party to an RFMO, and fishing in waters where no management measures exist and which is inconsistent with international responsibilities to conserve fish stocks (FAO 2001). Such a wide-ranging definition necessarily applied to a multitude of activities, and the IPOA's recommendations were correspondingly broad, addressing: state responsibilities to conserve fish stocks and respond to illegal fishing; 'Flag State' responsibilities to ensure vessels avoid breeching laws and correctly document their catches; the responsibilities of coastal states to police territorial waters; and 'Port State Measures' designed to prevent the landing of illegally-caught fish and the harbouring of illegal fishing vessels. The plan also recommended that the FAO and developed nations support developing nations in their efforts to mitigate illegal fishing (FAO 2001).

The release of the IPOA heralded more than a decade of sustained international interest in addressing IUU fishing. In 2003 the Organisation for Economic Co-operation and Development (OECD) committed to a second major investigation into the economic, social and environmental aspects of the problem. The OECD reports on 'Fish Piracy' revealed that IUU fishing had become more than a problem for scientists and managers; it was also of concern to conservation organisations due to by-catch of protected marine species and seabirds, and to labour and human rights organisations on account of poor working conditions and safety records aboard illegal fishing boats (OECD 2004, 2005). Other non-governmental organisations to respond to the problem included the Marine Stewardship Council (MSC), which was founded in 1997 to assist consumers to purchase seafood from sustainably-managed fisheries (Roberts 2012); Greenpeace and the World Wild Fund for Nature (WWF), particularly in relation to issues surrounding by-catch in IUU fisheries; and the International Labour Organization (ILO), to protect the interests of fishers working aboard illegal fishing vessels (OECD 2004). Among the challenges faced by the FAO, RFMOs, NGOs and national fisheries agencies were the common practises of 'Flag of Convenience' (FoC) fishing, wherein vessels operated under the flags of countries that are unwilling or unable to exert effective control over national fleets, and the transhipment of catches at sea, which allowed vessels to launder catches illegally (Gianni and Simpson 2005). Such problems pointed to the need to strengthen international regulations. The IPOA-IUU had developed out of the FAOs non-binding 1993 Fish Stock Agreement and the 1995 Code of Conduct for Responsible Fisheries, but a more rigorous approach was needed to replace these instruments. In 2009, the FAO developed the *Agreement on Port State Measures to Prevent, Deter and Eliminate IUU Fishing*, the first legally-binding measure designed to combat IUU fishing by blocking the flow of illegal and unreported fish to markets and detering FoC vessels from operating on the high seas (FAO 2010). By this stage, many countries in Europe, North America and Australasia had also implemented their own national plans to address IUU fishing, at the same time as offering assistance to developing nations to address the problem.

This raft of measures alludes not only to the rise but also to the persistence of IUU fishing since the late 1990s. Since 1990 the incidence of illegal and unreported catches is believed to have risen in five major ocean regions (the Southwest Atlantic, Eastern Indian, Northwest Pacific, Eastern Central Pacific and Antarctic; see Map 1) and to have fallen in 11 regions, although in only 6 of these regions (Northwest, Northeast, Western Central and Southeast Atlantic, Northeast and Southwest Pacific, and the Antarctic; Map 1) did the IUU catch account for less than 10 % of the total reported catch in 2003 (Agnew et al. 2009). In 2013 the US Congress named ten nations whose vessels, including FoC vessels, engaged in IUU fishing over the preceding 2 years; Columbia, Ecuador, Ghana, Italy, Mexico, Panama, the Republic of Korea, Spain, Tanzania and Venezuela (NOAA 2013). A range of factors underpinned the continuation of IUU fishing despite a determined international response. Strong market demand for wild-caught seafood irrespective of the origins or circumstances of capture, fuelled by ongoing population growth and rising living standards in the developing world and particularly in Asia, was the root cause of the problem. Substantial over-capacity in global fishing fleets at a time of dwindling fish stocks helped to encourage risk-taking in the form of illegal or unreported fishing. Finally, national governments and RFMOs were also faced with the perennial challenge of monitoring what actually takes place in EEZs or on high seas, where maintaining effective surveillance can be an expensive activity, and one that is often fraught with both legal and practical difficulties. The lack of effective state control is recognised as one of the main reasons why IUU fishing proved so difficult to halt during the 2000s (NOAA 2013).

From a longer-term point of view, however, the rise of IUU fishing is best understood within the context of the more far-reaching changes to marine capture fisheries that took place during the twentieth century. When the FAO first began to collect statistical data on fisheries production in 1950 the global fishing industry was in the early stages of a vast expansion in fishing power made possible by the rapid adoption of industrial technologies including fossil-fuel powered vessels, synthetic fishing lines, sonars and other fish-finding devices, and on-board refrigeration. From a



Map 1 Statistical areas for fishery purposes (Source: FAO Fisheries and Aquaculture Department [online]. Rome. http://www.fao.org/fishery/area/search/en. Northwest Atlantic is area 21; Northeast Atlantic 27; Western Central Atlantic 31; Southwest Atlantic is Area 41; Southeast Atlantic 47; Eastern Indian 57; Northwest Pacific 61; Northeast Pacific 67; Southwest Pacific 81; Eastern Central Pacific 77; Antarctic 48, 58 and 88)

harvest of just over 20 million tons, the global catch rose to around 90 million tons by the late 1980s. Since that time, although aquaculture has grown significantly and so underpinned the continued rise of total fisheries production, wild capture fisheries have been in decline despite the spatial expansion of fishing effort across almost all of the world's oceans (Swartz et al. 2010; Watson et al. 2012). Considering that the world's population rose from 2.5 billion to 6 billion between 1950 and 2000, the levelling off and then decline of the global capture harvest precipitated an increasing scarcity of fish that has yet to be remedied through large-scale and sustained recovery of over-exploited stocks. Historians have long observed that fishers, faced with declining catches, tend to shift to new fishing grounds, adopt new gears, and switch to new target species (e.g. Butcher 2004). Yet from the late 1980s onwards these traditional responses were increasingly likely to result in IUU fishing. Around the world, fisheries governance began to shift by the end of the twentieth century towards the adoption of property rights through the imposition of licensing arrangements and quota restrictions, a process that has left few stocks, even high seas stocks and highly migratory species, remaining under open-access arrangements. It is within this context that 'IUU fishing', which contravenes fisheries laws and regulations and often breeches property rights over wild stocks, emerged abruptly as a major international problem in the 1990s and 2000s (Hannesson 2006).

The shift to property rights in global fisheries heralded a fundamental reversal on a question that lies at the crux of IUU fishing – who owns the fish in the sea? In the Western conception of the Law of the Sea, the 'right to fish' was traditionally open to anybody who had the wherewithal to venture out upon the ocean, a principle famously espoused by the seventeenth century Dutch jurist Hugo Grotius in his *De Mare Liberum* (*The Freedom of the Seas*, 1609). In this seminal work Grotius argued that the world's oceans had been gifted by God for the common use of mankind, for navigation as well as for fishing; the sea itself was boundless and the fish within it inexhaustible, he reasoned, and therefore could not become the property of any one person or state. Three decades later the Englishman Jon Selden responded in his *Mare Clausum* (*The Closed Sea,* 1635) by arguing for the longstanding existence of state dominion over ocean waters and the right of sovereigns to claim jurisdiction over maritime territory and the fish stocks found therein. Both principles ultimately found expression in the Law of the Sea – during the nineteenth century most Western nations claimed territorial waters to a distance usually extending three nautical miles (nm) seaward of their coastlines, a limit that was set by the maximum range that a cannon could be fired from the shore, thus marking the reach of a state's power. Beyond this narrow coastal strip the oceans remained the common property of all people, and the marine life of the high seas could be freely exploited by anyone. In English-speaking countries, this right to fish was generally implied in common law, a situation mirrored in other major European maritime nations (Rothwell and Stephens 2010).

The doctrine of Mare Liberum in relation to ocean fisheries lasted for over 300 years. In its original conception it was, as maritime historians have observed, based on a simple reality; that 'the resources of the ocean were in fact endless and that there was no chance of extinction', so that exploitation by one nation could not limit another nation's potential to do the same (Heidbrink 2008). It was also the case that relatively little deep-sea sea fishing took place due to the expense and difficulties of preserving catches and conveying it to markets, when coastal and inshore fisheries could readily supply demand for fish products. Some of the first deep-sea and distant water fisheries, such as whaling and the North Atlantic fishery for Atlantic cod (*Gadus morhua*), were also subject to some of the first multi-lateral agreements designed to conserve stocks for sustainable exploitation. The rapid expansion of global fisheries in the second half of the twentieth century finally overturned the basis upon which open-access fisheries rights were founded. Faced with the prospect of near or total collapse of fishing industries, a new Law of the Sea developed, with the United Nations Third Convention of the Law of the Sea (UNCLOS III) formalising in 1982 a series of 200 nm Exclusive Economic Zones (EEZs) for the world's coastal nations (Rothwell and Stephens 2010). By the end of the twentieth century most of the world's major fishing nations had developed treaties for the management of migratory and High Seas fish populations not covered by EEZs and remaining vulnerable to over-exploitation by distant-water industrial fleets. The world's oceans had been enclosed, creating the conditions where illegal and unregulated fishing could occur on an extensive global scale (Hannesson 2006).

Yet it would be incorrect to presume that such conceptions of the 'right to fish' were universal, a point that bears on the rise of IUU fishing in several parts of the developing world. Until the twentieth century most marine fisheries in Southeast Asian, Southwest Pacific and Northern Australian waters were governed by cultural-legal systems of inherited rights, customs and privileges known as Customary Marine Tenure (CMT). CMT can take on diverse forms, but at its core is the simple principle that access to coastal and near-shore waters and the marine resources contained therein is not open to all but rather subject to an often complex system of clan or family ownership that governs who fishes, where and when fishing takes place, and what is caught (Cordell 1989; Sharp 2002). Its basis lies in balancing the needs of a community for food with the imperative of guaranteeing sustainable exploitation to conserve resources across the long-term, and of preventing individuals from acting in ways that are harmful to the interests of the group as whole (Kurien 2002). Through the operation of CMT arrangements, many traditional fisheries were historically able to avoid the 'Tragedy of the Commons' scenario that plays out, at least in theory, in open-access fisheries, where the commonly-owned resource inevitably becomes depleted over time (Berkes 1985). However, CMT systems have proven inherently vulnerable to the impact of colonialism and the forces of globalisation, among which are included technological change, rapid population growth, urbanisation, and environmental degradation. In some cases, such as the marine fisheries of the South Pacific, important fishery resources only declined after traditional CMT arrangements were subsumed by the commercial imperatives that result from incorporation of local economies into global economic systems, leading to decline of stocks that once supported coastal communities (i.e. Malm 2001). This, in turn, can drive small-scale fishers towards illegal fishing practises as a substitute for the sustainable livelihoods once derived from fishing under CMT arrangements.

Case Studies of IUU Fishing from the Indo-Pacific

Many examples of Customary Marine Tenure come from the seas of the Indo-Pacific, one of the world's principal maritime regions. Biogeographically, the Indo-Pacific refers to the warm tropical waters that encompasses the Indian Ocean north of the Tropic of Capricorn and extends in the centre of the Pacific Ocean. These seas have the highest levels of marine diversity anywhere on Earth, with the Coral Triangle, the 'global centre of marine biodiversity' in the waters bordered by Malaysia, Indonesia, Papua New Guinea and the Solomon Islands, laying at the heart of this ecoregion (Spalding et al. 2007). Geopolitically, the Indo-Pacific comprises the maritime space that extends from East Africa and the Persian Gulf to Japan and the Southwest Pacific, encompassing the 'island continent' of Australia and the 'maritime continent' of Southeast Asia, and touching the shores of the world's two emerging superpowers, China and India (Medcalf 2010). This geopolitical region embraces some of the world's principal fishing nations, including Japan, Thailand, Indonesia, the Philippines, Vietnam, Myanmar, Malaysia, South Korea, and Taiwan (FAO 2014). Indo-Pacific nations also have some of the world's largest EEZs, including Australia (third largest in the world), and Indonesia (sixth). The region was also at the forefront of the global expansion of marine capture fisheries in the second half of the twentieth century (Christensen 2014; Butcher 2004). Between 1950 and 2000 the fishing fleets of Asia and Oceania, the two FAO statistical regions that constitute the Indo-Pacific, increased their recorded marine catches by 422 % and 1218 % respectively, against a global average of 344 % (Watson and Pauly 2013). This growth was driven by the rapid uptake of modern industrial fishing technologies and an inexorable spread in the geographic and bathymetric frontiers of fishing activity, which in the case of the Asia, produced a 25-fold increase in effective fishing power across the same 50-year period (Swartz et al. 2010). In the early twenty-first century the Indo-Pacific also highlights the emerging global division in marine capture fisheries, containing both the well-performing fisheries of Oceania as well as the comparatively poorly-performing fisheries of Asia (Williams 2007; Mora et al. 2009).

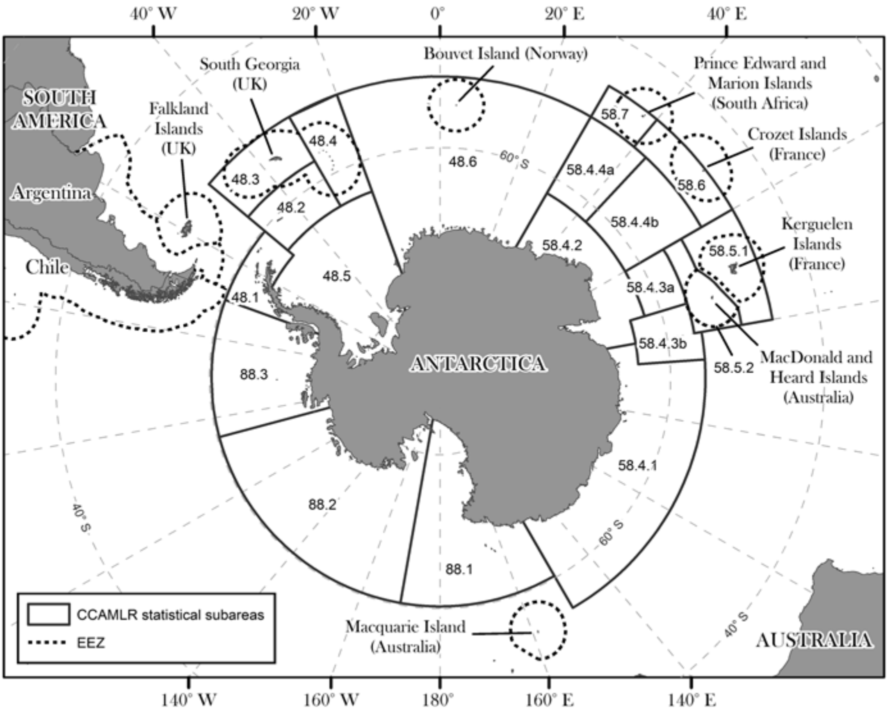
Perhaps unsurprisingly, the Indo-Pacific has also proven to be highly prone to IUU fishing. Indonesia presents an extreme example. The country has an enormous problem with illegal and unreported fishing, accounting for as much of 30 % of the world's IUU catch, and worth a staggering 100 trillion Indonesia Rupee (around US$8.5 billion) each year (Syafputri 2014). Adjoining countries such as Thailand and the Philippines also have substantial illegal and unreported fisheries, compounded as in the case of Indonesia by lax enforcement, limited scientific knowledge, and endemic corruption (Williams 2007; Nurhakim et al. 2008). At the other end of the scale there is Japan, the world's second-largest consumer of seafood after China, and a major market for IUU catches. To take one example, Japan is the destination for around three-quarters of the global catch of Atlantic Bluefin Tuna (*Thunnus thynnus*), which was illegally over-fished by an estimated 44 % in excess of international quotas between 2005 and 2011, during which time stocks became severely depleted and a major concern to fisheries management agencies and conservation organisations (Gagern et al. 2013). On the other hand, the Indo-Pacific also contains some of the world's leaders in the fight against IUU fishing such as Australia and New Zealand. The three case-studies examined below relate principally to Australia's experience with IUU fishing: the Southern Ocean fishery for Patagonian toothfish, which is important in helping to define IUU as a legal and political concept; the presence of Indonesian fishers in the Australian Fishing Zone (AFZ), which offers an insight into the complex socio-economic drivers of IUU fishing; and systematic Japanese under-reporting of Southern Bluefin Tuna catches, which exposes the strength of demand for seafood, irrespective of its mode of capture, that provides one of the main drivers of IUU fishing globally.

Patagonian Toothfish

Patagonian toothfish (*Dissostichus eleginoides*) is a cod icefish that inhabits seamounts and shelf areas off South America and the sub-Antarctic islands. A migratory species that can grow to in excess of 2 m and 100 kg, it has become the most important species of fish commercially harvested in the Southern Ocean, although exploitation of it only began on an appreciable scale in the late twentieth century. Patagonian toothfish was taken as by-catch by trawlers and longliners during the 1970s, before the first targeted toothfish fisheries developed in the mid-1980s off the Chilean coast by local vessels utilising deep-water demersal longlines, and in the vicinity of Kerguelen Island (France) by Russian and Ukrainian trawlers. Longlining expanded to the Kerguelen shelf, Crozet Island (France), Prince Edward Islands (South Africa) and Heard, McDonald and Macquarie Islands (Australia) between the early- and mid-1990s (Agnew 2000; Baird 2006; Martin et al. 2010). The popularity of Patagonian toothfish in the restaurant trade in the United States and Europe, where it is known as Chilean Sea Bass, and Japan, where it is called Mero, helped to drive this expansion. Market prices more than tripled between the early-1980s and mid-1990s, rising from less than US$5.00 per kg to US$15.00 per kg, underpinning an increase in reported landings from 5000 tons in 1983 to 40,000 tons in 1991, with catches fluctuating between 30,000 and 40,000 tons for the remainder of the decade (Bruce Knecht 2006).

This fishing took place within EEZs of parties to the CCAMLR. The Commission was established in 1982 in response to growing concerns over increasing catches of krill in the Southern Ocean, a key component of Antarctic marine ecosystems upon which other populations of marine life depended (Baird 2006). In 1985, the CCAMLR established a program to monitor harvests in the Antarctic and sub-Antarctic, providing a framework for assessing toothfish catches over subsequent years. The first catch limits were imposed in 1990. Concerns over the stock's status were first raised at the Commission's meeting in 1993 when it was reported that the biomass around South Georgia could be depleted to as much as 30 % of the unfished population. The first infringements of CCAMLR regulations were also reported at this meeting (Baird 2006). In 1995, following further observations of fishing activity outside of the designated season, the Commission reported that, in the area around South Georgia, the unreported Patagonian toothfish catch was as high if not higher than the reported catch, and that the reported catch may have represented only 40 % of the total catch over the past 4 years. A year later, further reports were received of the eastward movement of unregulated fishing towards Kerguelen Island, Prince Edward Island, and the Heard and McDonald Islands, linked to the reduction of catches in the traditional fishing grounds off South America (Map 2; Agnew 2000). The growing concern of member states over this activity led to the appearance in the Commission's 1997 report of the inaugural reference to 'IUU fishing' in international fisheries jargon, when it was reported that 'illegal, unregulated fisheries and unreported catches today exceed fishing activity by a factor several times over' (CCAMLR 1997). As many as 90 vessels were thought to be operating without authorisation at this time, when the IUU catch peaked at over 32,000 tonnes, or 72 % of the total Patagonian toothfish catch (Agnew 2000).

This rise of unregulated and illegal fishing was facilitated by the sheer size and isolation of these seas, making surveillance of EEZs and enforcement of regulations an enormous practical challenge. The Australian Government lost no time in addressing this problem. Armed fisheries patrols of the nation's sub-Antarctic EEZs



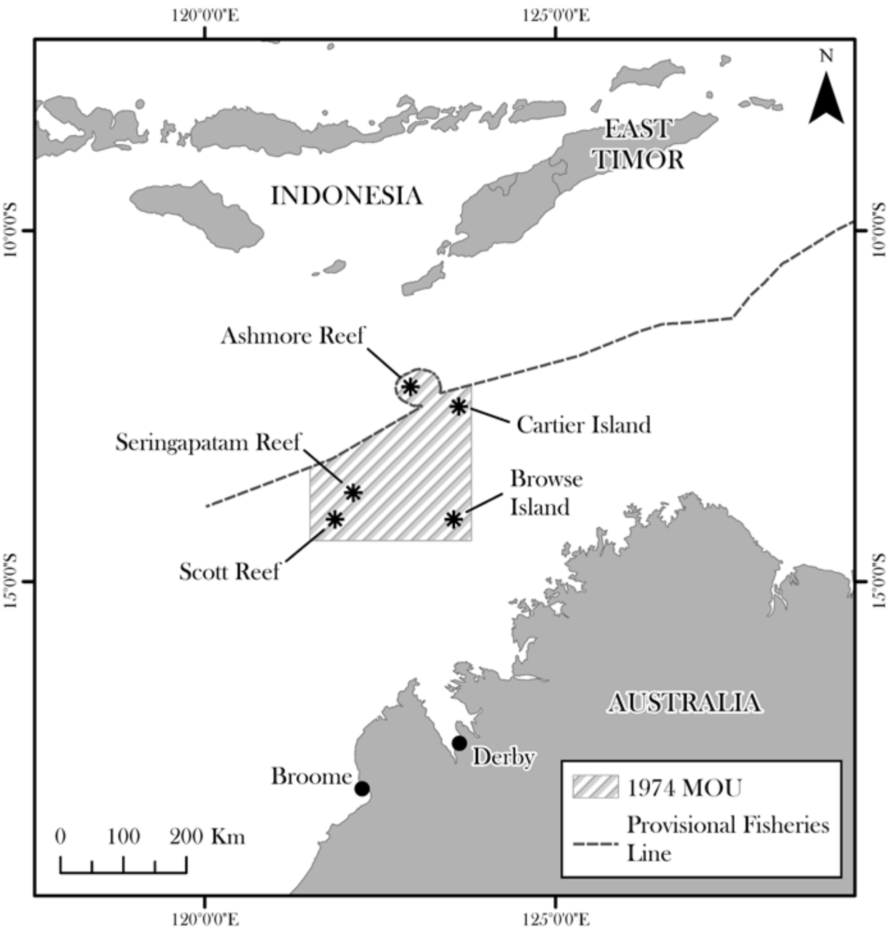
Map 2 Exclusive economic zones in the CCAMLR area (Source: Smith and Appleyard 2002; VLIZ 2014)

began in 1997 using vessels of the Royal Australian Navy and Australian Customs Service, leading quickly to a series of vessel seizures and prosecutions for IUU fishing. By 2004 a total of eight vessels had been apprehended, and many others warned off, by these patrols; one famous incident in 2003 saw the Customs vessel *Southern Supporter* engage in a 3-week, 2200 mile chase of the Uruguayan-flagged trawler *Viarsa 1*, culminating in the seizure of the trawler and the arrest of its crew (Bruce Knecht 2006). In late 2003 the Government announced a renewed commitment to full-time armed patrols as part of a comprehensive strategy to protect fisheries resources, and a new vessel, the *Oceanic Viking*, entered Customs service to monitor the distant Southern Ocean territories. It proved to be a successful approach. The last vessel to be seized by Australian authorities was a Cambodian-flagged factory ship in 2005. Since this time, it is believed that no IUU fishing has taken place in the waters off Heard and McDonald Islands. France, the United Kingdom and New Zealand also enhanced enforcement in their EEZs during the 2000s (Phillips and Larcombe 2008; Martin et al. 2010).

Yet IUU fishing has persisted across the wider CCAMLR area, despite this commitment to surveillance and the introduction of a raft of additional measures. From 2001 onwards, Vessel Monitoring Systems (VMS) were mandatory aboard all vessels licensed to fish for Patagonian Toothfish, providing a cost-effective means for monitoring the positions of vessels in the remote Southern Ocean. A requirement for all gears to be marked to prevent vessels cutting longlines and departing when approached for inspection was also introduced (Agnew 2000). Another measure, quite innovative at the time of its adoption in 2001, was the introduction of a Catch Document Scheme (CDS) for the Patagonian Toothfish fishery designed to demonstrate if toothfish have been caught in compliance with conservation measures by tracking landings and trade (Agnew 2000). In 2002, an IUU Vessel Database was also created by the CCAMLR to prevent vessels changing flags and otherwise seeking to obscure their identity to avoid restriction or prosecution for IUU fishing. Notwithstanding these measures, illegal and unreported fishing remained a significant problem for the Patagonian toothfish fishery. CCAMLR estimates showed the IUU totalling 19,215 tonnes between 2003 and 2007, but analysis of market data indicated an IUU catch of 26,465 tonnes, figures that suggest the Commission may have seriously under-estimating the extent of illegal catches, which would in turn have a significant bearing on long-term stock management models (Lack 2008).

Indonesian Fishing in the Australian Fishing Zone

The Arafura and Timor Seas separate Northern Australia from the Malay Archipelago and are today divided between the territorial waters of Australia and Indonesia. These waters also have a rich history of marine resource exploitation that can be traced back to a period that predates the British annexation of the Australian continent and the subsequent opening of the continent's northern coast to European settlement in the nineteenth century. The Bajo or Bajau Laut people and other 'sea nomads' of eastern Indonesia made regular visits to the Australian coast and its adjoining reefs and islands (see Map 3) from the early 1700s to gather trepang, or bêche-de-mer, an edible sea cucumber of the class holothurian, which was traded through Makassar to supply Chinese demand for this product as a culinary delicacy and pharmacopeia (McKnight 1978; Schwerdtner Mánez and Ferse 2010). This voyaging continued after the British laid claim to Australia in 1788, before the 'Makassan' fishers were evicted from the northern coast through the imposition of custom duties and a licensing system by Australian authorities in the early 1900s. Less frequent visits continued, however, to the offshore islands and reefs during the twentieth century. Here, Indonesian fishers took not only trepang, but also trochus shell, turtle, and shark fins from their traditional *praus*, a type of sail-powered vessel common in the Malay Archipelago. The scale of such voyaging is unknown, as contact with Australian authorities was sporadic, and indeed, after the decline of the commercial pearl-shell industry in the mid-twentieth century these waters were



Map 3 Australia-Indonesia Provisional Fisheries Surveillance and Enforcement Agreement line and 1974 Memorandum of Understanding (MOU) 'box', Timor Sea (Source: Geoscience Australia)

largely unutilised by Australian-based fishers and rarely visited by Australian mariners (Campbell and Wilson 1993; Powell 2010).

Marine resource use in these waters began to change following the official division of the Arafura and Timor Seas, which heralded a new phase of regulation and enforcement in what became part of the AFZ. The creation of maritime borders between Australia and Indonesia took place within the wider context of the enclosure of the world's oceans. In 1957, a year before the first 'Cod War' provoked by the Iceland's declaration of a 12-mile exclusive fishing zone in the North Atlantic, Indonesia declared itself to be an archipelagic state and laid claim to all waters within 12 nautical miles of a baseline drawn around the archipelago; Australia, which had unilaterally laid claim to all living natural resources of its vast continental shelf in 1952, 12 years before such claims were legitimised by the first United Nations Convention of the Law of the Sea (UNCLOS I), also laid claim to a 12-mile zone in 1968. During 1979 both nations extended their claim to 200 nautical miles, with the overlapping claims in the Timor and Arafura Seas set by a median line between Australia and Indonesia. These claims were formalised by UNCLOS III in 1982 (Campbell and Wilson 1993). A year earlier, the two nations had reached a fisheries surveillance and enforcement arrangement, agreeing to refrain from monitoring and enforcement action against boats licensed by the other outside of their respective EEZs. There was, however, an important exception made by the Australian Government. Following the 1968 claim to a 12-mile zone Australian fisheries authorities permitted Indonesian fishers access to the remote islands and reefs off the North-West coast, provided the purpose of the visits was 'subsistence fishing'. In 1974 a formal Memorandum of Understanding (MOU) was agreed to by the two nations, whereby Indonesian fishers were granted access rights to certain reefs and islets in the Timor Sea for 'traditional' fishing, defined as 'fishermen using traditional methods and traditional vessels consistent with the tradition over decades of time, which does not include fishing methods or vessels utilising motors or engines' (Stacey 2007; Fox 1998). The principle was to allow small-scale artisanal fishing to continue, but prevent commercial fishers crossing from Indonesia to fish in Australian waters, so as to conserve marine resources inside the MOU 'box' area (Map 3).

The signing of this agreement signalled the start of a new program of surveillance by Australian authorities. Much of this effort was directed at monitoring activities inside the MOU box. Three main types of small-scale fishing were taking place at this time in the waters between Indonesia and Australia: the trepang fishery; a shark fin fishery, supplying fins for the lucrative Chinese market; and for trochus shell (sea snails of the genus *Trochus*), prized for its nacre or mother-of-pearl (Campbell and Wilson 1993; Stacey 2007). It was not long before Indonesian fishers were being prosecuted for illegal fishing in the AFZ. A total of 74 violations of the MOU were reported in 1975, the first year that the agreement operated; for the period 1988–2001, for which more reliable figures are available, a total of 107 apprehensions occurred within the MOU box, while an additional 48 vessels were apprehended outside of the designated MOU waters between 1988 and 1999, half of which were targeting shark (Fox and Sen 2002). Most of the vessels apprehended inside MOU waters failed to meet the definition of 'traditional fishing' due to the gear types being used or because the vessels were equipped with engines or radios in contravention of the 1974 agreement. Other vessels, particularly those engaged in the shark fin trade, represented more opportunistic ventures to prey on the relative abundance of stocks in Australian waters. Apprehended boats, including vessels not classified as 'traditional', were seized and, taken back to the Australian mainland, burned in order to destroy the vessel and provide a public form of deterrence to other fishers. Prosecuted fishers were often sentenced to serve time in Australian prisons, before being repatriated to Indonesia. Australian authorities also embarked on education campaigns about fisheries regulations in parts of eastern Indonesia (Fox 1998; Stacey 2007).

Yet such measures did not halt the activities of Indonesian fishers in Australian waters. Against this backdrop of persistent infringements against Australian fisheries law, and confronted by the realities of custodial sentences for impoverished small-scale fishers and the policy of burning boats, which destroyed the livelihoods of entire families and threatened to exacerbate cycles of debt and law-breaking, historians and anthropologists have worked to provide context to the presence of Indonesian fishers off Australia's northern coast. Their work has pointed to the problems surrounding the definition of 'traditional fishing' and the juxtaposition between traditional and commercial fisheries, arguing that such conceptions ignore the longstanding commercial nature of trepang fisheries and incorrectly present groups such as the Bajo as static and unchanging pre-modern societies (Stacey 2007; Fox et al. 2009). It has also highlights the tendency for Australian authorities to group together fishers such as the Bajo, which have longstanding ties to the Timor and Arafura Seas, with other Indonesian fishers whose presence off the Australian coast is a more opportunistic and recent phenomenon. Another issue brought to the fore is the difficulty created by obliging fishers to avoid equipping vessels with radios or other navigational equipment, which can make fixing the position of maritime boundaries difficult, and the potential dangers that result from prohibiting engines aboard vessels that frequent seas that are remote from settled coasts, lack fresh water, and are prone to tropical storms and cyclones (Campbell and Wilson 1993). These studies also highlight the fact that, due to the severe depletion of marine resources in Indonesian waters, the risk of fishing illegally in the comparatively richer waters of Australia hold strong appeal both to small-scale fishers who lack alternative livelihoods as well as to larger commercial syndicates attracted by the potential profits of the shark fin trade. For all these reasons, Indonesian fishing in the AFZ remains an intractable, ongoing example of IUU fishing.

Southern Bluefin Tuna

Southern Bluefin Tuna (*Thunnus maccoyii*) is a long-lived, migratory species found in the southern Atlantic, Indian and western Pacific Oceans. A close relative of the Atlantic Bluefin Tuna, it is one of the most prized of all the tuna and tuna-like species, with single fish occasionally fetching more than US$100,000 on the Japanese sashimi market (Ellis 2008). Commercial exploitation of the species is believed to have commenced only in the late 1940s. The fishery initially developed along diverse lines, comprising of Australian and New Zealand pole-and-line and purse seine fisheries in coastal waters, and Japanese longlining, initially in the waters south of Java and off the Western Australian coast before spreading in the 1960s and 1970s across a wide swathe of the Southern Indian, Southern, South Pacific and South Atlantic Oceans, aided by the development of ultra-low-temperature (ULT) freezing and strong state support for the distant-water fleet. Korea and Taiwan also targeted Bluefin tuna through distant-water longlining in the 1970s, 1980s and 1990s (Caton 1994). The harvest peaked at around 80,000 tonnes in the early 1960s, and although catches were maintained for some time by the geographical expansion of effort, it began to decline during the 1970s. Stocks collapsed off the Southeast Australian coast in the late 1970s, and after studies pointed to excessive harvest rates, Australia moved in 1984 to drastically cut the size of its tuna catch through the imposition of quota restrictions. New Zealand and Japan also cut their catches shortly after, when the three nations agreed to the introduction of a Total Allowable Catch (TAC) for the fishery (Polacheck 2012; Adams 2014). But the species continued to be over-fished. In 2011 Southern Bluefin Tuna was added to the International Union for the Conservation of Nature's (IUCN) Red List of Threatened Species, when the population was assessed to have dwindled to 85 % of its virgin biomass, with no prospects of a recovery in sight (Collette et al. 2011).

This severe decline, which in hindsight was clearly exacerbated by IUU fishing, occurred in spite of international efforts to manage the stock sustainably. Although declining catch rates were first observed in the 1970s, the Australian action to cut its national catch in 1984 marked the beginning of this effort. Japan, after initially refusing to accept the quotas suggested by Australia and New Zealand, agreed to a TAC after its vessels were banned from Australia's EEZ in 1985. By 1989, when the TAC was cut by 50 %, Japan reported for the first time that its longline fleet had reached the new catch limit. These arrangements were formalised in 1993 through the establishment of the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) to formally manage Southern Bluefin Tuna stocks amongst these three principal fishing nations. Following a sharp spike in catches by other nations, the CCSBT was expanded through the inclusion of Korea (2001), Taiwan (2002), and Indonesia (2008), with catch shares allocated to each of these countries. The catch limits for Australia, New Zealand and Japan remained largely unchanged between 1989 and 2007 (Polacheck 2012). However, despite being set by the CCSBT at a level designed for 'the conservation and optimal utilisation' of Southern Bluefin Tuna, scientific opinion tendered to the Commission by Australian and New Zealand experts during the 1990s suggested that stocks were not meeting recovery targets. Japanese scientists, on the other hand, tended to adopt a more optimistic position on the stock's capacity to withstand fishing pressure and rebuild to a larger population size. Indeed, contrary scientific assessments were a feature of CCSBT meetings during this period, with the more cautious positions tendered by Australia and New Zealand being ultimately borne out by the revelations of systematic under-reporting revealed during the mid-2000s (Adams 2014).

Concerns about potential unreported catches of Southern Bluefin Tuna had in fact first been raised in the early 1990s, shortly after the catch limits agreed to by Japan began to actually restrict its fleet's catch, due to the incentive quotas create for under-reporting, high-grading, misreporting species and discarding of catches. In the late 1990s, Australian observers detected an apparent anomaly in Japanese market statistics, which indicated that the amount of Southern Bluefin Tuna being sold was substantially more than the total national catch allocations under the CCSBT (Polacheck 2012). A preliminary analysis in 2000 indicated that Japan's market sales of Southern Bluefin Tuna may actually have been double the nation's quota, but the concerns this created were not pursued in a formal setting due to uncertainty around the reliability of market data and challenges of interpretation. But the concerns persisted, and in 2005, the Australian Government commissioned a new, independent analysis of the market data. Following its finding that the amount of Southern Bluefin Tuna sold in Japan was substantially higher than could be accounted for in official catch statistics, a second major investigation was jointly commissioned by Australia and Japan in 2006 (Polacheck 2012). This resulted in the report *Independent Review of Japanese Southern Bluefin Market Data Anomalies*, which despite never being released in full due to commercial and diplomatic sensitivities, was nonetheless discussed at CCSBT meetings and its findings leaked to journalists; the report revealed that some 178,000 tonnes of Southern Bluefin Tuna had been taken by Japan in excess of its quota over the period 1985–2005, of which 138,000 tonnes was taken following the establishment of the CCSBT, an illegal and unreported catch worth an estimated US$8 billion, and which had been a major contributing factor to the depletion of the stock to a critical level (Darby 2007; also Polacheck 2012; Polacheck and Davies 2008). At their meeting for 2006 the CCSBT agreed, with Japanese consent, to reduce Japan's annual quota by 50 % for the period 2007–2011 (Polacheck 2012).

Conclusion: IUU Fishing in Historical Perspective

The diverse case-studies examined above point to a set of common themes which can assist with the study of IUU from an historical perspective. Viewed in the context of the long-term relationship between human societies and the marine environment, IUU fishing emerges as a contemporary problem with fundamentally modern causes – arising at the end of the twentieth century as an outcome of the rapid expansion of capture fisheries, increasing scarcity of wild fish stocks, and the fundamental change to the 'right to fish' linked to the enclosure of the oceans. Moreover, its underlying causes are associated with globalisation in the modern era, involving population growth, the integration of economic systems and the increase of world trade, the rise of Asian economies, environmental degradation, and arguably, the growing disparity between rich and poor around the world. In this sense, IUU fishing can be considered as one of the many problems that have arisen in global marine environments during the twentieth century, which include habitat destruction, pollution, the loss of biodiversity, and climate change (Roberts 2012). The three case-studies also demonstrate that, whilst it may be the case that 'IUU fishing' applies to activities for which a deficit of reliable knowledge exists, there is a direct link between surveillance and monitoring of fisheries and the documented existence of illegal fishing practises. This, in turn, highlights an important observation that historians have made about state claims over ocean space and marine resources, namely, that an 'Exclusive Economic Zone and related fisheries management will only be as good as the mechanisms to ban illegal fishing inside the zone' (Heidbrink

2008). The need to enforce territorial claims and associated laws are in fact long-standing challenges, underpinning the concept of a 3-mile territorial sea, which, measured by the range of a cannon shot, extended only so far as a state was able to project its power from shore. Labelling IUU fishing as ‘Fish Piracy’ (i.e. OECD 2004, 2005) is perhaps appropriate, casting as it does a contemporary problem within the traditions of piracy, poaching and smuggling that rank amongst the oldest forms of maritime activity.

As well as historical perspective, the historian can also contribute a valuable methodology to the study of IUU fishing. In the first instance, the historians’ approach to the interpretation of evidence is an essential tool for understanding what has taken place in the world’s oceans, as has been demonstrated by the History of Marine Animal Populations (HMAP) initiative (Holm et al. 2010). IUU fishing provides a stark example of the difference between data and sources in relation to the evidence produced by fishers. What a scientist will utilise as hard data to model harvest levels and population abundance will, to the historian, present a challenge of veracity and verification; something very much akin to historical source-criticism helped to identify the ‘market anomalies’ and in turn expose systematic Japanese under-reporting of Southern Bluefin Tuna catches, and indeed, of other high-value tuna species as well (Ellis 2008). A second example comes from the historical imperative of explaining the human factors that ultimately influence patterns of marine resource exploitation (Holm et al. 2010). IUU fishing demonstrates the influence that economic, social, cultural, political and legal factors can have on the location, intensity and target-species of fishing activity, and it exemplifies, as in the case of Indonesian fishing in the AFZ, that there is often a complex interaction of these factors driving fishing activity in specific temporal and spatial contexts. The historian is trained to critically evaluate such factors, finding causes and patterns that can be observed unfolding across time but which may not always be readily apparent to observers unfamiliar with the concepts and approaches of the historical discipline.

Finally, studies of IUU fishing are valuable in building a truly global picture of historical change in the marine environment. Here as well, the case studies explored in this chapter allude to the importance of comparative studies of marine tenure systems and historic conceptions of the ‘right to fish’, of the importance of considering market-based evidence from some of the world’s largest consumers of fish, and of drawing attention to the global spread of modern fishing technologies and the consequent expansion of industrial fishing effort to the most remote seas. A truly global picture of the transformation that has taken place in human exploitation of marine living resources during modern times must by necessity embrace all fishing industries, from artisanal to industrial, reach even into the most remote of the Earth’s seas, and cover all kinds of fishing activity, legal and reported or otherwise. The marine environmental historian confronts the constant challenge of pushing out the boundaries of knowledge, recovering insights from past human-environment interactions that remain, for the most part, beyond the realms of what is ‘knowable’ (Holm et al. 2010). IUU fishing will always be one of the more ‘unknowable’ types of fishing activity. Yet sufficient potential for such studies exist, and the rewards are too great to allow this opportunity to be neglected. The geographical and socio-economic dimensions of IUU fishing help to focus attention on comparatively poorly-studied fishing industries of Africa and Asia or the more remote waters of the Indian, Pacific and Southern Oceans, all of which tend to have been neglected during the rapid development of marine environmental history over the past decade and a half (Christensen 2014; Holm 2014). The potential insights that can be gained from investigating IUU fisheries can contribute to broader understandings of the transformation of marine capture fisheries in the second half of the twentieth century, to the larger goal of the socially-just division of property rights amongst all users of marine resources, and to wider understandings of the past impact of human harvesting activity and the setting of historically-accurate recovery targets for heavily exploited species and ecosystems. To all these objectives, the historian has a vital contribution to offer.

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Oral Histories: Informing Natural Resource Management Using Perceptions of the Past

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Introduction

It is now known that many marine ecosystems have been degraded as a result of anthropogenic impacts (Halpern et al. 2008), often to a much greater extent and for longer periods of time than we were previously aware (Jackson et al. 2001; Pandolfi et al. 2003). The collapse of fisheries such as western Atlantic cod, once an abundant and seemingly endless resource, have made it clear that there is much we still have to learn about the marine environment, its communities and our management of them (Walters and Maguire 1996). For example, even when we have extensive data on catch and effort for a fishery we often know little about the social, cultural and technological factors that have influenced changes over time. Yet the species we target, where we choose to fish and the effectiveness of the gear we use may all contribute to the degradation of a fishery or the environment it depends upon. Unfortunately, many fisheries throughout the world do not have records of catch and effort and even fewer records exist for non-targeted species or benthic communities, hence we must turn to other methods outside the realm of traditional resource management to build accurate pictures of change. Increasingly, researchers from multiple disciplines have begun to make use of local and traditional knowledge to acquire information on past and contemporary marine and coastal environments. Such knowledge can inform us about past events or experiences from the perspective of an individual or a group of people. Oral history is a commonly used method of gathering and recording these accounts of the past (Leavy 2011) and can provide

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novel data or perspectives to help us unravel changes that have occurred in the marine environment over time.

The scientific literature on the use of oral histories has grown rapidly over the past three decades (Johannes and Neis 2007), as oral histories have become an increasingly valued method to reconstruct past change and awareness of the need to incorporate the human dimension into natural resource management has grown (Mascia et al. 2003). In locations where scientific data on species abundance trends are limited or do not exist, oral histories may be the only way to source data on past species abundance or historical changes to marine communities (Sàenz-Arroyo et al. 2005). Where community or fisheries data do exist, oral history research has been shown to improve our understanding of past change by providing more fine-scale spatial resolution, sometimes over longer periods than most contemporary ecological survey assessments. For example, oral histories have provided detailed information on fisher recollections of catch and effort (Daw et al. 2011), trends in abundance of both target and non-target species (Lozano-Montes et al. 2008; Maynou et al. 2011), the influence of technology (Neis et al. 1999a) and patterns in the spatial distribution of fishing effort and fish stocks (Ames 2004). Oral histories provide a uniquely human perspective of change and, in addition to enhancing knowledge of past ecological change, lend themselves to unravelling the nature and history of broader social-ecological marine systems. For example, oral history data can help us to understand how coastal communities adapt to social changes such as improved market opportunities in terms of resource use patterns, or provide clues as to how a community might respond to different management decisions (Shackeroff et al. 2011).

One of the earliest contributions to oral history from a marine scientist was by Bob Johannes in 'Words of the Lagoon' (Johannes 1981), which described his efforts to record and test the knowledge of native fishers in the Palau Islands of Micronesia. By living with and interviewing them he was able to document and describe their knowledge of fishing and patterns in fish behaviour; knowledge that was gradually being lost as older generations of fishers passed away. A more quantitative approach was first provided by the work of Sàenz-Arroyo et al. (2005), which was one of the first marine studies to use oral histories to empirically test for the presence of shifting environmental baselines within a fishing community, a phenomenon where long-term environmental change goes unrecognised because of intergenerational changes in what is perceived as natural (Pauly 1995).

This chapter will discuss the importance of oral histories as a tool for helping us to understand past changes in the marine environment. In doing so, we will provide examples of oral history research from the nineteenth century to the present, using examples from the United Kingdom, the Gulf of Maine, the Gulf of California and the Arctic. Specifically, we will focus on the motivations for carrying out such oral history research, what additional knowledge oral histories provided to scientific knowledge, and why such data are important for contemporary natural resource management and the conservation of marine ecosystems.

What Is Oral History?

Oral history describes a recorded dialogue between an interviewer and interviewee (Ritchie 2003). These dialogues may differ depending upon the context of the interview and the objectives of the researcher, from informal conversations with a group of people about the past to more formal and structured interviews about a individual's recollection or perception of a particular past event. Whilst oral history has a long tradition dating back thousands of years, oral history research as we know it today is generally considered to have begun in the 1940s, when a systematic effort to record and preserve peoples' recollections was initiated with the founding of the Columbia Oral History Research Office (Ritchie 2003). Whilst oral history is multidisciplinary and can take on many forms, it is defined by its "*…availability for general research, reinterpretation, and verification*" (Ritchie 2003). That is, oral history is an interview that is then preserved as a record in some form for future generations. The timescale covered by oral history depends on each individual's age and length of recollection, as well as the events of interest in the study. Frequently, oral history will cover timescales of years to several decades, but on occasions where knowledge has been passed down through different generations that timescale can be much enlarged, although additional care must be taken in interpreting information that has not been personally experienced by the interviewee.

Oral history interviews are frequently used to collate various types of ecological knowledge. These include (but are not limited to): traditional ecological knowledge, which is defined as "*a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings* […] *with their environment*" (Berkes 1993); local ecological knowledge, which is "*knowledge held by a specific group of people about their local ecosystems* […], *a mix of scientific and practical knowledge, it is site-specific and often involves a belief component*" (Olsson and Folke 2001); and indigenous ecological knowledge, which is "*the articulation, and frequently the dialectic, of traditional and non-traditional knowledge*" (Stevenson 1996). Another type of knowledge particularly relevant for this chapter is fisher knowledge, which is described as "*local knowledge concerning interannual, seasonal, lunar, diet and food-related variations in the behaviour and movements of marine fishes and mammals*" (Johannes et al. 2000). Fisher knowledge can also provide information on catch rates, effort and fishing efficiency.

Uses of Oral Histories, Past and Present

In natural resource management, the importance attached to the contribution of local or traditional knowledge to scientific understanding has ebbed and flowed through time. For example, when the field of fisheries science was being developed during the nineteenth century, scientists often used fishers' knowledge to supplement their understanding of fish biology, distribution and movements (Bigelow and Schroeder 1925). However, throughout the twentieth century fisher knowledge appears to have taken second place to the development of predictive models using ecological surveys. In recent decades however, work by researchers such as Bob Johannes (1981) has re-emphasised the importance of fisher knowledge and its potential application to management. In addition, the recognition that marine resources cannot be successfully managed without a more holistic approach that aims to sustain both the target species and the wider ecosystem elements they rely upon has become a much greater focus in fisheries management (Pikitch et al. 2004). As such, the use of fisher knowledge is increasingly being perceived as a critical source of information capable of aiding scientific understanding of the complexities of marine systems and the species therein (Johannes et al. 2000).

We now turn to a series of case studies that demonstrate the ability of oral history techniques to gather and interpret knowledge on perceptions of change to species abundance over time, understanding of species distribution and observations of environmental change.

Data Gathering in the Absence of Quantitative Data

Oral histories can help us make sense of past changes in the marine environment for periods of time when scientific data are absent, or for locations where scientific data have never been collected. Whilst the use of oral history techniques by scientists has increased during the past few decades (e.g. Johannes et al. 2000; Azzurro et al. 2011), the practise of using oral histories to help understand changes within the marine environment has taken place over much longer periods of time. Indeed, when data on environmental change are not available or are sporadic, one of the only methods of sourcing information on changes is from the testimony of people who have witnessed such change.

Some of the earliest uses of oral histories in fisheries science come from nineteenth century Royal Commissions of Enquiry, which were conducted periodically in the days before fisheries statistics to provide information on the fishing industry. Analysing these enquiries thus utilises a mix of methods, namely oral history (recorded in the past) and secondary sources (the documents that house the transcripts of these oral histories). Whilst such large-scale enquiries took place in a number of countries, for example, the United States, Canada, the United Kingdom, Australia and New Zealand, we focus upon an example from the UK, the 1866 Royal Commission of Enquiry. This particular Royal Commission is notable for its recommendation that fishing should be conducted without restriction, a conclusion that was ultimately flawed (Roberts 2007). Despite this erroneous recommendation, the scale and detail recorded in the Minutes of Evidence provide us with a wealth of information on UK fisheries for an era that would otherwise be lost.

Prior to the mid nineteenth century, fish was a localised and often expensive commodity due to its perishable nature (Robinson 1996). However, improved

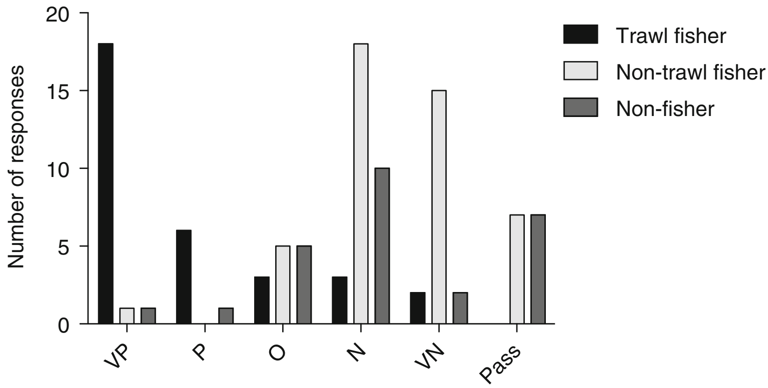

Fig. 1 Perception of trawling from witnesses interviewed during the 1866 Royal Commission of Enquiry (n = 104). Reponses were classified according to the Likert Scale: *VP* very positive, *P* positive, *O* neutral, *N* negative, *VN* very negative, Pass = trawling not mentioned (Adapted from Thurstan et al. (2013))

transport networks led to an opening of inland markets for fish (Robinson and Starkey 1996). Bottom trawling, a method of fishing where a net is towed along the surface of the seabed, found a ready market in supplying fish to inner towns and cities and trawling spread quickly throughout the UK. However, the rapid rise of trawling meant that other classes of fishers found their traditional fishing grounds encroached upon, their gear lost and markets flooded with fish. Furthermore, such an indiscriminate method of fishing had rarely been seen before and fishers became concerned for the future of their fish stocks. In 1863 a Royal Commission of Enquiry was commenced to enquire into the state of sea fisheries around the UK and to determine whether any methods of catching fish were particularly destructive to fish or their spawn (Report of the Commissioners 1866). Interviewees were asked questions about the changes in fish abundance they had witnessed throughout their careers and their perceptions of bottom trawling, as well as changes to the gear they used and the areas they fished. Overall, the enquiry provided testimony from over 700 fishers and individuals connected to the fishing industry. These oral histories were recorded word-for-word and at the time provided contemporary and past data on trends in fish abundance and the activities of the fishing industry.

In areas where the bottom trawl had recently been introduced, witness testimonies show a deep divide between fishers regarding their perceptions of trawling (Fig. 1; Thurstan et al. 2013). Non-trawlers were often vehemently opposed to trawling as they regarded it as taking away their livelihoods, destroying the spawn of fish and destroying the habitat that fish depended upon (Table 1). In contrast, trawlers and some other interviewees saw the trawl as providing a cheap source of protein to a rapidly growing population and as a source of fish species unable to be caught by lines, nets or pots (Table 1). The majority of non-trawlers who provided descriptions of change described their fisheries as declining, yet this perception was negated by the rapid rise in the quantity of fish landed by trawlers. Whilst such

Table 1 Reasons provided for and in support of bottom trawling by nineteenth century fishers

Reasons provided against trawling	Reasons provided in support of trawling
Destruction of fish spawn	Food provision to meet increasing demand
Destruction of juvenile fish	Increased productivity of fishing grounds
Destruction or waste of marketable fish	Cleaning the ground of predators
Destruction of habitat	Increased extent of fishable ground
Increased competition for fishing grounds between trawlers and other fishers	Availability of fish species not caught by other fishing gear
Increased competition for markets	A source of trained sailors
Loss or damage to static gear	

Sourced from the Royal Commission of Enquiry (1866)

conflicting testimonies presented a confusing picture for the Commissioners in 1866, today, these descriptions provide a window to an era prior to quantitative data collection. Most significantly, they provide us with information on the scale and rate of the changes that were taking place 150 years ago and the extent of alterations to habitats many years before ecological monitoring began. These past testimonies provide baselines for contemporary management in terms of how our marine environment looked and the productivity of our inshore waters prior to intensive trawling activities.

Providing Additional Information for Resource Management

Managing populations for future sustainability can be challenging when the processes structuring species abundance and distributions are unknown. For example, many marine species are formed of multiple subpopulations that may be spatially separated but mix to a limited degree, for example, during spawning periods or through the distribution of eggs and larvae by ocean currents. When subpopulations occur it is difficult to know the degree of interconnectedness between the different components of the population, but conservation of the different components is usually essential to maintain resilience for the species as a whole (Young 1999). This problem is of specific concern in fisheries, where subpopulation components may be gradually eroded through exploitation, thus reducing the ability of the remaining population components to remain resilient in the face of environmental perturbation or intensification of fishing effort.

The Gulf of Maine cod (*Gadus morhua*) fishery is an economically and historically significant fishery that has been commercially exploited for hundreds of years (Leavenworth 2008). Stock assessments indicate that the spawning stock has been in decline since the 1960s, with declines accelerating during the 1980s and the stock remaining at low biomass since then (Mayo et al. 2009). Historical studies also provide evidence that present Gulf of Maine cod stocks are dramatically depleted in comparison to early abundance estimates (Alexander et al. 2009), yet little is known about the historical distribution of subpopulations and spawning components. Ames (1997, 2004; Ames et al. 2000) investigated the historical distribution of Gulf of Maine cod spawning components and subpopulations using records of interviews conducted during the 1920s and supplementing these with contemporary interviews with retired Gulf of Maine fishers (Ames 1997). These were then compared to scientific knowledge of contemporary Gulf of Maine cod distributions. Retired fishers were able to provide information on the location of historical coastal spawning grounds, which were then verified either by comparing them to scientific surveys or by comparing two or more individual fishers' knowledge.

Ames (1997) discovered that whilst many historical spawning grounds were still active, others were abandoned and spawning components lost. Many of the abandoned grounds were part of the coastal fishery closer to shore, and hence would have been targeted earlier and more intensively by fishers. Documenting the gradual decline and subsequent extinction of inshore spawning areas would have been impossible without input from oral history research, as these spawning areas were not known from scientific survey methods because their subpopulations of cod became extinct prior to the commencement of monitoring. Furthermore, the fine-scale spatial descriptions provided by oral history interviews suggested that Gulf of Maine cod, presently managed as a single, homogenous stock, were actually composed of multiple subpopulations that had distinct spawning sites (Ames 2000). The loss of these grounds demonstrates spatial contractions in the fishery, with historical grounds not yet repopulated.

This example shows that whilst traditional approaches to natural resource management (i.e. stock assessment) cannot always account for population dynamics that work and respond at multiple temporal and spatial scales (Ames 2000), oral history interviews with retired fishers provided important insights into the early processes and the dynamics of a socio-economic system that led to overfishing (Ames 2000). In conjunction with contemporary studies into cod movement and genetic relatedness, these data have led to a greater research effort into the structure of Gulf of Maine cod stocks, which will be incorporated into future quantitative models (Gulf of Maine Research Institute 2012).

The potential for oral histories to provide information for natural resource management has also been demonstrated for mammals e.g. polar bears (Lemelin et al. 2010) and dugongs (Johannes and MacFarlane 1991), birds e.g. ivory gulls (Mallory et al. 2003) and reptiles e.g. sea turtles (Bird et al. 2003). Huntington (2000) interviewed indigenous hunters of Beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska, about their knowledge of beluga distribution, abundance, migration, calving and nursery grounds. Huntington found that whilst the spatial scope of knowledge was more limited than the aerial surveys used to track belugas, hunters' knowledge provided considerably greater detail than could be gained from scientific data, for example, beluga feeding behaviour. Furthermore, the information provided by the hunters considerably extended the temporal scope of scientific knowledge (Huntington 2000).

Using Oral Histories to Uncover Shifting Environmental Baselines

The term 'shifting environmental baselines' (Pauly 1995) describes the phenomenon where long-term environmental change goes unrecognised because of intergenerational changes in what is perceived as natural. Without an appreciation of the past our perception of what is natural is wired to our early experiences of an area (Fig. 2). As much of the environmental degradation we observe extends across multiple generations the true extent of change usually fails to be appreciated *within generations*, with the result that tales of abundance by older generations may seem fantastical in comparison to contemporary experiences. The lack of a natural ecological baseline is an impediment for resource management when attempting to set restoration or conservation targets. This effect is particularly felt in marine systems where long-term sampling of species or communities is often patchy or non-existent. Our lack of knowledge of the magnitude of changes that have occurred in the past leaves us with little idea how much our marine environment has degraded (Lozano-Montes et al. 2008) and a reduced capacity to develop accurate stock assessment models (Rosenberg et al. 2005).

The first study that quantitatively tested for shifting environmental baselines in the marine environment was a study conducted in the Gulf of California (Sàenz-Arroyo et al. 2005). Sàenz-Arroyo interviewed three different generations of fishers about their memories of past fishing. All were asked how many species they perceived as depleted, their best ever day's catch of Gulf Grouper (*Mycteroperca jordani*), currently listed as Endangered on the IUCN Red List (Craig et al. 2008), and the largest Gulf Grouper they had ever landed. Sàenz-Arroyo found that when asked about how many Gulf grouper (*Mycteroperca jordani*) they had caught on their best ever fishing day, old fishers stated that they caught up to 25 times as many in comparison to young fishers (Fig. 3a), whilst the largest Gulf grouper ever caught also declined through the three generations (Fig. 3b). Disturbingly, many younger fishers were already unaware or dismissive of the changes that were recalled by the older generation of fishers, showing that this community's environmental baselines had shifted even whilst older generations and their memories were still alive.

Since Sàenz-Arroyo's work, examples utilising oral histories from different parts of the world have also provided evidence of shifting environmental baselines (e.g. Bunce et al. 2008; Lozano-Montes et al. 2008; Turvey et al. 2010), showing that this phenomenon is widespread and applies from single species to marine communities. For natural resource management, the identification of shifting environmental baselines is of utmost importance to both identify baselines for restoration, and to try and slow the process of such temporal myopia by documenting memories of past abundance. However, such a phenomenon may already be obscured in areas where the greatest changes occurred prior to living memory or where environmental variables also have a strong influence on community composition (e.g. Dayton et al. 1998). In such cases, studies across multiple generations may fail to find significant

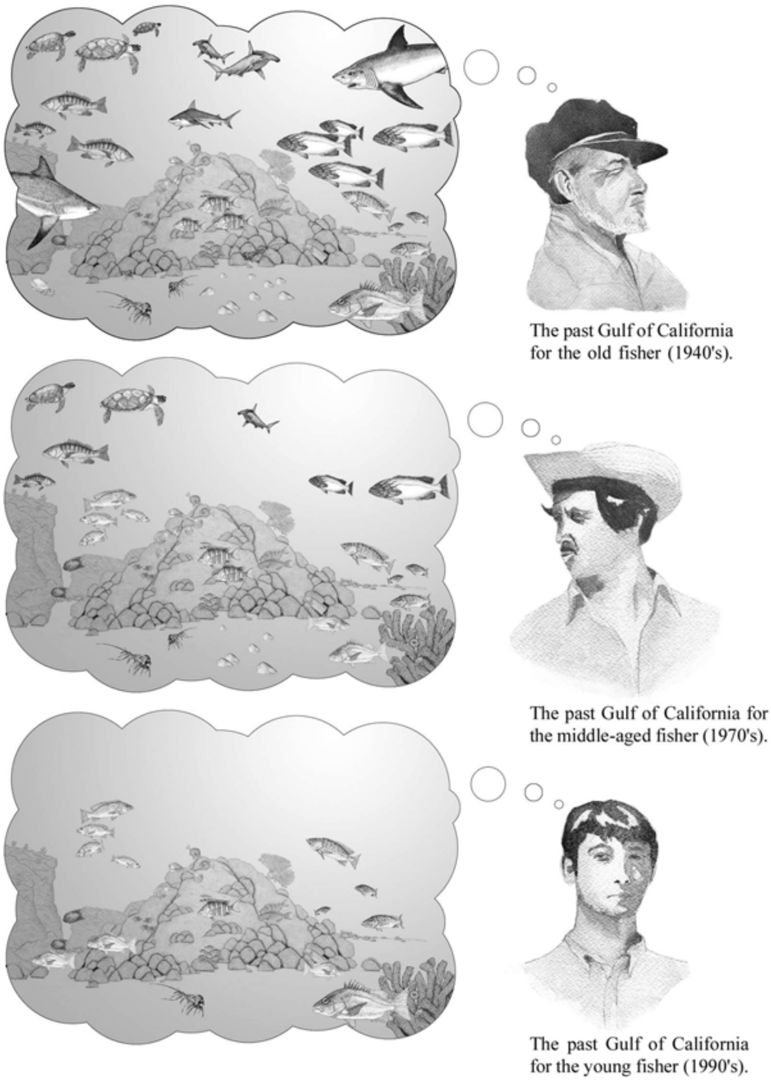

Fig. 2 Shifting baselines in the Gulf of California (Image by Anne Randall, Pier Thiret and Juan Jesus Lucero, reproduced with permission of Comunidad y Biodiversidad, A.C)

differences and the extent of environmental change can be underestimated as a result. The only way we can minimize the obscuring of shifting baselines is to increase our research efforts. Oral histories have already been shown to be a vital tool to document such changes and will continue to provide insights into past marine systems that cannot be documented by more traditional scientific methods.

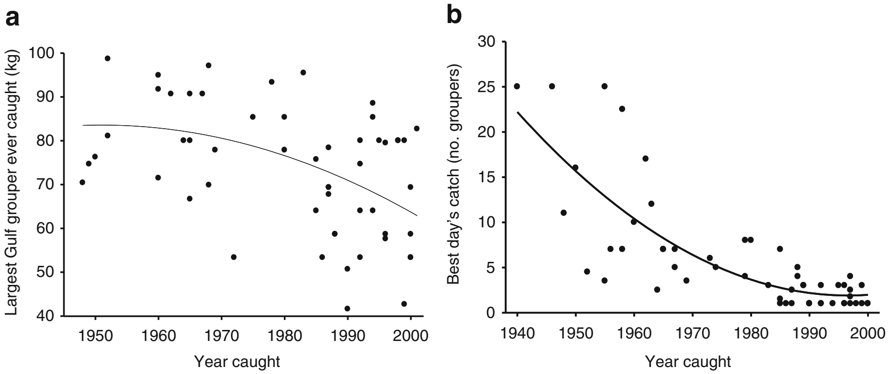

Fig. 3 Evidence of shifting baselines from fishers in the Gulf of California; **a** years where fishers recalled the largest gulf grouper ever caught and **b** years where fishers recalled their best day's catch (Adapted from Sàenz-Arroyo et al. (2005), by permission of the Royal Society)

Using Local Knowledge to Complement Scientific Research

One of the more commonly described uses of oral history is to gather local or traditional knowledge that will complement and enhance scientific understanding (Le Fur et al. 2011). The impacts of climate change are likely to be experienced most strongly over the polar-regions, where the largest average annual temperature increases are expected to occur (Anisimov et al. 2007). However, although we know that the effect of temperature increases will include the thinning and shrinking of ice caps and ice sheets, data collection in such remote regions tends to be expensive, opportunistic and limited both in time and space (Nichols et al. 2004). As a result, we have little ability to predict localised responses to climate change. Such uncertainty subsequently extends to the responses of natural systems and the ability of the societies that depend upon these systems to be resilient to future change. In the Arctic, oral history research has been found to be effective at providing long-term (intergenerational), place-based descriptions of environmental changes being experienced first hand by indigenous communities (Krupnik and Jolly 2002).

Indigenous Arctic communities have long relied upon knowledge of changes in sea ice cover and the factors that influence sea ice freeze and breakage to hunt and to survive (Nichols et al. 2004). In 1999, in response to concerns about environmental changes raised by Indigenous communities living in Sachs Harbour, located in the Western Canadian Arctic, the Inuit Observations of Climate Change (IOCC) project was begun. This project aimed to document and explore the potential of Inuvialuit knowledge to contribute to scientific research on climate change. Indigenous knowledge about aspects of sea ice and observations of environmental variables that influence sea ice extent and composition were collated using semi-structured interviews. Oral histories were conducted with community elders and individuals who were identified as being experts on sea ice. These interviewees consistently agreed that in recent years multiyear ice (ice that has survived for two summer melt seasons or more) was reduced in extent and occurred further offshore compared to past years, and that first year ice was also less abundant and thinner (Nichols et al. 2004).

Indigenous knowledge of changes in sea ice extent and distribution was complementary to scientific understanding, despite the different spatial scales at which these observations occurred. Furthermore, indigenous knowledge provided longer-term, but more spatially detailed information on observations of sea ice change than is currently gathered using scientific data alone. Nichols et al. (2004) suggested four ways in which indigenous knowledge might be able to complement scientific data: provision of environmental baselines against which to measure change, the use of community monitoring to detect local-scale change, detecting relationships between environmental variables and observed changes, and using community observations to validate or interpret climate change models.

Ecological observations and perceptions of change have also been collated for underwater environments using oral history techniques. For example, Jung et al. (2011) interviewed anglers and scuba divers about their perceptions of change in Port Phillip Bay, Australia. Perceptions of change in the abundance of two commonly targeted species (snapper, *Pagrus auratus*, and flathead, *Plathycephalus* spp.) were consistent among anglers, most of whom stated that snapper had recently begun to increase in abundance and that flathead had declined, although perceptions of change in a third target species, King George whiting (*Sillaginodes punctatus*) were more varied. Angler observations complemented scientific studies which showed a recent increase in snapper, a long-term decline in flathead species and highly variable trends in King George whiting (Jung et al. 2011). Whilst diver accounts were more variable, they were able to provide accounts of non-target species abundance including declines in seagrass and macroalgae (Jung et al. 2011).

Potential Issues with Oral History Research

The use of oral history to fill information gaps for long-term reconstructions of species, communities and ecosystems has accelerated in the past decade, even though the accuracy of oral history information is sometimes disputed (Cutler 1970). In order for oral history findings to be more broadly accepted by natural resource managers and scientists, researchers need to validate oral histories findings. Researchers can address this issue through a number of approaches, some of which are outlined below:

- *Ensure the selection of appropriate participants* (i.e. '*experts*'). Participants can be chosen on the basis of in-depth knowledge and/or long-term experience, for example, elders in the community or individuals with long-term experience (Davis and Wagner 2003). Collaboration with the communities, leaders in the community, resource users, local government and research groups will assist in the identification of experts. Women frequently play essential roles in fishing activities or marketing of fish products, particularly in small-scale fisheries and developing countries, and thus may be able to offer important additional perspectives to what is traditionally viewed as a male-dominated industry (Matthews and Oiterong 1992; Williams 2008).

- *Corroborate findings between resource users*. Researchers should aim to achieve a sufficient sample size of resource users to be able to cross-validate data between individuals from the same region and timeframe. Sampling techniques such as snowball sampling and referrals from local resource user associations are not random but will enable surveys of as many experts as possible (Neis et al. 1999b). Different groups of resource users with in-depth knowledge should also be included to account for variability in perceptions, i.e. commercial and recreational fishers (Ainsworth et al. 2008). Levels of agreement between different participants or perception of variables should be tested, whilst larger sample sizes will give greater power to subsequent trends observed in the data.
- *Account for memory bias*. When extracting quantitative data from long-term memory, researchers need to account for biases that can occur, such as recall bias, generational amnesia and memory illusion (Daw 2010). Studies such as Turvey et al. (2010) used various analytical approaches to demonstrate a marked contrast between different generations' knowledge of species disappearance in China. Without the analysis of intergenerational differences these bias are unaccounted for and lead to uncertainty in the application of oral history data. Over the past decade, researchers are increasingly accounting for age and experience-related biases by surveying a range of generations and experience levels within a community (e.g. Papworth et al. 2009; Bender et al. 2012).
- *Account for variability*. Researchers need to account for variability in ecosystems (both environmental and human-induced) across spatial and temporal scales. To try and best approximate variability, as large an area as possible should be included during the reconstruction of marine ecosystem baselines. For example, researchers should gather species-specific knowledge across as much of a species' spatial distribution as feasible, or across a range of environmental pressures. Dulvy and Polunin (2004) investigated fisher knowledge across 12 islands in the Lau group, Fiji regarding the decline of the giant humphead parrotfish (*Bolpometodon muricatum*). This investigation inferred that the humphead parrotfish is locally extinct in parts of Fiji and that exploitation was the driving force behind declines.
- *Validate local knowledge with alternative data sources*. Where possible, local knowledge should be validated with alternative data sources such as official catch landings, personal logbooks, and scientific surveys, to gauge consistency and levels of error. For example, Rochet et al. (2008) found that fishermen's perceptions of changes to the fish community in the English Channel over 15 years agreed with quantitative monitoring data from landings and trawl surveys. Aswani and Hamilton (2004) tested the validity of local ecological knowledge (i.e. timing of spawning season, locations of aggregating fish) with corresponding

fisheries and scientific data. The comparison confirmed that in three out of four cases, local knowledge agreed with scientific observation. However, it is important to note that studies have found that oral history data sets can both agree and contrast with alternative data sources of corresponding time series (e.g. Otero et al. 2005). This does not render oral history useless, instead it highlights that the uncertainties associated with oral history data must be acknowledged and quantified (O'Donnell et al. 2010).

- *Assess the reliability of knowledge against multiple sources*. Another technique for validating oral history data is to assess the reliability of knowledge using multiple criteria. Criteria such as experience level of participant, the extent of corroboration of information by others and consistency with alternative sources of data can be investigated to determine the different levels of reliability for each oral history (Ziembicki et al. 2013). The reliability can be determined by ranking each interview against the criteria: a higher ranking indicates the oral history is more reliable.

Ethics and Oral History

Guidelines for the ethical conduct of oral history research are provided by a number of organisations (e.g. the Natural Science Foundation's Principles for the Conduct of Research in the Arctic, and the Oral History Association of Australia Guidelines of Ethical Practice). These focus upon the interviewer's responsibility to preserve the rights of individuals by explaining the purpose of the interview, the anticipated outcome of the research, ensuring confidentiality, respect for local customs and appropriate interpretation of knowledge, which often involves sending transcripts of oral history interviews back to the interviewees for agreement and cross-checking (Canadian Institute of Health Research 2008; Oliver and Eales 2008). The United Nations Declaration of Human Rights relating to the rights of indigenous peoples also identifies acknowledgement of intellectual property as a human and cultural right (United Nations 2008). Issues surrounding dispossession and the commercialisation of indigenous knowledge are outside the scope of this chapter (see Posey 1990) but there are also ethical considerations concerning the use of ecological knowledge for research and management. For example, the publication of ecological knowledge may create conflicts between local user-groups as long-held local knowledge becomes exposed, or may inadvertently favour particular groups who can lay claim to such knowledge as it becomes written word (Maurstad 2002). It is also questionable whether it is ethical to use this knowledge 'against' resource users, for example, in the form of management restrictions. An awareness of the potential outputs of such research may also result in refusal to participate in research or a falsification of observations in the belief that it will provide more agreeable management measures. Such considerations must be considered prior to conducting oral history research.

Contribution of Oral History Research to Management and Conservation

Whilst research has demonstrated how oral history can reconstruct and provide context to changes over time, further work needs to be done to highlight their potential application to management (Brook and Mclachlan 2008). Traditionally oral history tended to use a more qualitative approach to account for changes in the marine environment, an approach that has proved difficult for management to incorporate into quantitative models. More recently, a shift to gathering quantitative data has been successful in extracting data that is more appropriate for management, for examples, changes in catch across generations (Sàenz-Arroyo et al. 2005), catch rate and quantification of increases in technological efficiency (Neis et al. 1999a). For example, Robins et al. (1998) used fisher knowledge, logbooks and landing returns to demonstrate that fishing power on vessels with GPS and plotter systems increased by 7 % annually. Quantitative oral history research has been further extended by Daw et al. (2011), who questioned artisanal trap fishers in the Seychelles on their range of contemporary and past catches. In doing so, Daw et al. were better able to account for short-term temporal variability in catch. Such work is necessary to avoid simplified assumptions and scientists are increasingly attempting to account for variability and biases using oral history research (e.g. O'Donnell et al. 2010).

Oral history data can be used and incorporated by scientists and managers for a variety of purposes for the management of natural resources. Oral histories can provide an assessment of changes in a broad range of species over time to inform management for the prioritisation of species for fisheries assessment and conservation action (Lavides et al. 2010). Oral history research has also proved useful in the case of conservation of cryptic species, for example, Turvey et al. (2013) demonstrated that local knowledge on the relative spatial abundance and decline of the Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*) corroborated with data collected from boat-based cetacean surveys. Studies in data poor countries such as Brazil have also demonstrated how local knowledge can be accessed, assessed and incorporated into the management and conservation of species. Experts' information on Goliath grouper's aggregations and distribution were sketched onto satellite imagery maps identifying key spawning aggregations and a suitable site for a marine protected area (Gerhardinger et al. 2009). In addition, Bender et al. (2012) demonstrated how older, more experienced fishers can pinpoint which local reef fish species are declining. Hence local knowledge can prove pivotal for future management strategies.

As our case studies show, oral history has much to contribute to natural resource management (Table 2). However, for oral research to be accepted and incorporated by management, collaborative research between scientists and management is required throughout the entire process: from the development and design of interviews, the wording of questions, through to the analysis and interpretation of such knowledge (Acheson 2006; Wilson 2003). Management systems must also enable the incorporation of both qualitative and quantitative knowledge. These hurdles must be overcome if oral history research is to make a significant contribution to conservation of marine ecosystems.

Table 2 Ways in which oral history can contribute to scientific understanding, and potential barriers to implementing such information

Contribution of oral history data to science	Barriers to implementing oral history data
Extending temporal depth of knowledge	Complementarity of local knowledge and scientific data
Past presence of now extinct species	Mismatch in temporal scale
Species abundance trends over time	Mismatch in spatial scale
Localised environmental change	Local versus scientific language
Species introductions	Interpretation of data
Improving spatial resolution of scientific data	Perceived bias or inaccuracy of recalled events
Past species distribution	Memory illusion
Scales at which environmental variables operate	Shifting environmental baselines
Feeding/spawning/migratory patterns	Validation of recalled events/past abundance
Species range contractions	
Adaptation to change	Building descriptive information/context into quantitative models for resource management
Social, cultural or technological adaptations to resource depletion or environmental change	

Conclusions

Despite a growing number of examples demonstrating the magnitude of changes that have occurred and the presence of shifting environmental baselines, many people still fail to appreciate the changes to marine environments as a result of human impacts. Oral history has an important part to play by filling gaps in scientific knowledge and demonstrating how communities adapt to the changes they are experiencing. Oral history research has always crossed disciplinary boundaries, and the multidisciplinary application of oral history will ensure that novel findings continue to fill gaps in our understanding of changes to the marine environment. Finally, the descriptive and personal nature of oral histories can hold much greater meaning to the wider public than 'hard' scientific data, leading to a greater acceptance of the changes being observed. In natural resource management, such acceptance by the public will often hold the key to successful conservation outcomes.

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A Sea-Change in the Sea? Perceptions and Practices Towards Sea Turtles and Manatees in Portugal's Atlantic Ocean Legacy

Cristina Brito and Nina Vieira

Introduction and Historical Background

«Reconstruir o passado, conhecer o presente e prever o futuro, eis o difficil e sublime papel da sciencia.»

«To reconstruct the past, to know the present and to predict the future, this is the hard and sublime role of science.» [Baldaque da Silva, Portuguese naturalist, 19th century]

The exploitation of marine resources, the intercultural trade and the collection of marine animals has a documented history which changed dramatically with the European Overseas Expansion and the exploration of the Atlantic (Costa 2009).

The onset of the European maritime discoveries in the Atlantic during the fifteenth and sixteenth centuries, marked Europe's history, culture, economy, and even science. The open-sea soon became a center of transoceanic fishing activities, maritime journeys and affairs, and politics, consequently yielding rapid expansion of economic trade and of local and global knowledge. Economic and political benefits of the historical focus on the ocean and coastline left an imprint in the grandiose patrimony, and created a place for several European nations in the annals of an Atlantic economy. During the early modern centuries, humans established new links – primarily by sea – around the entire world. In large measure because of naval capacity and improvements, a new, truly global economy coalesced (Richards 2003).

Following the first successful crossing of the ocean by the late fifteenth century, the Atlantic Ocean gradually became the scene of an integrated system of exchange for people, commodities and ideas (Kupperman 2012). This moment opened the so-called post-Columbian period in the Atlantic. Even though it was marked by great opportunities and also great loss and suffering, modernity was born there. The

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intensive voyages and knowledge of other people and lands that followed the earlier journeys led participants in all four continents to rethink their inherited lore about the world and its history (Kupperman 2012). New views of the world started to take place over medieval conceptions and changes in human societies started to emerge. From the late fifteenth century to the early nineteenth century, the pace and magnitude of change increased in human societies in every part of the world. In this same period, human societies developed the largest, most complex, and most efficient state and private organizations known since classical antiquity. The Atlantic became a new world for everyone (Kupperman 2012).

This new Atlantic world was composed by masses of waters from different origins and far flung environments, with ecosystems formed by distinct trophic nets of animals and plants. Every stretch of coast was included in trade with common as well as more exotic new species of plants and animals (Costa 2009; Kupperman 2012) which dramatically change life in lands and cultures bordering the ocean. New commodities in increasing quantities and variety flowed to markets in trade centers spread throughout the Atlantic margins (Richards 2003). People began to realize the existence of a new Nature – global surroundings rather than localized and familiar environments -, similar species in different continents and oceans and the existence of marine animals in counterpart to the already known terrestrial ones, most of them quite strange. And throughout this time period, people have liked some species, loathed others and for a number of creatures thought nothing about them at all.

Human responses to animals and environments shapes, and are shaped by, existing knowledge about a species and dominant social perceptions about its character and value. Some species are liked and valued for their economic usefulness, which means that they can be converted into products or services for human consumption, and this in turn shapes how the species is understood and described, or labeled (Goedeke 2004). There are many other, however, that people favor, despite having lost or never attained importance as a commodity. This is the case with companion animals – exotic monkeys and parrots are good examples of such (e.g. Masseti and Veracini 2014) – or wildlife with a spiritual or cultural importance, or that symbolizes a community and tradition (Goedeke 2004; Szabo 2008; White et al. 2011). Several species of large marine animals fall in one (or all) of these categories – they are economic resources, they have a spiritual property and they are symbols of people, places or a character – and consequently they are sources and material of history.

At the start of the early modern period, all levels of the society regarded the natural world from its own perspective and viewpoint and tended to classify it less according to its intrinsic qualities than according to its relationship to man (Thomas 1983). This viewpoint lasted for centuries. Social meanings attached to particular creatures due to an array of factors (Goedeke 2004) always existed but now they have changed. Only in recent decades, did the attitudes, perceptions and some practices start to be modified and the cultural relationships that people forge with animals have been marked, as humans started to view themselves not merely from an anthropocentric perspective in an ethical state above nature, using its resources only with economic purposes, to a more biocentric perspective where they are an integrated part of nature (Vining et al. 2008).

A number of reasons influence public attitudes toward animals such as aesthetics, cultural and historical importance, economic value, and level of public knowledge, and presently the popularity of a particular species depends on perceptions about its usefulness, cognitive characteristics and loveable qualities (Driscoll 1995). Research on environmental perception shares a paradigm of man-environment relations in which man's individual and collective understanding of the environment is seen as a major force in shaping that environment through the action of their own choices and behavior (Whyte 1977). Only very recently, since the 1970s, humans' perception of the environment has been considered fundamental to analyze the man-environment relations. A perception approach to man-environment relations recognizes that for each objective element and relationship in the biosphere many perceived elements and relationships exist as seen and understood by different people, at different times and places (Whyte 1977).

Large marine animals have always captured people's imagination, figuring in ancient legends and visual representations as terrifying sea monsters and inspiring poets and artists with their strange grace and immense size (Szabo 2008). Over the centuries an entire oceanic mythology grew up, inspired by the mystery surrounding these creatures' habits. But the shared history is a bitter one, for the animals have long been hunted for their valuable oil, meat, bones and other products. This is particularly true in the case of whales and whaling throughout time (Szabo 2008; Brito and Sousa 2011; Brito 2012), a theme extensively discussed in the historiography. The history of whaling has always been subject of interest and references can be found, at least, from the early twentieth century (e.g. Jenkins 1921) to the present day (E.g. Reeves and Smith 2006). But for many other marine species and related maritime activities an investigation and discussion is still lacking.

In the present research a set of changing perceptions and attitudes towards a multiplicity of marine species has emerged but we will discuss only some aspects of two charismatic marine species. This chapter aims to reflect on some processes by which human beings intervened in marine environments during the early modern period (Richards 2003), using sea turtles and manatees in the Portugal's Atlantic Ocean legacy as case-studies.

Addressing Environmental and Social Changes in Atlantic History

While some authors pointed out the ways in which the ocean must be accounted for in the well-established field of Atlantic history, marine environmental history also has the potential to help historians recover hitherto overlooked oceanic worlds that embrace both humans and animals (e.g. Bolster 2006). Thinking about life beneath the waves, transforms our view of events on the surface. It uncovers new historical actors, reshapes traditional geographies, and complicates older stories of the Atlantic as a projection of imperial and commercial power (Richards 2003; Jones 2013). As some authors did for the Pacific Ocean (Jones 2013), it is possible to look below the Atlantic waves and reveal all the complexities of humans' historical relationships with oceans. This is supported in the principle that the living, changing sea is an important factor in any oceanic history (Jones 2013).

Large marine mega fauna (marine mammals – cetaceans, seals and sirenians -, sea turtles, and large fish), although being animals living in an intimidating environment for humans, are big, most of them need to come to surface to breathe or to land to breed, and almost all show conspicuous aerial behaviors (e.g. whales breaching; dolphins' porpoising; dolphinfish feeding; sharks or manta ray jumping). Taken together, they are historically subjects of interest and their existence raised questions and issues throughout different cultures around the world. Some are present to some extent in modern fishing reports, but for the large majority their products did not appear as systematic import/export listings, nor were they explicitly registered in trade records. They are somehow ethereal animals, and left, as we came to comprehend, few material traces over time. However, these animals were also object of numerous written records and discussions on their geographic presence, their use in several places and cultures, and their ecological and economic importance overtime. And from our work on this research field, we believe that most of these records still remain unseen.

To gather information on these species and the changes of human perceptions towards them, and to frame it into the current historiography, is essential to go through different types of sources, data and material. These can range from medieval to early modern written sources, iconography and cartography, modern fishing and import/export statistics, journals and newspaper reports, articles and naturalists' records, to contemporary oral history and conservation movements/measures (see chapter by Poulsen, this volume). All this information needs to be integrated into models of analysis to answer problems and scientific questions (changing patterns of activities, uses and perceptions). The historical timeframe ranging from early modern to contemporary times is quite large making it difficult to analyze and interpret different types of data. If we consider the past few centuries, data will most certainly be very scattered and patchy and for each time period, and each region, its economic and cultural contexts need to be kept in mind. This may allow for temporal comparisons as "Then" versus "Now", and may provide valuable insights into past and recent changes, as long as the historical context is carefully considered (Lotze and McClenachan 2013). Historical records can provide information on past occurrence, distribution, and abundance of a certain species, as well as on impacts of human activities as they were being used as food, fuel, for clothes and to other purposes (Lotze and McClenachan 2013).

Here, we aim to study over time trajectories and drivers of past and recent changes in marine populations and ecosystems and in societies. Case-studies were chosen based on the identification of a historical research question in relation to a present-day societal need/response/change, and the analysis is supported on the tracing of human activities, or uses and perceptions left on the historical records. As discussed earlier, several species of large marine animals became commodities in the early modern period and they offer examples of the natural wonders reaching Europe from the newly discovered and explored Atlantic regions and are subject of intense exploitation and use since the early sixteenth century (Costa 2009). Simultaneously, they are presently considered charismatic megafauna and flagship species for the conservation of marine ecosystems and populations.

Catching Sea Turtles: From Food Items to Conservation Icons

Sea turtles (Family Cheloniidae and Dermochelyidae) live in tropical and subtropical waters of all oceans. They are migratory marine reptiles that undergo long journeys between feeding areas and the beaches were they nest. Depending on the species (seven species of sea turtles still exist today), the breeding period varies and when females come to the beaches to lay their eggs is when encounters between them and humans usually occur. Sea turtles have been traditionally considered a very valuable marine resource and captures have occurred throughout their range. Presently all seven species are highly endangered and they face major threat from depletion (McCauley et al. 2015).

Historically, they have been hunted in their breeding beaches, mostly for their meat, eggs, and shells. They have also been used as traditional medicine in several parts of the world (Loureiro and Torrão 2008). Moreover, they have long fascinated people and have figured prominently in the mythology and folklore of many cultures. For instance, in the Miskito Cays off the eastern coast of Nicaragua, the story of a form of a "Turtle Mother," still lingers. Unfortunately, the spiritual significance of sea turtles has not saved them from being exploited for both food and for profit. Millions of sea turtles once roamed the earth's oceans, but now only a fraction remain (more about the biology and conservation of sea turtles can be found in http://www.conserveturtles.org).

In the Cape Verde Islands, the history of the relation between humans and sea turtles goes far back to the European discovery and settling on the archipelago and the ways of perceiving and using the animal results from the mixture of people that inhabited the islands. As a consequence of the cultural heterogeneity of communities living in the islands, sea turtles were perceived in a multiplicity of ways. Here, sea turtles were used as food or as an ingredient for traditional medicine, as well as to produce artifacts (Loureiro and Torrão 2008):

> *We also captured a quite large sea turtle that we ate and was very tasteful. Lepers recover from their illness eating turtle meat, and also passing turtle blood all over the body, and cooking all the meals with its fat, and after two years they are completely healed* (…). *These sea turtles are of considerable size, and with their shells it is possible to make a good shield for protection during a combat* (…).

Since the late twentieth century, in the Cape Verde Islands the sustainable use of marine resources and conservation of endangered species is a new concern. As a result of such new ways of perceiving the marine natural environments, new laws were introduced in order to invert the tendency of a predatory hunting of sea turtles for the consumption of their meat and eggs towards a more sustainable approach. So, the multi-secular way of doing things is being replaced by a new prevailing current of opinions and behaviours. Conservation is now overcoming old practices. Once and again, the same Europeans (Spanish, Portuguese, Italians and other) that introduced continuous exploitation and consumption are the ones starting current conservation movements. However, exchange of ideas and attitudes with the Cape Verdeans is being assured (Loureiro and Torrão 2008), and both national and international conservation actions are ongoing.

São Tomé and Príncipe is also a paradigmatic case-study for changes in perception and practices related to sea turtles. Here, as in many other places, a recent change from a long history of eating and using sea turtles to present-day more environmental and conservation oriented attitudes is taking place. During the Portuguese expansion of the fifteenth century along the West African shores, several observations of sea turtles were reported. Sea turtles were an important protein source for the sailors and they could also be an indication of an approximate geographical position or of land proximity. For the region beyond the Cape Bojador (Zurara 1989 [1453]):

> *«And already inside the bays they have seen an island which is outer than the others, however small and sandy, where they launched their skiffs out to see if they could find something of what they sought. The true is that the Moors not long have been there as it seemed from the nets and fishing gears that were found, and especially for a large group of turtles that should be 150. And because all of those who read this story may not know this fish, do learn that turtles are tortoises of the sea, whose shells are such as shields* (…) *And even if in those islands there are very many good fish, the Moors have this one as the most special.»*

From several Atlantic regions, descriptions and observations of sea turtles reached Europe, but the intention beneath early human interest in these animals was an economic and predatory one. They were valuable resources for people from all parts of the Atlantic and soon become a common interest and a contact point to different human cultures spread out over this oceanic basin.

In fact, also in São Tomé and Príncipe, and until very recently, sea turtles kept on being an important source of animal protein with relevance to the local economy. Their meat was eaten as well as their eggs, and it was sold in fish markets. Shells were also used to produce handicraft and artisanal jewelry that during all the twentieth century were highly priced by local people and highly requested by Europeans living or travelling to this region. Recently, a drastic change occurred due to international and national efforts towards the conservation of sea turtles coming to nest in the archipelago's sandy beaches. Local campaigns focusing on environmental education, ecological tourism and sustainable management of marine resources started to be conducted in the 2000s and now are already a common place. Local NGOs, such as MARAPA (more information on the website http://www.marapa.org), were able to change local mentalities, public perceptions and practices regard-

Fig. 1 A public list of captured sea turtles in the island of São Tomé (São Tomé and Príncipe), showing location of captures, species and numbers. This postcard also alert to the importance of their conservation (Source: MARAPA)

Fig. 2 Photograph of Hipólito Lima, a former turtle hunter and presently a sea turtles' pro-conservationist and a local educator (2014) (Source: MARAPA)

ing sea turtles. For the last couple of years, they have regularly published lists of sea turtle captures (numbers and photographs) (Fig. 1) alerting to the importance of their conservation and correct management. As a consequence of local efforts, in 2015, a law for sea turtle protection (forbidding their capture and commerce, and criminalizing the capture and consumption of eggs) was passed by the São Tomé and Príncipe Government. Former sea turtles hunters are now the advocates for their conservation (Fig. 2) and structured programs of surveillance of furtive hunters, education for children and fishing communities, nest building and protection, and turtle release to the sea are currently taking place. Ecotourism practices are also currently an important source of income. All these campaigns are public and with a strong national and international focus (Fig. 3) and result from the engaging of different stakeholders, from the artisanal fishers to the foreign tourists.

Similar situations occur all over the world. For instance, in Brazil since 1980 several sea turtle protection mechanisms were implemented and are presently cases of success in sea turtles' conservation (for more information on the Brazilian and the Portuguese sea turtles' conservation programs check the websites http://www.projetotamar.org.br and http://tartarugasmarinhas.pt). The first so-called conservation manifest regarding sustainable captures of sea turtles is from the eighteenth century Brazil. Here, Alexandre Rodrigues Ferreira, wrote about the indiscriminate captures of aquatic animals (fish, manatees, and sea turtles) using the term "predatory fishing" (Pádua 2002). He considered that the unregulated exploitation of turtles was a relevant issue (Ferreira 1972):

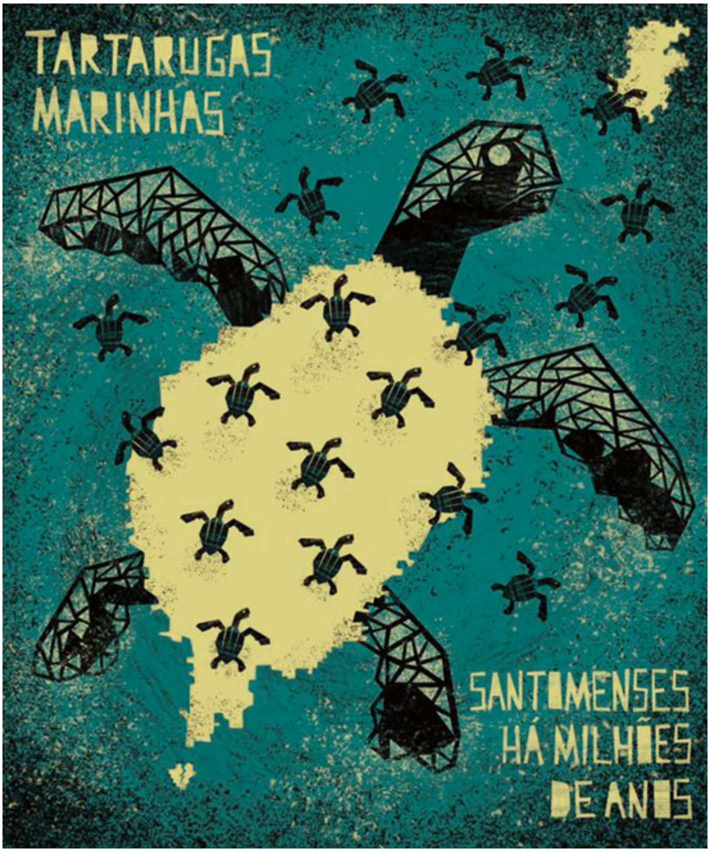

Fig. 3 An illustration pro-conservation of local sea turtles in a 2014 national contest for awareness rising in São Tomé and Príncipe, organized by a local NGO (Source: MARAPA)

> «"*This amphibian so useful to the* [*Portuguese*] *State has not yet received the care or measures that are necessary to avoid the abuses that are practiced against it. A turtle to reach its proper growth takes some years. Countless are wasted every year due to the absolute will of the Indians*; *all nests are discovered*, *are trodden in rows and almost all little turtles are eaten without need*, *and this all together influences their rarity in the course of time* (…)».

But his main concern was guaranteeing the future continuity of such an important economic activity and not moving towards the prohibition of its capture. Therefore, Ferreira's views did not work to the environmental protection but rather to the protection of State economic interest (Pádua 2002). This approach is common throughout modern history as a management tool for species with high economic values; a well known example is the establishment of the International Whaling Commission in 1946 for the conservation of whales stocks and the management of whaling (Donovan 2009).

Currently all sea turtle species are threatened and, as a result, most worldwide human cultures advocate for their conservation. They are a flagship species for the marine environment and conservation efforts are being pulled all over their geographical range. They are still at risk due to defaunation, exploitation of other marine resources where they can be a bycatch, such as in trawl nets, or due to the pollution of the oceans with plastics. However, in several African countries (e.g. Guinea Bissau) their capture is still a traditional activity and conservation efforts may still take long to be effective. Public education, participation and engaging seem to be the way to overcome current conservation difficulties and work towards global protection of sea turtles.

Magical Manatees: From History to Local Knowledge

Marine defaunation, or human-caused animal loss in the oceans, emerged only hundreds of years ago contrary to terrestrial depletion which has been occurring far longer (McCauley et al. 2015). Still today the loss of terrestrial species is far more severe that marine ones. However, if we consider marine species that have terrestrial contact, such as sea turtles (as discussed previously), sea otters, sea lions and seals, and seabirds and shorebirds, the number is much higher than in exclusively aquatic species (McCauley et al. 2015). This is also the case with sirenians (manatees and dugongs) (e.g. Romero et al. 2014).

Ongoing research (e.g. Brito and Sousa 2011; Brito 2012) on the historical importance of marine animals to early modern societies has resulted, so far, in the compilation of 35 written sources for sirenians. These refer to the historical presence and descriptions range from the fifteenth to the eighteenth century both for the Atlantic and Indian Ocean. In the case of the three species of manatees, the extant Atlantic living sirenians, historical sources show their current distribution as severely constricted in Brazil (Fig. 4) and fragmented in West Africa (Silva 2001). In the both sides of the Atlantic, manatees are listed as Vulnerable by the IUCN Red List of Threatened Species.

In America, two species of manatees occur and they range from the north of Florida to the northeast of Brazil, including the great Amazon basin. The first known reference from Brazil, where both the West Indies and the Amazonian manatee can live, is from Father José de Anchieta in the sixteenth century (Anchieta 1946) who refers to this animal when writing about the "*Province of Brazil*":

> «*In the rivers that flow into the sea there are manatees that weight 20 to 30 arrobas. Inside the brain of these a most medicinal stone for those who have stone pain can be found and the flesh is priceless, it can be cooked with sprouts and taste like beef; with spices, it taste like sheep and also pig and it is made from it a very good slaughter.*»

In West Africa, manatees presently occur from southern Mauritania to the Kwanza River in Angola (Barlow 2002), and historically they were very abundant in the Congo River (Cavazzi 1965 [1687]):

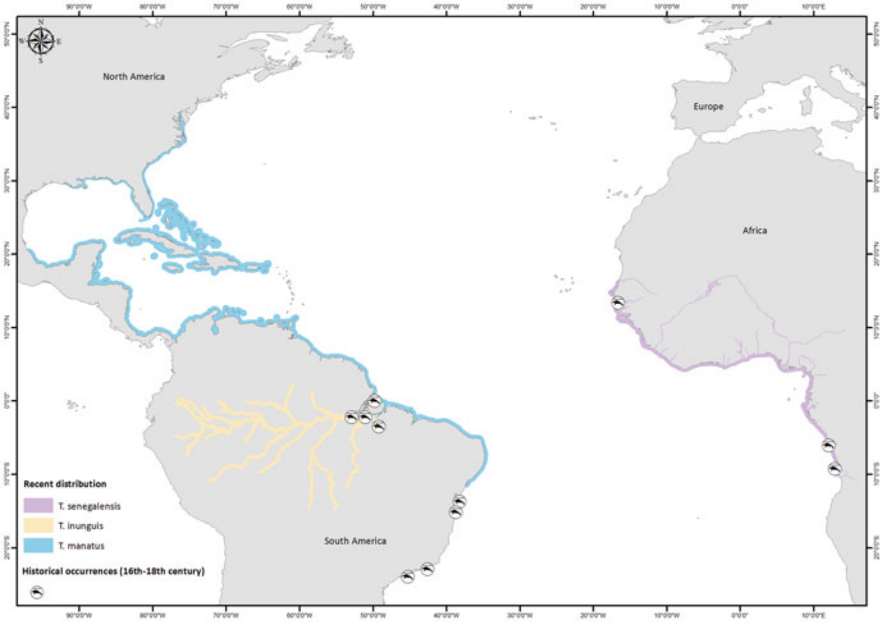

Fig. 4 Current geographic distribution of the three species of manatees (IUCN shapefile) showing historical observations in the Southern Atlantic with an indication of an approximate geographical position (n = 11)

> «(…) *there is one that the Europeans call women-fish and the indigenous call* ngulu-a-maza [*literally in* kikonco, *water-pig*], *beautiful in name but horrendous in form*. (…) *The teeth are like the dog*; *the fins*, *like arms*, *reach half the body*, *finishing with five cartilaginous fingers and misdeeds. The tail has more than 3 spans*, *and the breasts*, *where I suppose the name comes*, *seems like those of a women*. (…) *Both its meat is tasty to the palate as it is harmful to the stomach. The fisherman*, *to catch it*, *dig holes in the banks of a river*, *and the fish*, *deceived*, *goes into them. Then*, *taking off the water*, [*they*] *easily catch it*, *because it is naturally lazy and slow* (…)».

Manatees have historically been perceived as an easy and valuable resource as they provided a different food sources for sailors, explorers and pirates roaming Atlantic waters (e.g. Roberts 2007; Romero et al. 2014). As mentioned above, also across the Atlantic (as in Brazil) parts of manatees (such as a "brain stone") were valued and used for their medicinal or magical properties, something that was reported as early as the sixteenth century (Anchieta 1946). Still today in West Africa, some parts of the manatee (such as the heart) are used in ritual ceremonies and are an important natural element for traditional communities. In these regions, the hunt of the manatee is also a tradition passed from the father to the son Morais et al. (2006).

Manatees have been hunted severely throughout their range and the only mention of concern about its disappearance comes (as for the sea turtles) from Alexandre Rodrigues Ferreira in eighteenth century Brazil (Ferreira 1972; Pádua 2002). He stresses that all the animals are harpooned, with no distinction of size or age, even the pregnant females, and states that this is the reason why in some lakes the numbers of animals have decreased.

Despite the increasing conservations measures until the late last century, and its conservation status, West African, West Indian and Amazonian manatees are still being captured for consumption throughout their distribution areas. This takes place in South America (such as in Brazil, Chile, Colombia, Ecuador, French Guiana, Peru, Suriname and Venezuela) and in West Africa (such as in Benin, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Niger, Nigeria, Senegal, Sierra Leone, Togo, Angola, Cameroon, Chad, Democratic Republic of the Congo, Congo, Equatorial Guinea and Gabon) (Robards and Reeves 2011). In these countries manatees have been reported as being consumed in the period from 1970 to 2009. Some of these countries, besides hunting and consuming marine mammals, exchange their products for consumption in other countries, showing that external markets add incentives to those captures beyond the nutritional needs of the catchers. For instance, in Africa, manatees' meat has been illegally transported and sold from Chad to Cameroon (Robards and Reeves 2011).

In recent times, several local NGO and other manatee supporters worked to replace ignorance and negative impressions of manatees with knowledge and sympathy. In some parts of the world, such as in Florida, these efforts appeared to pay off as the manatee's image underwent a transformation; perceptions of the animal shifted dramatically in a matter of just two decades (Goedeke 2004). But, as seen before, this is not so the case in African countries and some parts of Brazil. Early modern to recent literature published about manatees often described them as monstrous animals, ugly and grotesque. This type of description perpetuated over time does not inspire the kind of imagery necessary to elicit support based on aesthetics (Goedeke 2004) and it needs to be changed previous to conservation measures can be applied. However, manatees have two qualities that can translate into a good deal of public support: rarity and unique ecological role. In Florida, the manatee's endangered status alarmed those who supported it and made the need for protection indisputable. The species' ecological uniqueness and importance as an umbrella species were united, which meant that were the manatee protected then a plethora of other species and systems would be protected by default. Finally, the manatee also came to be defined as an important indicator species (Goedeke 2004). These aspects should also be worked with local communities in other parts of the world.

Both in South America and Africa, manatees face serious problems in recovering to their pristine (or early modern) populations. They are still being captured by local people that use them as a food and medicinal resource (Fig. 5), from the effect of by-catch in other traditional fishing activities (e.g. Silva 2001) or habitat destruction due to anthropogenic pressures in marine and riverine habitats. Local and international efforts have been developed since the late twentieth century in order to disseminate the importance of manatees in the balance of the aquatic ecosystems. For instances, in Brazil, a National Action Plan for the Conservation of Sirenians is being set since 2011 (Luna et al. 2011) and presently in Angola, the so-called Fundação Kissama is developing educational campaigns for the general public

Fig. 5 A manatee captured in a shore trap by the local ethnic group "*Fula*" in Guinea Bissau, during the twentieth century. (Source: http://senegambia.blogspot.pt/2005/03/guinus-616.html)

through the publication of books (Fig. 6). Globally, human populations have caused increased demands on natural resources and the endangerment of numerous species, particularly on parts of the world with limited resources. In such cases, attitudes and perceptions of resident human populations regarding natural resources are often the deciding factor in the success or failure of local species conservation efforts (White et al. 2011) and these must to be taken into consideration.

Discussion

The creation of a global system of transport and communication that begun in the early modern period, meant that human beings travelled long distances more readily than at any time in human history (Richards 2003). Verbal and written information passed between the world's regions and within regions at new levels of accuracy and quantity, and identifying, naming, and classifying of the world's landforms, seascapes, climates, minerals, human groups, animals, and plants proceeded at a dizzying pace (Thomas 1983; Richards 2003; Costa 2009). Moreover, the Atlantic as a unit started to emerge in this period and became itself a subject of inquiry and multiplicity. It allowed connecting people and regions to develop commerce networks and to create a new sense of a Global World and a new perception of Nature and its elements as a whole. In fact, the fifteenth century heralded the onset of Europe's global ocean exploration (Roberts 2007) and the first contacts with new and exotic marine animals.

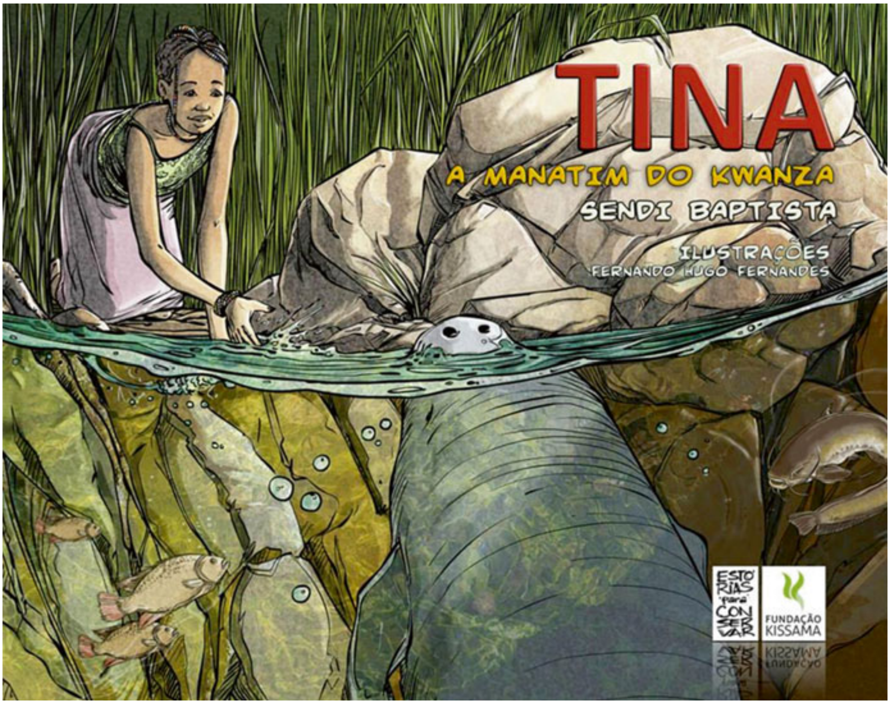

Fig. 6 Illustration by Fernando Hugo Fernandes of a manatee of Kwanza River in a book by Sendi Batista ("Estórias para conservar" collection by Fundação Kissama) (Source: https://www.facebook.com/fundacao.kissama)

Exploitation of several marine species started in this period, but for centuries only with effects in local populations. Marine resources were historically harvested, however, until the advent of industrialization, rapid depletion and ecological tipping effects were hindered by lack of technological advances. Simultaneously, most new and exotic large marine animals were mainly perceived as monsters and potential dangers (Szabo 2008) and as mythical prophecies from the Christianity coming alive or even as mirrors of human notions of right and wrong (Poulsen 2002). The sea is historically associated to a multiplicity of myths (Cardoso 1998). Marine marvels, such as the animals we have been discussing, were considered not just part of nature but rather they transcend it; they were both monstrous and mundane and many times were equated with supernatural creatures that one should fear (Szabo 2008). The sea, the place of origin and habitat of these animals, was itself a place to fear and even an instrument of punishment both for people and the animals (Cardoso 1998; Poulsen 2002).

Historically, people's perceptions and practices towards these marine species – whales, sharks, sea lions, sea turtles or manatees – were built on negative perceptions and predatory contacts (Thomas 1983). Both fear and economic value contributed to the decimation or near decimation of species. Overall, different types of exposure to these animals contributed to the construction of early modern perceptions (e.g. Poulsen 2002; Szabo 2008). But in some cases, an historical evolution and some changes of those perceptions took place.

It appears that species can be socially and culturally reinvented, improving their chances of protection (Goedeke 2004) and allowing for a true sea-change for some marine animals and populations. For instance, modern perceptions of whales while long separated from the past monstrous whale traditions, retain some of the ancient fascination with these great creatures (Szabo 2008). Today people show genuine concern for the conservation of some species of marine fauna. This was the case with sea turtles where perceptions about the importance of its presence in marine ecosystems changed along with a positive valuation. The manatee benefited (or is starting to benefit) from just such a process, going from ugly monster to charismatic, gentle giant worthy of being saved (Goedeke 2004). Several marine animals warrant a multi-faceted history of their exploitation, economic value, cultural significance, scientific novelty, and changing place in the ecosystems. As seen above, several of these organisms were, at any given time, tightly tied to communities of local producers, which, in turn, were affected by changing markets, evolving technologies, scientific studies, regulations regarding access, and contradictory opinions regarding sustainability.

In addition to the case studies presented, other examples need attention, in particular in world regions were little attention has been given either to historical sources and present day conservation such as Africa and South America (for a review see Schwerdtner Máñez et al. 2014). One example may be related to the recent change from whale hunting to whale watching in some regions, and how this process evolved locally and globally. Future research should focus on drivers, patterns and moments of change, and differences and similarities between distinct geographical areas and cultures. As said before some species have become charismatic and flagship species for the marine environment conservation and its sustainable use. But others did not. For instance, the historical and cultural reasons for the continuous captures and consumption of tuna in different geographies and cultures leading to the overexploitation of several commercial species over time are also worthwhile exploring (see Christensen, this volume). This would relate with the ecological impacts on marine populations and ecosystems, the social and cultural impacts and influences in local maritime societies and global trade markets in the past and the present day.

Marine mega fauna exploitation and use, and their products' trade, may work as an analytical framework of investigation and comparison for the Atlantic which, in turn, may emerge as a coherent unit of past, present and future scientific understanding. Considering detailed case studies from different oceans and time periods may allow us to examine important shared processes of social and environmental change over the long term of several centuries. Even if some of the case studies may take a kaleidoscopic effect, each of them has connections and juxtaposed details, colors and shapes that will form a pattern (Richards 2003).

The puzzle of the Atlantic Ocean (and particularly the South Atlantic Ocean) is far to be completed but as research on this topic develops, more issues and questions will arise as well as new questions. It is important to understand if there is an Atlantic or oceanic pattern, or rather local comparable patterns. Also, what sorts of marine environmental impacts occurred and what shared historical drivers and processes might the case studies demonstrate. The analysis of past processes may add to understanding of the history of interactions between human culture and non-human nature in the early modern and modern world as it is ever more relevant to present day actions and to future practices.

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Fish Is Women's Business Too: Looking at Marine Resource Use Through a Gender Lens

Kathleen Schwerdtner Máñez and Annet Pauwelussen

Introduction

Fisheries are usually perceived to be a male domain (Choos et al. 2008). This is partly the result of the roles most societies have traditionally allocated to men and women: men are regarded as providers, while women take care of the home and family. It is also based on a rather narrow understanding of fishing as the catching of organisms with certain gears, for example lines, nets, or spears. Activities such as the collection of shellfish and other organisms from shorelines and reefs – often carried out by women – have rarely been considered as fishing. Additionally, there is a general assumption in most research that fisheries operate in the public domain (usually male dominated), which is why the private domain (female dominated) is hardly the focus of attention. Especially in small-scale fisheries, much of the administration and logistics including financial issues, as well as the processing happens in the household and through family networks. Hence, an analytical focus on public and formal practices misses not only women's roles, but also a considerable part of what it takes to organize and *put a fishing operation into practice*.

To be a women is not to be a fisher(man) (Yodanis 2000).

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Traditionally, women have mostly occupied the pre and post-harvest sector and the processing and marketing of the catch (Bennett 2005). In many fishing communities, women provide substantial financial contributions from other income sources to fishing operations, and it is often their support that keeps fishing viable. Still, in most economic, social and historical research they have largely been ignored. Elisabeth Scott has used the phrase "those of little note" when referring to groups that were considered of little importance by dominant social groups, but also to characterize those people that are largely absent from the written records we use because they were not seen as relevant to write about (Scott 1994). Women in fisheries are such a group, and their role in marine resource exploitation has often remained invisible. Such ignorance leads to an underestimation of the social, cultural and economic contributions that women provide in fisheries, but also to a substantial underestimation of fishing pressure, especially in coastal areas (Harper et al. 2013).

If we are going to avoid a one-sided perception of the past "… we should be interested in the history of both women and men … (…) to understand the significance (…) of gender groups in the historical past" (Davis 1975: 90). It is important to point out that gender is not the same as sex. Gender is "a constitutive element of social relationships based on perceived differences between sexes … and a primary way of signifying relationships of power" (Scott 1986: 1067). Gender is not a natural or biological category, but constructed through social interactions in families, societies, economics and politics. It is strongly related to cultural norms and traditions, and as such, to the history of people and their interaction with their environment. Power is an inherent part of gender construction, meaning that the specialized knowledge resulting from the different domains in which men and women operate is also valued differently (Kelkar 2007). Only a careful differentiation of the roles, responsibilities, access and opportunities of men and women will provide us with a more complete picture of how both have used, governed, and changed their marine environment over time (Williams 2008; Bennett 2005). This requires an analysis of the knowledge of, access to, and use of, fish and other marine resources, differentiated between women and men.

This chapter aims to contribute to the analysis of gendered processes in fisheries, by shedding light on the manifold roles of women, in order to complement and challenge the results of historical fisheries research. After a short review on existing studies on fisheries, gender and history, we provide a systematic overview on important aspects pertaining to women's role in fisheries. We will then introduce a case study on giant clam collection and trade in Indonesia to illuminate how women influence and sustain fisheries in practise, and over time. The case study especially shows the importance of female-dominated historical family networks, an informal institution that is usually overlooked in formal governance-oriented fisheries research. Based on these results, we argue that if fisheries history would regard fisheries also as informal activities immersed in family networks, women might be identified as key-actors, and 'drivers' of the course of fisheries over time.

Studies on Fisheries, Gender, and History

There are not many studies on gender issues in fishing communities, and even less on fishing history. The majority of these few zoom in on women instead of showing wider gendered patterns. This is certainly related to the scientific interest to study less powerful societal groups, to which women often belong (Bennett 2005). It has also to do with the origins of the gender concept, which lay in feminist studies. But for the most part, it has been a response to the limited knowledge of the role of women in fisheries. Interestingly, Allison has recently pointed out that although most fisheries social research is on men, it does not engage with masculinity perspectives/concepts. He argues that both the physical settings and the distinct culture of fishing societies shape a kind of globally shared "marine masculinities". Gendered labour division and men's absence from their families and communities supports a strong masculine group identity, which is potentially reinforced by social and political marginalisation (Allison 2013). Research on masculinity will also support the analysis of women's positions in fishing communities, and might contribute a better understanding of problems such as high HIV rates, alcoholism, and violence found among many fishing communities (Allison and Seeley 2004; Seeley and Allison 2005).

Earlier research explicitly considering women's fishing activities can be found in the anthropological literature about Oceania from the 1920s to the 1950s (Buck 1930; Handy 1923; MacGregor 1937; Firth 1957). Most authors pointed out that women who fished or dived were just as skilled as men. Their observations confirmed that female fishing activities were common at many islands in Melanesia, Micronesia, and Polynesia, although the degree of women's involvement in the different activities varied considerably between individual societies.

The first consolidated publication on women in fishing communities has been the book "To work and to weep" by Nadal-Klein and Davis (1988). It contained 12 essays with a wide cultural and geographical range, some of them also with a historical perspective. A few years later, a publication on the social history of labour in North Sea fishing communities contained two essays which explicitly focused on the historical role of women in Norwegian and Dutch fishing communities (Fischer et al. 1992).

Since then, gender and fisheries research has become an emerging research field. A collection of essays on the lives and experiences of fisher women in Newfoundland and Labrador from early settlement to late twentieth century can be found in MacGrath et al. (1995). The International Collective in Support of Fishworkers (ICSF) has been publishing work on the role of women in fisheries in its newsletter on gender and fisheries "Yemaya" since 1999. In 2000, the journal Women's Studies International Forum published a special issue "Women and the Fisheries Crisis" Davis and Gerrard (2000). The first global symposium on gender and fisheries was held a couple of years later in 2004 (Williams et al. 2006). In 2005, Neis and colleagues published their book "Changing tides: Gender, Fisheries and Globalisation". It provided an overview on the state-of-the art at this point in time, including some 20 regional case studies on a wide range of fisheries, regions, and topics (Neis et al. 2005). Some case studies such as the study on women's crucial role in the Nova Scotia coastal fishery (Binkley 2005), or the section on the Salmon canning industry of British Columbia (Muszynski 2005) employed historical analyses. In 2008, the journal "Development" published a special issue on gender and fisheries. Over the last decade, the number of studies has grown rapidly (Béné and Merten 2008; Frangoudes et al. 2008; Weeratunge et al. 2010; Zhao et al. 2013; Harper et al. 2013). Some key contributions are introduced below.

Yodanis (2000) has studied the social construction of gender in fishing communities in the United States. Her results show that differences between women's and men's orientation towards fishing in her case study were socially learned: while boys were supported if they showed an interest in fishing, girls' interests were interpreted as part of a childlike play. Although many women in her study were active in the fishing business and even helped their husbands on board, these activities were never fully acknowledged as part of the fishery. Women themselves would undervalue the importance of their contributions.

The fisheries dependence on women has been highlighted by several authors (Harper et al. 2013; Bennett 2005). Clay and Olson (2007) even see the strong involvement of women in the resource enterprise as a characteristic that distinguishes fishing communities from other communities. Thompson (1985) has argued that this dependency also gives women more responsibility, and potentially more influence at home and in their community. One important study of the social lives of seventeenth century Dutch fishing communities supports the idea of relatively independent women. Despite of the fact that women in general had few legal rights in the seventeenth century: the seafarers' wives enjoyed a relatively independent status in economic matters: a necessity, when the husband was away for extended periods of time. Also in moral matters, such as cases of adultery, these coastal communities looked more mildly on unfaithful fishermen's wives, than women in general (Wit 2008).

It has sometimes been argued that there is a "dichotomy of sexual geography", under which land is the domain of women and sea the domain of men. This dichotomy has been explained with the frequent absence of men from their families and community, leading to female dominance in the household. Empirical results have shown that this reaches far into the economic and power structures of the fishing community (Pollnac 1984). However, the existence of the sea-land male-female dichotomy itself has been challenged by several contributions in Nadal-Klein and Davis (1988) collection, which showed that women are in charge of, but not necessarily limited to land-based activities. While there is evidence that in some regions, fisherwomen in the past enjoyed greater autonomy in work and social relations than today (Cole 1991), in general the influence of women in fisheries management and decision-making seems to be increasing (Meltzoff 1995; Frangoudes et al. 2008).

At present, there appears to be a general trend from disciplinary publications in anthropology and sociology focussing on selected communities and locations, towards more general considerations of gender issues in fisheries. While earlier work often analysed specific aspects such as power asymmetries (Thompson 1985) or certain aspects of women's work (Volkman 1994), this is now changing to more comprehensive overviews on the role and importance of women in the sector (Harper et al. 2013). Despite the increase in research in gender and fisheries, historical research in particular is still paying very little attention to gender aspects in the marine and coastal realm.

Gender Aspects to Be Considered in Historical Research

There are a number of aspects which deserve more attention in historical research. We are differentiating between catching and collecting of marine resources, pre-and post-harvesting activities including processing and trading, and female governance and institutions. Because historical studies are limited, we also include more recent examples in order to provide a systematic overview on the role of women in fisheries.

Catching and Collecting of Marine Resources by Women

Although most of fish capturing is and seems to have been carried out by men, women have always been fishing. Comparatively well-known are the contributions of women's fishers in the Pacific (Kronen and Vunisea 2007), also through the already mentioned literature from the 1920s to the 1950s. A more recent case study from Fiji states that women are still involved in all kinds of fishing activities, but that their roles have changed over time. For example, net fishing was widely practised by women in the past, but since the introduction of large gillnets, men took over this activity. Women also used barriers or fences to catch fish, which they then caught by hand or with a spear. Other activities such as nocturnal torch fishing are still carried out by women and men in search of eels, octopus, sea cucumbers, and shellfish. Women also continue to dive for shells, which they collect in depths between 8 and 15 m (Vunisea 2005). A new study from the Comoros has not yielded findings on considerable changes. Female fishers in this region still use a large variety of gears, including different nets, baskets, traps, pipes and spears, hand lines, and toxic plants (Hauzer et al. 2013). In Indonesia, Bajau women collect giant clams though reef gleaning and diving, as a case study will show later on in this chapter.

The roles of women in catching and collecting marine resources differ considerably between cultures. Oliver has argued for the Pacific that islands with a higher variety of marine environments are characterized by more stratified gender roles (Oliver 1989). He noticed that in traditional Pacific island cultures living on islands with steep shorelines, few beach and reef areas; men and women are involved in open and deep-sea fishing. On islands with shallow waters and beaches, the more dangerous deep-sea fishing activities are usually carried out by men, while women stay close to the shore. Another study has shown that in the vast majority of societies within Oceania, women have been involved in several types of reef fishing, although the fishing of bonito, tuna and turtles remains restricted to men (Chapman 1987). It seems that generally, men have capitalized the more dangerous, fairly long-term, but also more prestigious fishing activities. However, more research is needed especially to confirm if this is a rather recent, or indeed a long-standing tradition.

Research in the Amazon region has revealed that in the past, women went fishing close to the coast for consumption or sale (Maneschy and Alvares 2005, and references therein). With the beginning of industrial processing, they became workers in gear manufactures as well as fish and crab processing facilities. Still, women use fixed fish traps close to the shore, such as shrimp traps, or large fishgarths. As these large traps cannot be operated alone, they are run and maintained by teams of relatives, who also do the daily harvesting. The importance of women in this sector is mirrored by the special names given to them, such as *pescadeiras* and *marisqueiras* (fish and shellfish harvesters).

Women have played a major role in the development of some fishing industries, such as the Scottish herring fishery from the middle of the nineteenth until the first half of the twentieth century. Fishwives and young girls worked as gutting quines, cleaning and packing herring. These cutting quines would also follow the herring fleets which caught wandering shoals of herring around the coasts. The absence of women from household-based fisheries had a considerable influence on both domestic fishing activities, as well as on the social role of women in coastal fisheries. While the domestic role of women lessened, the power of middlemen and fishmongers grew in small-scale coastal fishing (Nadal-Klein 1988).

Similarly to the herring fishery, girls and young women were employed as fishworkers and cooks in the Newfoundland cod fishery from the late eighteenth to the mid-twentieth century. They also would occasionally fish to increase their income (Thompson 1985). In the early nineteenth century, fisherwomen worked in the sheltered inner fjords of the north Norwegian coast. They also joined the traditional beach seine net fishing of this region and received their part of the catch (Paine 1965 in Thompson 1985). In Swedish Baltic Sea communities, women went out regularly on small inshore boats to fish for bait. In some areas, they also participated in the more dangerous herring fishing farther offshore (Löfgren 1979). A German law of 1587 indicated that female seafarers were common in the Baltic Sea, as it obliged skippers to take a male seaman onboard rather than their wives or young women (Berggreen 1979). In Europe, these activities are nowadays part of fishing history. In other parts of the world such as the Philippines, women still help their husbands in hauling nets and lines, and through installing and maintaining stationary gear (Siason 2012).

An interesting case of female supremacy in the collection of marine resources is the case of Asian *ama* divers. *Ama* (literally "sea women") dive in some coastal areas of Japan, Korea and China. Throughout the year, they collect seaweed, shells and abalone. The women dive 5–20 m either from a boat with a male boat handler, or swim from the shore. The earliest known documentation of *ama* comes from Japan's first chronology *Nihonshoki*, published in 718 (Kato 2006). There has been much debate about why the large majority of *ama* are women. The *ama* themselves believe that women have extra layers of fat on their body, which allows them to stay longer in the water. Traditionally, only girls were introduced into the *ama* community, and received diving gear as their wedding gift (Kato 2006). This is exactly the opposite to what Yodanis (2000) has documented in her study on the construction of gender in a rural fishing community of the United States, and shows how the social construction of gender roles in different societies is the underlying driver of "male" and "female" activities.

In many parts of the world, women gather shellfish and other invertebrates, or fish from the shore or reefs. This activity is known as gleaning, although this not fully captures the importance of this activity. Gleaning has traditionally served subsistence and local market demands, and often plays a major role for nutrition. Valuable resources such as sea cucumbers, giant clams, or octopus, are also collected, and the contribution of such gleaning activities to the family income can be significant. Gleaning activities usually involve a minimum of equipment, but they require a solid understanding of the behaviour of inshore marine resources, weather and sea conditions (Kronen and Vunisea 2007; Hauzer et al. 2013). Simple methods such as locating fish with the feet implicate a very adroit use of the senses, and skilful utilisation of fisheries knowledge (Vunisea 1997). Consequently, gleaning has to be considered as a separate fishing activity. Increasing demand and a higher value of many shellfish species has even strengthened the economic importance of gleaning in many areas. In the Spanish nationality of Galicia, female mussel collectors – the *marisquadoras* – have increasingly professionalized their activities since the 1960s (Meltzoff 1995).

The involvement of women into different fishing activities makes them important knowledge keepers. Given that men and women mostly fish in separate areas, women possess knowledge that men do not have. As a result of their different roles, men and women are exposed to different environments, skills and experiences, and are therefore likely to develop gender-specific domains of knowledge (Kelkar 2007: 301). It has been shown that women may be more knowledgeable than men in terms of certain ecological features (Chapman 1987). Historical research can employ this knowledge to obtain a deeper understanding of a certain ecosystem and its changes over time. As we will explain in the following sections, women also possess comprehensive knowledge on economic and other aspects of fisheries, which can be used for better insights in exploitation patterns over time.

Pre- and Post-Harvesting Activities, Processing and Trading

In many fisheries, women have traditionally occupied the pre and post-harvest sector through processing and marketing the catch (Bennett 2005). Pre-harvesting activities are multifaceted and reach from mending of nets to gathering bait and preparing food for the fishers. For example, Scottish fishwifes would spend several hours per day for gathering the baits and baiting the lines which men used to catch white fish (Nadal-Klein 1988). Portuguese archival documents from the sixteenth century suggest that women played a major role in the maritime trade at this time, including the financing of fishing expeditions to Newfoundland (Abreu-Ferreira 2000). In many West African countries, women provide credit to fishermen and act as patrons in patron-client relationships (Tvedten and Hersoug 1992). In such a relationship, the clients are economically and socially dependent on their patrons, and vice versa. For example: in exchange for credit, clients have to agree to sell their catch at a certain price to their patron, while the patron provides social security even if catches are low. Fanti fishtraders in Ghana often own canoes and fishing equipment, and control fishing operations through loans to fishermen (Endemano Walker 2002). In this way, they have a considerable influence on the realization of fishing activities, although Overå (2003) has argued that the extent of male cooperation determines the space for female entrepreneurs in this male-dominated sector.

Post-harvesting activities include carrying fish from the shore, and the sorting and cleaning of the catch. In small-scale fisheries, the catch is usually divided into a part for own consumption and a part that is sold. The preparation of fish for the household, but also further processing and the selling are typical female occupations. Processing may include drying, smoking, freezing, fermenting, and cooking. The marketing and selling of fresh or processed marine products is in many areas of the world dominated by women. In some regions, traders specialize in single products, such as the *pulpeiras* of Galicia (Northern Spain), who sell only octopus (*pulpo*).

Their role as processors and traders provides women with unique information on changes in target species, sizes and quality, and price fluctuations. This data is often not being accounted for, because the majority of studies interview fishermen and male household heads. Gathering knowledge from fish processors and traders may provide a much broader and more detailed picture of species composition changes and species availability over time. In particular price changes are important indicators for increasing rarity, but also for upcoming demands.

Managing: Gendered Governance and Institutions

Current research indicates that women traditionally seemed to have had very little influence in formalised marine and fisheries management (Fröcklin et al. 2013). McCay has argued that women's participation in the politics of fisheries governance has mainly been important when the men were out fishing (McCay 1993). Only over the past decades, there is evidence that fishermen's wives have increasingly become active as political representatives and lobbyists in fisheries issues, at least in developed countries. As part of organizations such as the "Maine Fishermen's Wives Association" and the "Gloucester Fishermen's Wives", women are now increasingly involved in policy making processes (Yodanis 2000).

Women have also entered formal governance institutions related to fisheries management. One example is the so-called "shellfish revolution" in the late 1980s in Galicia, under which female shellfish collectors have entered the *cofradía*, a traditional community fisheries organization. *Cofradías* ("brotherhood") have been exclusively run by men for centuries, and the active participation of women for more than 30 years has led to a substantial change of women's status and political power in their community (Meltzoff 1995). In developing countries, women's empowerment has often been an obligatory part of fisheries development programs. As a result, they are more often included into existing management structures, although this does not necessarily lead to a reform of the gendered governance structures themselves (Resurreccion 2008).

Their role as collectors and fishers of certain species did of course make women de facto managers through the way they utilized these resources. Unfortunately, there is hardly any literature on the involvement of women in informal marine resource management, perhaps because most historical studies have not taken women seriously as actors engaged in, or even driving marine resource exploitation. Additionally, resource management studies have been preoccupied with formal institutions. Consequently, the few studies that discuss gender issues in (formalized) governance structures point out that woman have been underrepresented therein.

However throughout history, decisions about where, when and what to fish, as well as to whom to sell and on what terms, have also been mediated through informal arrangements. Such arrangements may be nested in networks of family ties, friendships or patron-client relations (Volkman 1994) as well as cultural and spiritual traditions, including taboos to fish in certain places or caring for sea spirits to ensure future yield (Clifton and Majors 2012). It is in these domains that women may have executed (and still execute) considerable influence on fishing practice and fish trade. An example of this is the way in which networks of fishing and fish trade have been organized among the Bajau in Southeast Asia, a case we turn to below.

Case Study: Bajau Women Collecting Clams

A case of giant clam collection and trade by Bajau women in Indonesia demonstrates the importance of women's roles in the organization of marine resource exploitation over time. The Bajau are an indigenous group dispersed over a vast marine zone in Southeast Asia (Saat 2003). Traditionally, they have sustained sea-based livelihoods, living off maritime trade and subsistence fishing (Sather 1997). Whereas the Bajau are often associated with a sea-nomadic way of life (Chou 2006; Warren 1980), their majority lives along shores and on islands in (semi) permanent villages (Clifton and Majors 2012).

In Bajau communities, women can enjoy considerable status and power. They may head households or become spiritual leaders, they are often actively involved in village affairs, and their property (inheritance) is not fused through marriage (Sather 1997). In this respect, gendered power structures among the Bajau differ from some other, more patriarchal maritime groups in Indonesia, such as the Buginese (Pelras 1996). Bajau women are also actively engaged in daily activities of collecting, processing and trading marine resources (Gaynor 2010; Sather 1997).

Their contribution to fisheries and their social networks are therefore indispensable to the organization and continuance of Bajau maritime livelihoods.

Below is a case study of Bajau women's involvement in the collection and trade of the giant clam (a subfamily of bivalve mollusks: *Tridacninae*, or *kima* in *Bahasa Indonesia*) in Berau, a coastal regency in East Kalimantan (Indonesia). It is based on insights from ethnographic research carried out by one of the authors in this region in the years 2011–2013. The case shows that including the activities and social-historical networks of women is essential to an understanding of how fisheries and fish trade networks in the region are organized and sustained.

The Berau coastal area consists of a mangrove delta, coral reefs and a shallow sea. Attracted by its rich marine biodiversity, Bajau families have migrated to the islands and coastal villages of Berau since at least as early as 1919, coming mostly from the Southern Philippines and Sabah (Malaysian Borneo) (Krom 1940; Pauwelussen 2016). Although some people have moved inland, most Bajau still sustain a close relationship to the sea, and the condition and rhythm of the sea pervades almost every aspect of community life, such as household activities, life-cycle rituals, and culinary practice. Bajau fishers are skilled in line-, net-, and spear fishing over reefs, along with manual collection of marine species at low tide, and braving the open sea to catch pelagic fish offshore. In Berau, these fishing techniques are complemented nowadays by the use of bombs and poison (blast fishing and cyanide fishing) (Pauwelussen 2015). Manual collection of marine species at low tide is referred to in the literature as (reef) gleaning; a fishing activity introduced earlier in this chapter. While in *Bahasa Indonesia* this activity is generally translated as *berkarang* (*karang* referring to coral or coral reef) the local Bajau term for gleaning "*ne'bah*", *nubba* in Eastern Indonesia (Gaynor 2010: 84), includes also the gathering of marine animals and plants from sand banks, beaches and mangroves.

In Berau, as in most other places, women take the lead in reef gleaning. They are particularly skilled in identifying and assembling a wide array of edible and/or usable produce from different tidal marine ecosystems. Whereas men and boys do join some gleaning expeditions, 'tending the sea- or coral garden' is referred to as a typical women's job. As a village elder and spiritual leader on one of the islands explained in an interview: "(for us Bajau) The coral reefs are the gardens of women. We men go to the sea, while our women tend to their garden". This tending includes using the proper spells and offerings to nourish relations with the sea spirits that dwell in these gleaning places.

A highly valued resource collected from Berau's coral reefs for both subsistence and market demands is the giant clam, or *kima*. Raw or cooked, it is part of traditional Bajau cuisine, and a vital ingredient for Bajau wedding ceremony banquets. While Bajau communities all over Berau consume *kima*, it is particularly on the islands that the collection of these marine creatures has taken a commercial turn. Along the coast, they are among the most sought-after marine resources by traders buying for Malaysian-Chinese markets. The animal's adductor muscle is highly valued by Chinese, because of its purported aphrodisiac properties.

It is important to note that the collection and exchange of *kima* for commercial purposes is officially prohibited in Indonesia,[1] and it has been given the status of 'vulnerable species' (VU – A2cd) in the 2004 IUCN Red List of Threatened Species (Baillie et al. 2004). As Berau's delta has by now been stripped of most large specimens (some species can measure up to more than one meter in diameter), the major part of *kima* yield nowadays consists of smaller animals (10–15 cm on average) nested in shallow reefs.

While staying in the Berau coastal zone for over a year,[2] one of the authors was able to observe the ways in which *kima* collection is organized. Generally, older women prefer to use an individual canoe to peddle from the island to a nearby reef, alone or with one or two other women in their own canoes. After a day of collecting clams they return home. There are also married couples (sometimes accompanied by children) that use a small boat to gather on reefs further away from the island. They are usually gone for 1 or 2 weeks, sleeping and eating on the boat, and collecting a range of different animals for trade and consumption. The household-based gleaning trips resemble the Bajau fishing expeditions in the 1960s in Sabah (Malaysia), described by Sather (1997). There is also an increase of commercially organized *kima* gleaning trips in Berau which resembles the turn towards niche species by Bajau women described by Gaynor (2010). According to Gaynor this has led to new social relations of production, in which Bajau women gather increasingly scarce resources, such as *kima*, for international trade, often becoming indebted to traders in the process. The commercially organized *kima*-collecting trips in Berau are carried out by groups of eight to ten women (occasionally, a man joins) on a boat owned by a local trader and credit supplier. In these arrangements the trader (mostly a married couple) provides the collectors with a boat and fuel, and in exchange the women are obliged to sell their catch to them. Thereby, the arrangement becomes a form of patron-client relationship, common among Berau's coastal communities (Gunawan 2012), especially when the trader facilitates credit loans in exchange for (future) catch.

Joining these *kima*-collecting trips during the fieldwork shed light on how this fishing practice is carried out. First of all, timing is crucial. Around full moon and new moon the reefs are exposed enough (during low tide) to make the activity safe and worthwhile, which gives the collectors a maximum of 2 weeks per month to gather *kima*. During these weeks, boats leave well before low tide, to moor on or near the reef before it has become too shallow. Women cover themselves with cloths (including shoes) to protect their bodies from the sharp coral, venomous stingrays and the scorching sun. As soon as a suitable spot is found, one of the women asks

[1] Law of the Republic of Indonesia No. 5, year 1990 on the Conservation of Natural Resources and Ecosystems, and Appendix Indonesian Government Regulation No. 7, year 1999: Types of Plants and Fauna.

[2] The research was set up as a multi-sited ethnography. Whereas all three of Berau's inhabited islands were involved in the research as fieldwork locations, one island functioned as base from where different trips and visits were made elsewhere. Because the commercial exploitation of giant clams is officially banned in Indonesia the names of places and people are not given here, in order to protect research informants.

Fig. 1 Bajau woman wading through water looking for kima

the spirits for permission to enter their home, sprinkling the water surface with cooked rice. Then the women get into the water, and start collecting clams while swimming and diving to a depth of 1–3 m, using goggles and a floating piece of Styrofoam to warn passing boats (see Fig. 1). As soon as the water level has dropped, they can walk on and around the coral structures, speeding up the collecting process. They usually collect only the clam's meat, the shell is left behind. To cut the animal out of its shell the women stick a bar between the valves (to keep the shell from closing), while they swiftly cut the abductor muscle with a knife or the same bar. The meat is put in a net, and they quickly proceed onwards, wading through the water, bent forward, peering through the shallow water to spot the next clam in the reef. In just a couple of hours a group of women like this can easily strip nearly all *kima* from half a square kilometre of coral reef.

When the water level rises, the women gather at the boat to go back home. Underway, they compare their catch, and discuss the features of the spot: the coral, the creatures they encountered, and the movement of current and wind. While there is a certain atmosphere of competition between the women regarding the amount of the catch, exchanging information and experiences is a vital part of their gleaning trips.

Earlier we pointed out that women can be valuable sources of knowledge of the marine environment. Obviously, the women gleaners in Berau are experts on local reef flora and fauna, currents and weather as well as changes in the reefs' condition over time. Yet, they are not consulted as such by conservation and government agencies. Staff of the local Fisheries Department hold the assumption that women have no serious role in fishing and that their knowledge is limited to household shores and petty trade (personal communication 2012).

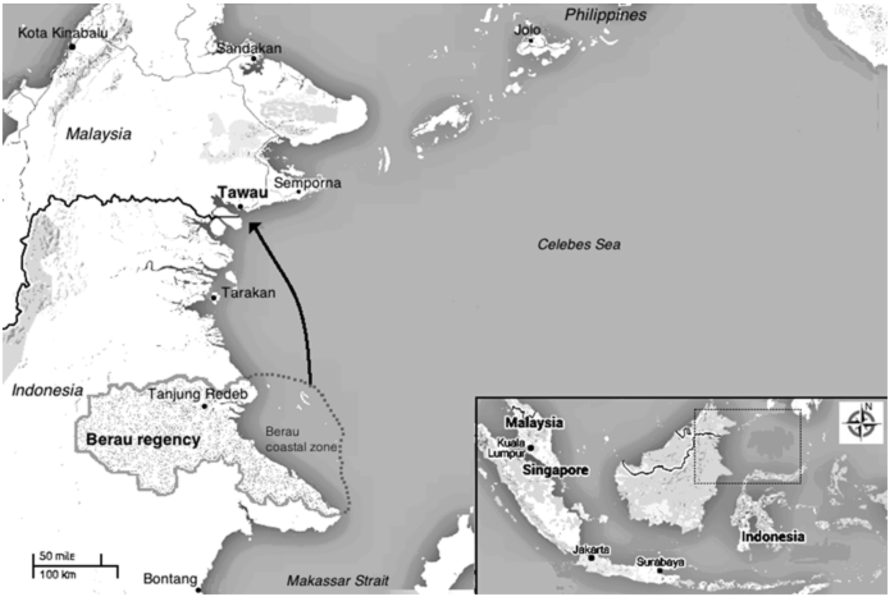
Besides leaving out women as bearers of ecological knowledge, there's also another gap to be mentioned here. As we argued earlier in this chapter, fishing activities of women need to be taken into account to make a reliable estimation of fishing pressure. Based on interviews with local *kima* traders in 2012, we estimate that 300 k of dried *kima* was exported in that year per month, from just one of the three Berau islands involved in *kima* trade (field notes 2012). But because gleaning is considered a fishing practice of little significance, this particular form of marine resource exploitation is invisible in regional fishing statistics and management (DKP Berau 2012). This is striking considering the fact that Berau's coastal zone was declared a marine protected area in 2005 and the trade in *kima* has been officially banned for decades. This status of illegality may in fact be another reason why *kima* exploitation is rendered invisible in regional statistics.

Trading Kima

Most of the *kima* exported from the Berau islands is sold to Chinese traders in Tawau, a border town in Sabah (Malaysian Borneo), often together with fresh or dried fish, squid, sea cucumbers, mother of pearl, shark fins and other marine resources that are highly valued on Chinese markets. Historically, the Bajau have played an important role in maritime trade in this region (Gaynor 2010). Maritime trade by Bajau in the Berau zone dates from at least the late 1800s (idem), possibly even from the tenth or eleventh century (Sather 2002), but historical evidence is scarce.

Besides doing the collecting, Bajau women also preside over much of the trade in *kima*. Earlier studies of the Bajau in Sabah have shown that women have traditionally played a central role in the processing and marketing of marine resources as well as the trade of these resources to Malaysian towns like Semporna and Tawau (Morrison 1993; Sather 1997). In Berau *kima* trade is not restricted to women (nor Bajau), and as we already mentioned above, often husband and wife collaborate in the trading business. But even if a man is known publicly as *kima* trader, it's often his wife who actually manages sales and logistics 'behind the scene'.[3] Over the course of the research, a close relationship was developed with a female Bajau clam trader who positions herself rather on the forefront of the trade business, operating practically independently from her husband. To protect her identity, she is given the pseudonym 'Ibu Mutiara'. Joining her on oversees business trips and family

[3] To illustrate: When the researcher asked around for giant clam traders, people mostly directed her to male traders first. But when asking these men about the clam trade (price, organization, logistics) they referred the researcher to their wives instead, saying something like: 'for the specifics you'll have to ask my wife, it's her business'.



Map 1 Trade network of Ibu Mutiara in the Berau region, Indonesia

meetings yielded some in-depth views on a gendered trade network stretching from Berau to Tawau (see Map 1) (Pauwelussen 2015).

Ibu Mutiara buys sun-dried *kima* directly from the collecting women on the island (the main fieldwork location). She regularly visits the island to buy the clams, paying the women in cash, kind or a reduction in outstanding loans.[4] She doesn't shun away from lending millions of IDR (Indonesian Rupiah) in cash or kind,[5] to be repaid by loyalty and new clams in the future. With such (patron-client) arrangements Ibu Mutiara binds the women to her business and ensures a more or less steady supply of product whenever she visits the island.

Ibu Mutiara manages her business mostly (and preferably) with women. This is not only because of the gendered collection of *kima* or the fact that same-sex contact is considered more appropriate in a dominantly Muslim society. Also, like we indicated above, in many Bajau households women are de facto running the financial and logistical part of the fishing operation. While Bajau *men* generally catch the bulk of marine resources, it's *their wives* who are in charge of processing these resources for export. On the Berau islands we observed that women not only handle sales with traders like Ibu Mutiara, they also manage credit loans and place orders

4 In 2012, 1 k of sun-dried clams was worth 100.000 IDR to 130.000 IDR on the island (8–11 Euros at that time).

5 Providing the women with fishing or household products that she imports from Malaysia.

for fishing gear from Malaysia with the traders they collaborate with. The fact that most of these women's management activities are acted out informally does not diminish their importance in fisheries. After all, small-scale fisheries and fish trade are to a great extent enmeshed in informal relations and practices.

This fusion of informal and business relations is also manifest in Ibu Mutiara's trade network. For the buying, transporting and selling of her *kima*, she goes along with Bajau custom in which networks of collaboration follow or mimic relations of family (Nolde 2009; Sather 1997). New business allies are added to her network by (mutually) determining a certain kinship affiliation, no matter how distant. And if there is no faraway niece or uncle to be found to ascertain such connections, they fall back on a common Bajau ethnicity, which is also referred to as: 'we are all one family'.

The historical-geographical dimension of Bajau social networks is crucial for the way fisheries and fish trade is organized in Berau. Ibu Mutiara descends from the Malaysian-Philippine Bajau groups that have migrated southwards to East Kalimantan in the last 100 years or more (Sather 1997). Until today, Bajau families in Berau sustain close ties of trade and family with oversees places and kin, and there is a constant flux of relatives and trade partners coming in and going out of the Berau delta (Pauwelussen 2016). Although such networks of Bajau affiliation are dynamic and geographically dispersed, they are also cohesive. They are made cohesive through continuous visits, phone calls and exchanges between kin in (and moving between) different places.

Among the Bajau, it is particularly women who make an effort in keeping alive family relations. Because of the tendency to matrilocal residence among the Bajau, the connections between female relatives generally predominate over those between men (Morrison 1993). Moreover, as they do most of the 'networking' through gossip, exchanges and attending ceremonies, Bajau women are also more involved in, and knowledgeable about, family ties than men. Clearly, their social networking is of considerable importance to the way in which fishing and fish trade is organized and sustained.

This historically grown, transnational network of real or imagined relations of family and Bajau ethnicity also form the feeding ground of Ibu Mutiara's business, patterning the lines along which loyalty and reciprocity is motivated and mobilized for her *kima* trade interests. The immersion of business and family is particularly apparent in the way Ibu Mutiara safeguards passage of her *kima* load through customs (crucial because of the protected/illegal status of her trade ware), by maintaining productive relations with (related/Bajau) politicians, police and navy officers (often through their wives) all along the trade route to Malaysia. This routine is supported by the tendency among the Bajau to identify stronger with ethnic-historical affiliation oversees than with national borders and to show more loyalty to family customs than to customs rules.

Summary

Most writings in fisheries history have turned a blind eye to the role of women. Apart from a few noteworthy exceptions which we have tried to summarize in this chapter, the overwhelming majority of studies do not employ a gender perspective. Although gender issues are now increasingly becoming relevant in the fields of fisheries, aquaculture, and marine and coastal management, historical studies are still laying behind. That is astonishing, given the importance of women as harvesters and collectors of marine resources and their central role in processing and trading. The vital role of women in the Scottish herring and the Newfoundland cod fishery are just two examples of female contributions that had a major influence on the development of these industries. As our case study in Berau has shown, women play a major role in the way fishing and fish trade in this region is organized and sustained. They sustain the networks of regional trade patterned along (informal) family/Bajau networks across the sea. Important is the historical dimension of these trade connections: the development of trade networks in time and space, networks in which relations of family, business, and trans-national ethnicity is fused. Based on the findings in this chapter, we argue that a gendered perspective on the different roles of men and women has much to contribute to a better understanding of the history of marine resource exploitation. Insights from a gendered perspective may also help to improve the governance and management of current and future marine resource use.

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