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

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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

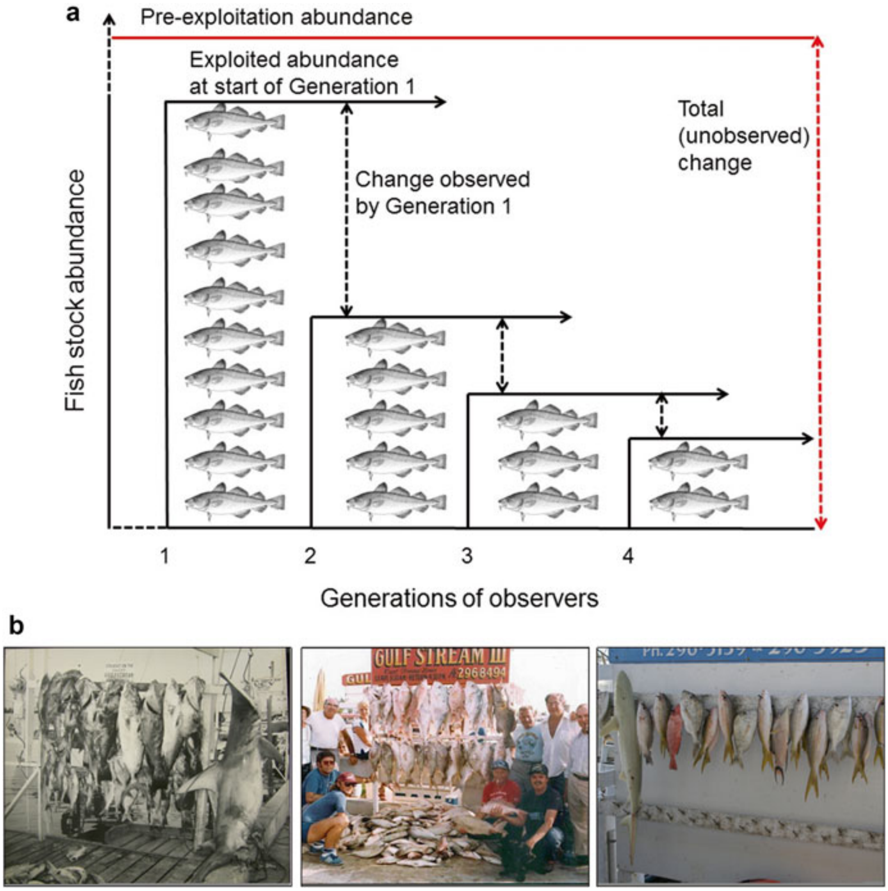

Fig. 1 The shifting baselines syndrome. **a** (*top*) is a conceptual diagram showing shifts in what subsequent generations of observers perceive as a natural population (in this example, a fish stock). Generation 1 initially perceive a stock size slightly declined from pre-exploitation levels, and throughout 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-

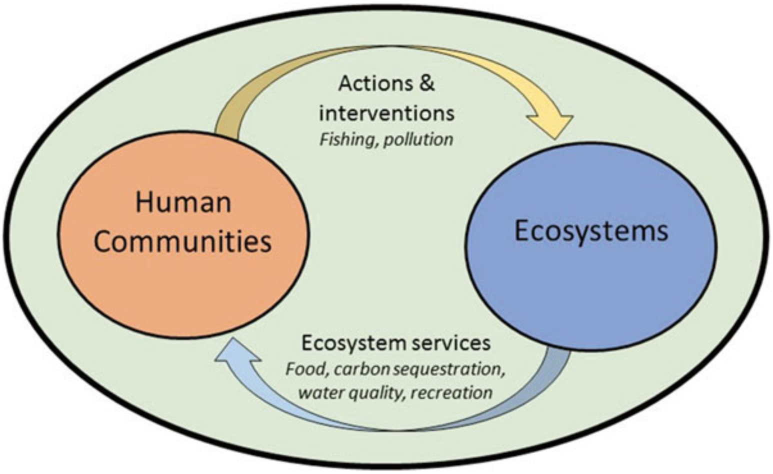

Fig. 2 Schematic of a *social-ecological system* (also described in the literature as a *coupled human-natural system*), demonstrating that human (or social) communities and ecological communities (or ecosystems) are intrinsically linked and interdependent. Ecosystems are altered and shaped by human 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

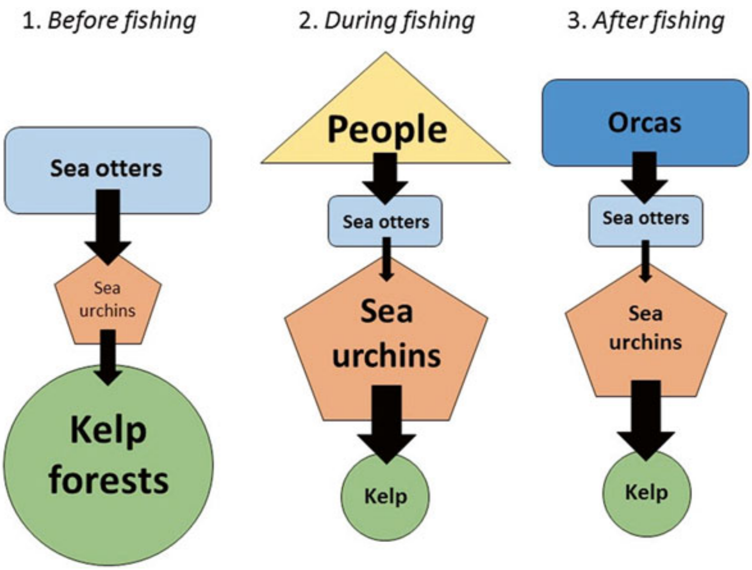

Fig. 3 The impact of fishing on the predator-prey dynamics of a coastal marine ecosystem. Before hunting, sea otters predated upon sea urchins, which in turn grazed kelp. Sea otters were hunted by Aboriginal Aleuts from 2500 B.P., and then subsequently almost to extinction by fur traders during the 1800s. 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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