POLICY PERSPECTIVE

From archives to conservation: why historical data are needed to set baselines for marine animals and ecosystems

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Abstract

Intergenerational loss of information about the abundance of exploited species can lead to shifting baselines, which have direct consequences for how species and ecosystems are managed. Historical data provide a means of regaining that information, but they still are not commonly applied in marine conservation and management. Omission of relevant historical information typically results in assessments of conservation status that are more optimistic, recovery targets that are lower, and fisheries quotas that are higher than if long-term data were considered. Here, we review data and methods that can be used to estimate historical baselines for marine species including bony fishes, sharks, turtles, and mammals, demonstrate how baselines used in management change when historical data are included, and provide specific examples of how data from the past can be applied in management and conservation including extinction risk assessment, recovery target setting, and management of data-poor fisheries. Incorporating historical data into conservation and management frameworks presents challenges, but the alternative—losing information on past population sizes and ecological variability—represents a greater risk to effective management of marine species and ecosystems.

Introduction

A growing number of marine ecologists and fisheries scientists has recognized long-term human impacts on marine species and ecosystems, and developed new analytical methods to incorporate historical data into assessments of change (e.g., Jackson *et al*. 2001; Lotze & Worm 2009). These studies have revealed substantial changes in marine fish, turtle, and mammal populations, providing baselines against which modern populations can be benchmarked (Pauly 1995). Yet while the relevance of these baselines to conservation and management has been noted (e.g., Samhouri *et al*. 2011), in practice, agencies and organizations concerned with long-term trends in the abundance of marine animals rarely use historical data. Relevant data from the past are often overlooked or discarded in extinction risk assessments, recovery target setting, and fisheries management (e.g., Prefontaine 2009). By contrast, terrestrial ecosystem management more commonly employs data from the past, including paleoecological data (e.g., fossil pollen and tree rings) to identify invasive species and wildfire regimes (Willis & Birks 2006), and historical data (e.g., written narratives, photographs, and land surveys) to identify reference conditions for forest restoration (Moore *et al*. 1999).

The historical exploitation of marine animals, which has influenced their modern abundances, typically occurred over shorter timescales than are recorded by marine sediments and fossils, but longer than are captured by modern ecological observations, so that neither adequately reflects anthropogenic impacts. Information from the past several decades to centuries—the recent past—is particularly relevant for long-lived, exploited species, such as marine turtles, mammals, and slow growing fishes. Here, we show how relevant historical data can be gathered and analyzed for a range of marine species and ecosystems, demonstrate that the omission of these data can lead to significantly different outcomes than when they are included, and outline specific conservation and marine management frameworks that would benefit from the inclusion historical data.

Recent historical data: challenges and revelations

Historical data relevant for understanding human impacts on marine animal populations and ecosystems include narrative and archival documents, early survey and monitoring records, interviews with fishers and other resource users, and recent zooarchaeological remains (Figure 1, Table 1). While these data are nontraditional in marine science, disciplines including history, geography, and anthropology rely on them, and have established protocols for their collection and use. When interpreted in an ecological context, such data can be used to estimate quantitative baselines for historically exploited marine animals and to provide perspective on past ecosystem states (Lotze *et al.* 2011a; Table 1). Information from structured interviews with fishers in the Gulf of California ($n = 108$), for example, provided evidence that maximum daily catches of Gulf grouper (*Mycteroperca jordani*) declined by a factor of 25 over the past 60 years ($r^2 = 0.62$, $P < 0.001$) (Saenz-Arroyo *et al.* 2005). Spatially explicit daily catch records from the 1850s for Atlantic cod (*Gadus morhua*) were validated with ancillary historical records and integrated into traditional fisheries models to estimate that cod biomass on the Scotian Shelf in 1852 was 1.26 million metric tonnes (mt), 25 times larger than at present (Rosenberg *et al.* 2005). Zooarchaeological remains and spatially explicit descriptions of the Caribbean monk seal (*Monachus tropicalis*) were modeled with biological parameters from extant species to estimate that 13 breeding populations were eliminated between 1700 and 1952 (McClenachan & Cooper 2008). Methods to analyze historical data include meta-analysis of trends derived from multiple sources (e.g., Branch *et al.* 2004; Ferretti *et al.* 2008), "then and now" comparisons of past and modern abundance information, catch statistics, and trade records (Baum & Myers 2004; Lotze & Milewski 2004; Saenz-Arroyo *et al.* 2005; Rosenberg *et al.* 2005; McClenachan *et al.* 2006), and spatial analyses based on georeferenced data from past resource users and early naturalists (Ames 2004; Lotze & Milewski 2004; McClenachan & Cooper 2008).

Despite advances in historical data collection and analyses of long-term changes in abundances and distributions of marine animals, historical data are not commonly incorporated into existing conservation and management contexts, for several reasons. Historical data are difficult to collect; they may be in a variety of languages, only accessible in small archives for which no metadata or electronic resources exist, or buried in documents created for a different purpose. Furthermore, the challenge of integrating unfamiliar data sets, such as narrative accounts and trade records, into established quantitative modeling frameworks or standardized assessment protocols presents a barrier to their use, as does the fact that data from the past are often imprecise and are therefore not valued as highly as recent monitoring data. Finally, funding barriers exist: management agencies do not typically have the resources to develop new expertise to conduct historical research.

When historical data are included in marine population status assessments they frequently reveal more drastic declines than can be seen with short-term observations alone (Figure 2). The long-lived and historically exploited green turtle (*Chelonia mydas*) provides an example of how the duration of data significantly affects assessments of population change. Green turtles were hunted globally for centuries; historical sources describe tens of thousands of turtles killed for local consumption and export markets, with extirpation of nesting beaches and severe population declines (McClenachan *et al.* 2006; Table 1). Where historical data (>100 years) on the abundance of nesting females on specific nesting beaches are available, "then and now" comparisons reflect these declines, estimating a population reduction of >80%. In contrast, similar comparisons in locations where data are only available over periods of <30 years show net population increases approaching 30% (Figure 2A; data from Seminoff 2004).

Hawksbill turtle (*Eretmochelys imbricata*) populations provide an even more striking example. Intensive hunting of hawksbill turtles for tortoiseshell had severe effects on populations (McClenachan *et al.* 2006): when "then and now" comparisons of nesting females are made with data spanning 52–107 years, they reflect near extirpation, with average declines of 91%. In contrast, similar comparisons using data from the past 8–31 years show populations to be increasing, at an average of 333% over the span of the data. Increases exceeded 700% over 20 years for one breeding population, an implausible figure for the population dynamics of this long-lived species (Figure 2B; data from Mortimer & Donnelly 2008). In the most recent International Union for the Conservation of Nature (IUCN) Red List assessment, qualitative and semiquantitative data from sources including 19th century customs records and natural history descriptions were used to validate the long-term trends derived from historical nesting data, demonstrating that while localized

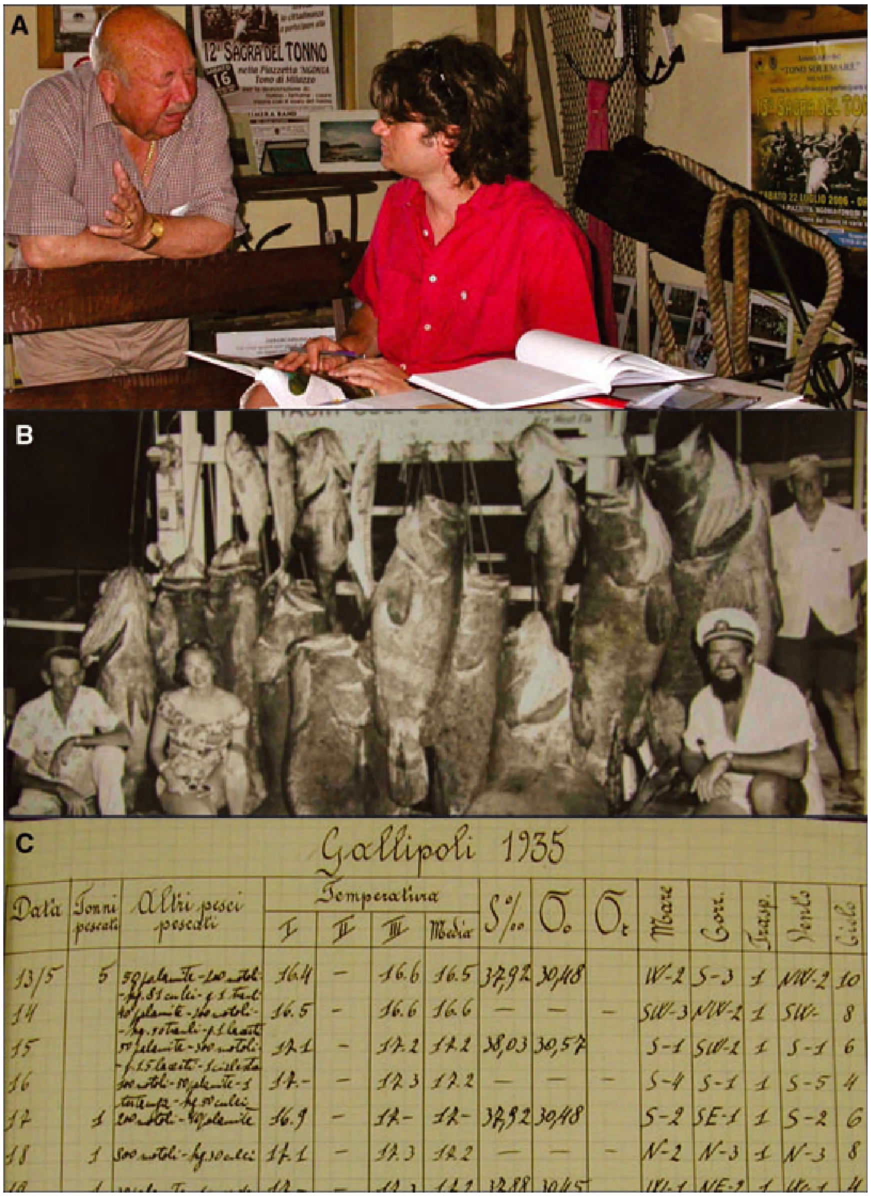

Figure 1 Examples of historical data used in population assessments. (A) Oral information from interviews with resource users in Milazzo (Italy) used to locate tuna trap logbooks (F. Ferretti and tuna trap fisher Tommaso Salmeri; photo credit: G. Osio), (B) Photographs from recreational fisheries in south Florida provided information on size and species composition of fisheries in the 1950s, before survey data exist (Monroe County Public Library, McClenachan 2009), (C) Sample page from the logbooks of the tuna trap in Gallipoli, southern Italy, 1935, retrieved from the personal archive of A. Scaccini.

population increases have occurred recently, globally hawksbill turtle populations have experienced net decreases of >90% over the past century (Mortimer & Donnelly 2008).

Similar results emerge for oceanic sharks, which have been caught incidentally in commercial fisheries for at least the past half-century. For blue sharks (*Prionace glauca*) in the Mediterranean, meta-analysis of instantaneous rates of change derived from a variety of historical data sources, including commercial landings, scientific surveys, and sighting records beginning in 1950, suggested population declines of 97% (95% confidence interval [CI]: 15–99%), which would imply a baseline 2.5 times greater than previous estimates based on comparisons of catches per unit of effort between 1978 and 1999 (Figure 2C; Cavanagh & Gibson 2007; Ferretti *et al.* 2008). For oceanic whitetip sharks (*Carcharhinus longimanus*) in the northwest Atlantic Ocean, recent pelagic longline

Table 1 Examples of studies using historical data to estimate baselines for marine species and ecosystems and descriptions of the insights gained through the use of these data

Baseline date	Species & region	Historical data type	Insight gained	Reference
1960s	Black leather chiton, Kenai Peninsula, Alaska	Traditional ecological knowledge (directed interviews with village elders), historical records, zooarchaeological data	Declines driven by serial depletion of other marine invertebrates, as well as predation by reestablished sea otters	Salomon *et al.* 2007
1960s–1920s	Atlantic cod, Gulf of Maine	Interviews with retired fishermen, early scientific studies and records	Almost half of coastal cod spawning grounds lost over 50–70-year period	Ames 2004
1950s	Oceanic whitetip & silky sharks, Gulf of Mexico	Fisheries research surveys & written descriptions	Populations declined by 99 and 90%	Baum & Myers 2004
1940s	Large marine megafauna, Mediterranean Sea	Interviews with fishermen	Frequency of encounters between large megafauna (sharks, turtle, dolphins) and fishers decreased between 1940 and 2008	Maynou *et al.* 2011
1940s	Gulf grouper, Gulf of California	Interviews with fishermen	Catch rates declined by a factor of 25	Saenz-Arroyo *et al.* 2005
1920	Goliath grouper, Florida Keys	Photographs & newspaper articles related to recreational fishing	Catch rates declined by 86% between 1956 and 1979; fewer fish were caught from shore after 1950	McClenachan 2009
1905	Blue whale, Antarctic (South of 60°S)	Historical catch records, sighting surveys, life histories, rates of change of other blue and baleen whales	Modern population abundance is <1% of abundances in 1905	Branch *et al.* 2004
1890s	Bottomfish, England & Wales	Landings data corrected for increases in fishing power	Decline in landings of 94%	Thurstan *et al.* 2010
1852	Atlantic cod, Scotian Shelf, Northwest Atlantic	Commercial fisheries logbooks	Biomass was 25 times larger than at present	Rosenberg *et al.* 2005
1827	Large sharks, Mediterranean	Commercial & recreational fishery landings, scientific surveys, sighting records	Five species declined 96–99.99%	Ferretti *et al.* 2008
1600s	Lobster, Juan Fernandez Archipelago, Chile	Fishers' ecological knowledge, historical anecdotes, catch data	Virgin biomass was >6 greater than biomass today	Eddy *et al.* 2010
1400s	Green and hawksbill turtles, Caribbean	Historical observations of distribution and hunting from sailors, naturalists, settlers	Twenty percent of nesting sites are extinct; populations have declined by >99%	McClenachan *et al.* 2006

logbook and catch rate data that were standardized using generalized linear models suggested population declines ranging from 50% to 70% over 8–13 years (Baum *et al.* 2003; Baum & Blanchard 2010), while a "then and now" comparison of catch rates in exploratory (1950s) and recent (1990s) tuna fisheries synthesized in a similar modeling framework suggested declines exceeding 99% for this species in the Gulf of Mexico (95% CI: 98.3–99.8%; Figure 2D; Baum & Myers 2004). For sharks and other species caught as bycatch, the use of "nontraditional" historical data and analyses can greatly enhance evaluations of long-term change, as time series data used

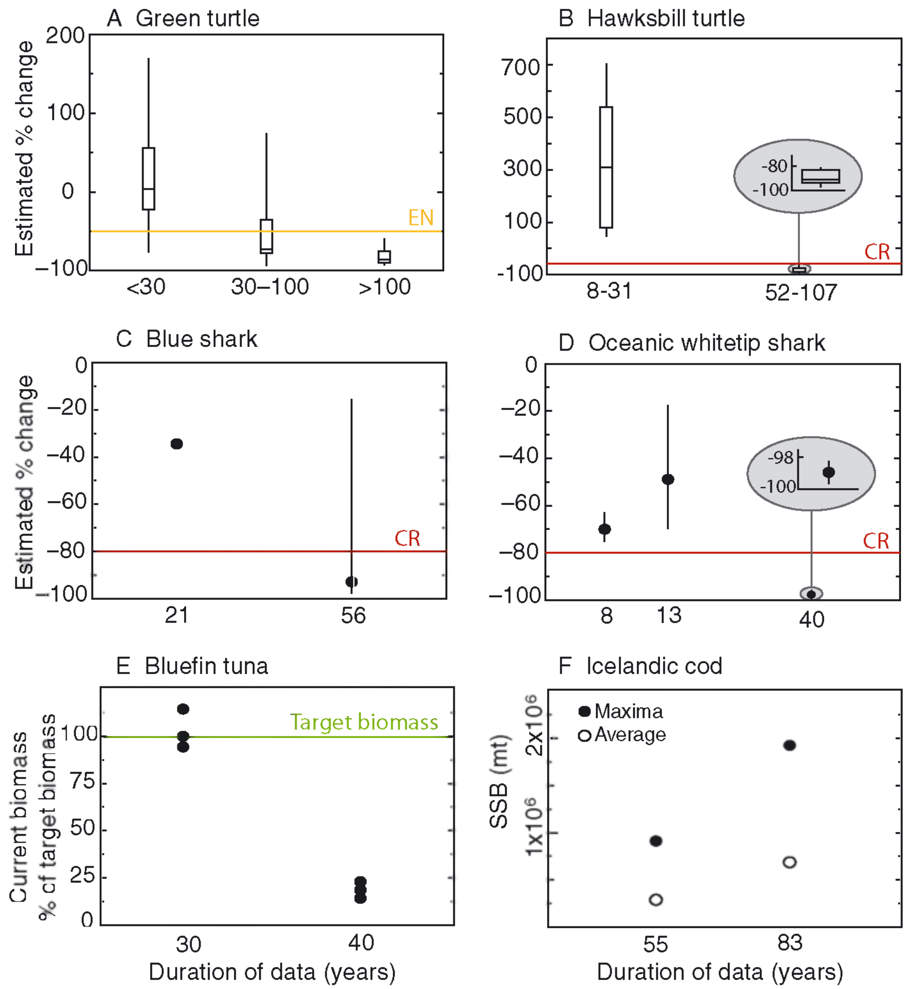

Figure 2 Estimates of long-term population change are typically more negative when long-term or historical data are included. (A) Green turtle: Population trends from nesting beaches with data that span <30 years, 30–100 years, and >100 years suggest median population change of 7% (full range: –77% to +170%); –73% (full range: –88 to +75%); and 83% (full range: –65% to –93%), respectively. Those with data spanning >30 years would be assessed as Endangered by the IUCN (yellow line) whereas those with data spanning <30 years would not (Seminoff 2004). (B) Hawksbill turtle: Population trends from nesting beaches with data that span 8–31 years and 52–107 years suggest median population change of –96% (full range: –80% to –99%) and 308% (full range: 64–705%), respectively. Those with data spanning 52–107 years would be assessed as Critically Endangered by the IUCN (red line) whereas those with data spanning 8–31 would not (Mortimer & Donnelly 2008); (C) Blue shark: Comparison of catch per unit effort data over 21 years suggested declines of 38.50%, whereas meta-analysis of multiple time series data over 56 years suggested declines of 96.53% (95% CI: –15 to –99%) and indicated that the species is Critically Endangered (Cavanagh & Gibson 2007; Ferretti *et al.* 2008); (D) Oceanic whitetip shark: Data from the north Atlantic over 8 & 13 years suggest declines of 70% (95% CI: –62 to –75%) and 50% (95% CI: –17 to –70%) respectively, but data from 1955 to 1959 suggest declines of 99.3% (95% CI: –98.3 to –99.8%), which qualified the population for Critically Endangered status (Baum et al. 2003; Baum & Myers 2004; Baum & Blanchard 2010); (E) Bluefin tuna: Current stock size for western bluefin tuna exceeds targets (SSB 2009/SSB MSY) when shorter time series (30 years) are used, but are only 15% of targets when longer time series (40 years) are used (ICCAT 2010); (F) Icelandic cod: Truncation of the earliest 27 years of data obscures maximum levels of SSB, suggesting that the maximum SSB was less than half of peak values in the 1920s and 1930s and reducing the overall average SSB (Prefontaine 2009; ICES 2011).

to develop indices of abundance or population dynamics models are typically short and often not species-specific.

Truncation of time series in fisheries management leads to a similar loss of information about past conditions. When the target stock size (B_{msy}) for western bluefin tuna (*Thunnus thynnus*) is estimated with data beginning in 1970, the stock emerges as severely overfished (biomass of only 15% of the target). In contrast, excluding data from the 1970s—when populations were more robust and more juvenile fish were observed entering the fishery—suggests that the current biomass exceeds target values and implies that fishing has had little impact on the stock (Figure 2E; Safina & Klinger 2008; data from ICCAT 2010). For Atlantic cod (*G. morhua*) in Iceland, truncation of the earliest 27 years (1928–1954) of time series data removed data from decades when average stock sizes were six times greater than at present, obscured maxima in spawning stock biomass (SSB) and reduced estimates of long-term average biomass, making current stocks appear less depleted by contrast (Figure 2F; data from Prefontaine 2009, ICES 2011). A recent analysis suggests that such data truncation is not uncommon: 32% of North Atlantic stock assessments for commercially exploited fish excluded previously used data from the earliest dates in a time series. On average, 24 years of early data were discarded, resulting in reductions in estimates of the maximum levels of SSB for several herring (*Clupea harengus*), haddock (*Melanogrammus aeglefinus*), and cod (*G. morhua*) stocks (Prefontaine 2009).

Perhaps most importantly, failure to consult relevant data from the past results in a loss of information on population dynamics and ecosystem variability. For 96% of the stocks considered by Prefontaine (2009), truncation removed information on extremes in SSB, population fluctuations, or precedents in recovery or decline. For one stock (summer spawning Icelandic herring), discarding the earliest years of data obscured an SSB minima, and one would expect that for species such as American lobster (*Homarus americanus*), whose populations have increased due to declines in predator abundances (Steneck & Wilson 2001; Frank *et al.* 2005), historical data would include population minima outside the range of modern data. For blue sharks (*P. glauca*) in the western North Atlantic, data beginning in the 1950s revealed complexities in the population trajectory not captured by more recent data, which suggested declines of 60% since the mid-1980s (Baum *et al.* 2003). Synthesis of multiple time series suggested that declines in the 1980s were preceded by a period of stable or increasing abundance (1950s–1970s), so that overall decline may have been less dramatic (Aires-da-Silva *et al.* 2008). Such information on variability over time is essential for interpreting modern population changes, evaluating recovery potential, and understanding long-term dynamics in marine ecosystems.

Conservation and management applications

The use of historical data frequently reveals the extent to which humans have altered population abundances and ecosystem dynamics, and in doing so, encourages more precautionary conservation and management. For green turtles, hawksbill turtles, and oceanic sharks, the use of data spanning the entire three-generation time period commonly used in extinction risk assessments not only demonstrates severe declines as noted earlier, it also makes populations emerge as endangered or critically endangered when they appeared not to be at risk if only shorter term data were considered (Figures 2A–D). Including the entire time series for bluefin tuna would suggest that recovery targets should be higher and that fishing should all but cease (Safina & Klinger 2008; ICCAT 2010). For these and other marine species, historical data facilitate more accurate assessments of extinction risk, better-informed recovery targets, and more robust and ecologically grounded assessments of fisheries stock status.

Extinction risk

The most straightforward application of historical data is to assessments of extinction risk, such as those coordinated by the IUCN Red List, which estimate population change over a species' most recent three generations (but no less than 10 years, Criteria A1,2 v3.1). Marine animals evaluated as Endangered or Critically Endangered using these criteria had an average three-generation time period of 45 years; for 25% of species, it exceeded 60 years (data from IUCN 2011), demonstrating a widespread need for long-term data to conduct accurate assessments of extinction risk. These assessments are frequently bedeviled by a lack of data, hindering the management of species from small invertebrates to large charismatic species such as sharks (McClenachan *et al.* 2012). A quarter of marine species evaluated by the IUCN lack sufficient data for assessment (data from IUCN 2011), and in many cases, historical data prove to be the only reliable information for use in assessments of extinction risk. For example, targeted research in archives, fisheries management agencies, and local libraries yielded multiple data sources spanning 180 years on the abundance of large sharks. These data were used to estimate trends in abundance of five species that previously lacked regional quantitative assessments (Table 2, Cavanaugh & Gibson 2007; Ferretti *et al.* 2008). Similar efforts are underway for sawfish (Pristidae) arguably the most endangered group of marine animals (IUCN 2011). Sawfish abundance and distribution records are sparse, but a long history of targeted exploitation, combined with the unique appearance of these fishes, suggests that historical records documenting sawfish exploitation exist and can be used to develop baseline estimates and extinction risk evaluations.

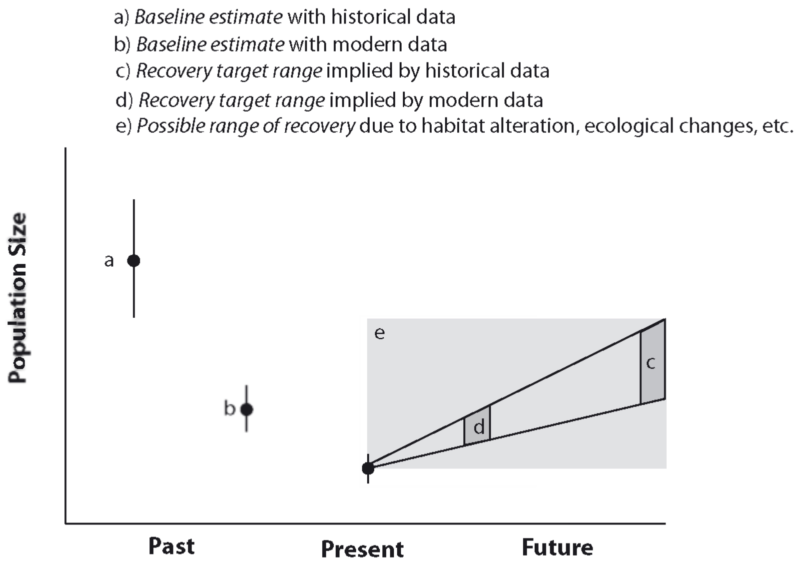

Figure 3 Estimates of past population sizes are typically greater, though less precise, with historical data (a) than without (b). Setting a recovery target is a political process but is often informed by past abundances, so that targets may increase when historical data are used (c vs. d). Recovery potential can be limited by changes in the ecosystem, so restoring "pristine" abundances may not be possible (e).

Table 2 Long-term change in shark populations, with and without historical data (Ferretti *et al.* 2008; Cavanagh & Gibson 2007)

	Without historical data		With historical data	
Species	Baseline date	Trend	Baseline date	Trend
Prionace glauca	1979	–38.50%	1950	–96.53%
Alopias vulpinus	Absent	Absent	1898	–99.99%
Lamna nasus	Absent	Absent	1827	–99.99%
Isurus oxyrhincus	Absent	Absent	1827	–99.99%
Sphyrna zygaena	Absent	Absent	1827	–99.99%

Contextualizing recent recovery and setting targets

Historical data pertaining to past abundances or geographic ranges can also be used to help to inform recovery targets (Scott *et al.* 2005). Unlike estimates of extinction risk, setting recovery targets is a political decision. For many reasons, including changes in environmental regimes (Duarte *et al.* 2009), fluctuations in predator and prey population abundances (Baum & Worm 2009), habitat loss (Marsh *et al.* 2005), and management goals, it is often neither possible nor desirable for recovery targets to be equivalent to historical baselines (Figure 3). Nonetheless, clear understandings of past population trajectories and ecosystem condition are essential to inform these decisions.

Under the U.S. Endangered Species Act (ESA), past population abundances, range sizes, and extent of historical habitat commonly inform recovery planning. Recovery targets might be equivalent to observed abundances in the recent past, such as for the Endangered Kemp's Ridley sea turtle (*Lepidochelys kempii*; FWS 2010) and the Hawaiian monk seal (*M. schauinslandi*; NOAA 2007), or may be a percent of estimated historical abundances, such as for the Endangered southern sea otter (*Enhydra lutris nereis*) whose target is approximately 20% of estimates of its early 20th century abundance (FWS 2003). Recovery targets also may include explicit ecosystem baselines, such as for the Endangered smalltooth sawfish (*Pristis pectinata*) whose delisting requires that at least 25% of mangrove habitat observed in aerial photographs in 1940 be available (NOAA 2009). Past conditions are commonly referenced in recovery plans, but resources often do not exist for a systematic review and synthesis of historical sources, so that accurate population "baselines" that could be used to inform these legally binding recovery targets are often unknown.

Qualitative and semiquantitative historical data are particularly relevant to recovery target setting for historically exploited species that are experiencing recent population increases (Lotze *et al.* 2011b). For example, Branch *et al.* (2004) used Monte Carlo simulations, Bayesian statistics, and meta-analyses to combine and analyze data from early 20th century whaling logbooks and unstandardized sighting surveys beginning in the 1960s for the Antarctic blue whale (*Batenoptera musculus intermedia*). The results suggested that although the population increased by ~7% per year from 1974 to 2004, it was still below 1% of preexploitation abundance levels, and should therefore remain protected under the Endangered Species Act. This and other recent population increases are promising, but without data describing the period of exploitation, the magnitude of the recovery can be overestimated. Historical data can contextualize recent recoveries and provide more realistic assessments of population dynamics than can be derived from modern ecological data alone.

Fisheries management

In the management of large-scale fisheries like for tunas and groundfishes, early time series and historical data can contextualize current stock status and inform strategic decisions about recovery goals (Ricard *et al.* 2012). Data truncation due to uncalibrated changes in research protocols, such as survey designs, gear, or vessels (e.g., STECF 2008) often precludes the use of early data for estimating reference points (e.g., B_{msy} and F_{msy}), which rely on time series data of catch, fishing effort, and indices of abundance from research surveys. However, completely discarding early data risks losing important information on historical maxima of stock health indices, such as fish size, relative abundance compared to other species, or unexploited SSB, which are critical in understanding long-term stock dynamics and recovery potential.

Historical data also have great potential to be used in data-poor fisheries, for which reference points and recovery targets are typically generated with a diversity of data types. The precedent for using Traditional Ecological Knowledge to help understand stock structure and distinctiveness, migrations and ontogenetic changes, and trends in landings and catch per unit effort (Neis *et al.* 1999; MacKinson 2001; Berkes 2003) suggests the potential to use historical data to manage these stocks. In fact, reference points such as B_{msy} can be set using historical catch trends (Berkson *et al.* 2011), and recovery targets for data-poor fish stocks have been set using a variety of nontraditional data sources including and interviews with resource users and diver logbooks spanning 20 years (Porch *et al.* 2006). Frameworks therefore exist to integrate a diversity of historical data sources that reflect long-term population dynamics (e.g., McClenachan 2009).

Engaging the public and stimulating policy changes

Finally, historical data can help stimulate public engagement and conservation action where there is a demonstrated need. For oceanic sharks, the scale and magnitude of population declines revealed by historical data helped to garner support for improved shark conservation measures, including shark finning regulations, a ban on retaining oceanic whitetip sharks taken as bycatch in international waters of the Atlantic Ocean, and the European Union Action Plan for Sharks, which should reduce bycatch of >40 threatened species of elasmobranchs in the Mediterranean, North Atlantic, and global seas (European Commission 2009; Shark Alliance 2010). In the recent designation of marine protected areas in California, photographs depicting the decline in size of recreationally caught fish over 50 years drew attention to underwater changes in fish communities and engaged the public in debates over designating areas closed to fishing (LaFee 2009). And in the Florida Keys National Marine Sanctuary, ecological baselines have been used to demonstrate to stakeholders how the abundances and distributions of major habitat types such as mangroves have changed over the last century, and to communicate the goals of habitat conservation within Sanctuary boundaries (FKNMS 2011).

Ways Forward

Two distinct methods of approaching conservation assessments exist. One prioritizes the precision of quantitative data and structures assessments around the availability of consistent, standardized time series. If the goal is to understand long-term population change, however, more realistic results will be achieved by reversing the process. In this case, the appropriate temporal scale of analysis should first be determined, and then the best data to describe change over this time period should be identified. In some cases, the best data will be qualitative or semiquantitative, lack consistency, or come from several unstandardized sources (e.g., Branch *et al.* 2004; Mortimer & Donnelly 2008). Identifying multiple data sources is particularly important for historically exploited long-lived species for which long-term trends can rarely be evaluated accurately with a single source.

Locating data that most appropriately reflect long-term changes often requires a major interdisciplinary effort (e.g., Rosenberg *et al.* 2005). Data appropriate for assessments often can be found by employing historical, sociological, and information technology research methods, including targeted searches in local and regional archives and libraries (Lotze & Milewski 2004; McClenachan *et al.* 2006), interviews with past resource uses (Saenz-Arroyo *et al.* 2005; Ames 2004), and compilation of scattered fisheries records maintained by disparate management bodies (Ferretti *et al.* 2008). Efforts to make data accessible, such as those by the History of Marine Animal Populations (www.hmapcoml.org), Ocean Biogeographic Information System (www.obis.org), and by researchers themselves (Reichman *et al.* 2011) should facilitate the use of historical data in both academic and management contexts. Finally, although it is methodologically simpler to rely exclusively on modern standardized data, relevant data should not be discarded because they differ in format, quality, resolution, and scale from the recent data with which they will be compared. Statistical approaches including meta- and Bayesian analysis, which allow researchers to synthesize data from heterogeneous sources and incorporate semiqualitative or qualitative data about past conditions, such as expert opinion (Newton 2010), have provided new insight about past population states (e.g., Branch *et al.* 2004; Ferretti *et al.* 2008).

Conclusion

Terrestrial ecosystem management has expanded its use of data to incorporate information from the past, including paleoecological data and historical narratives. In marine resource management, the quest for historical baselines has evolved from a search for "anecdotes from the past" into the formal discipline of historical marine ecology, whose data and methods can do much to inform IUCN Red List Assessments, Endangered Species recovery plans, and fisheries assessments. Inclusion of such data is especially pertinent to data-poor species that lack more traditional time series data and populations whose abundance trajectories have reversed (from declining to recovering), such as marine mammals and turtles. Incorporating historical data into management and conservation often increases estimates of maximum population abundances and of the capability of marine ecosystems to support large, productive populations of marine fish, turtles, and mammals, and can alter scientists', managers', and the public's perceptions of recovery potential. Finding and integrating historical data into modern population assessments is not trivial but ensures that useful information is not lost and the best data are used to establish accurate benchmarks for conservation and management.

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