

ORIGINAL ARTICLE



WILEY

Pathways for integrating historical information into fisheries decision-making

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Funding information

Canada Research Chairs, Grant/Award Number: 2020-00204; Pew Marine Fellows Program, Grant/Award Number: 00036365; Save our Seas Foundation; Conservation Paleobiology Network; Russell E. Train Education for Nature; The Rufford Foundation

Abstract

Historical information has provided key insights into long-term ecological change to marine species and ecosystems, with value to fisheries. Yet, pathways to integrate these diverse data sources into fisheries decision-making have not been clear. Here, we identify an array of biological, ecological, and social information suitable for contemporary science-based decision-making, derived from local ecological knowledge, historical archives, archaeological middens and palaeoecological material. We outline two broad pathways to integrate these historical data into fisheries decision-making, demonstrating that data-driven use of historical information is relevant across a range of management contexts. First, historical information can inform fisheries assessments that range from simple to complex, affecting indicators of stock status. Second, it can inform estimates of biological potential and social preference, affecting the choice of fisheries reference points. Using the Caribbean Sea as an example, we illustrate these ideas with case studies representing diverse species and historical data types. Integrating historical data can improve indicators of the current state of fish populations and result in management decisions based on a more complete understanding of a potential range of variation, avoiding shifted baselines. The urgency of this work is underscored by accelerating environmental changes and the rapid loss of invaluable historical information sources. By illuminating pathways, our goal is to increase the accessibility of these types of information and to underscore that scientists, managers, and resource users have roles to play in identifying and integrating relevant long-term data at various spatial and temporal scales to sustainably manage marine fisheries.

KEYWORDS

Caribbean Sea, fisheries assessments, fisheries management, fisheries reference points, historical ecology, shifting baselines

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1 | INTRODUCTION

Marine ecological systems are complex and variable, affected by both environmental and anthropogenic drivers of change that work on a variety of time scales. Monitoring these dynamic systems through time is crucial for informed management aimed at improving ecological health, fisheries productivity, and the livelihoods they support. One common management challenge is reconciling temporally truncated monitoring programs with longer term dynamics, including at population, species, and ecosystem scales. Shortened time series can result in reference points and associated indicators of change lacking historical context, contributing to shifting baselines and an erosion of knowledge about ecosystem productivity and potential (Pauly, 1995). For example, truncation of time series used to assess the status of North American commercial fisheries led to decreased knowledge about carrying capacity, natural variability, population fluctuations, and precedents in recovery or decline (McClenachan et al., 2012; Schijns & Pauly, 2022). This lack of historical awareness can affect fisheries decision-making. In the case of the economically and culturally valuable Atlantic bluefin tuna, a shortened time series suggested a lower carrying capacity and target population size, underestimating the impact of decades of intensive fishing (McClenachan et al., 2012).

One promising solution for providing a longer term perspective on ecosystem dynamics is the use of historical data (Jackson et al., 2001). Drawing from diverse sources including paleoecology, archaeology, historical archives, and local ecological knowledge, historical ecology has yielded invaluable insights into marine species and fisheries. Use of these long-term data has revealed orders of magnitude declines in biomass (Rosenberg et al., 2005), catch rates (Thurstan et al., 2016), individual body size (McClenachan, 2009a), geographic distribution (Alleway & Connell, 2015), and ecological function (Zu Ermgassen et al., 2012), alongside serial depletions across trophic levels (Steneck & Pauly, 2019). While it may not be possible to fully restore this past productivity in some cases, knowledge of past baselines can serve as a catalyst for recovery. In southern Australia, for example, historical information about oyster bed distribution derived from 19th century maps and catch records motivated oyster restoration as essential habitat for recreationally caught fish (Alleway & Connell, 2015). Similarly, in the North Sea, information on herring distribution since the 1930s was used as evidence to support local management, enhancing the potential for recovery of spatial resilience (Engelhard et al., 2016).

Yet, instances of historical data use in fisheries decision-making are less common than might be expected. While recorded or estimated fisheries catch data are frequently used in fisheries assessments, these are usually truncated and limited relative to what may be available (Engelhard et al., 2016). Linking historical ecology research to fisheries management has been constrained by a need for two sets of specialized knowledge: the specific data needs for fisheries decision-making and the existence of historical data that would meet these needs. Here, we aim to help bridge the gap between historical ecologists and fisheries scientists to outline paths to leverage historical data to inform sustainable fisheries

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management. The need for this work is underscored both by a loss of diversity, productivity and resilience in marine ecosystems (Steneck & Pauly, 2019) and the rapid loss of crucial sources. Our framework for including historical data to improve management is transferable across geographies and management contexts, with the goal of more accurately quantifying historical baselines, which may support more ambitious targets for restoring ecosystem productivity, functioning, and resilience.

2 | HISTORICAL DATA

2.1 | Historical source types

A variety of historical data sources exist that are relevant to fisheries decision-making (Figure 1a,b). Local ecological knowledge (LEK) is information acquired empirically that reflects the lived experiences

of individuals and their relationship with the environment (Brook & McLachlan, 2008). LEK can be collected via in-person interviews or surveys with local knowledge holders and is available over the living memory of these knowledge holders. It can also be passed down over generations when it is called Traditional Ecological Knowledge (TEK). TEK includes information from cultural stories and artefacts, which can provide information including markets and trade, gear and vessels, and species preferences. For example, the Haida origin story from British Columbia describes the first people emerging from a clam shell, emphasizing the importance of clams to coastal communities (Hayes et al., n.d.). All individuals hold some degree of LEK, but the value of this information increases according to their proximity to and interest in the ecosystem of interest. For example, older fishers with decades of experience are often key knowledge holders in their communities. While potential biases in these data exist as fishers' memories are imperfect and there may be incentives to misreport observations (McClenachan & Neal, 2023), fishers' LEK has proved to be a cost-effective monitoring tool for fisheries in data-limited situations, and can help to describe the history of exploitation and use, including historical fishing grounds for critically endangered species (Rubio-Cisneros et al., 2023) and general historical trends in fish abundance (Beaudreau & Levin, 2014).

Archival or documentary sources are typically associated with written human history. Sources can include early observations of new environments associated with colonial exploration, trade logs

documenting the establishment of markets, tax records on products sold in these markets, early natural history studies, government surveys and records generated by residents and travellers, such as newspaper articles, photographs, restaurant menus and nautical charts. Archival data sources can provide insights into marine fisheries spanning several centuries, in particular for species with high value such as Atlantic cod and bluefin tuna (Del Valle et al., n.d.). These sources can be found in institutional or government archives, or in personal collections (Van Houtan et al., 2013). Archival records do not exist consistently for all species or at the species level, and exist as a function of the past social or economic value of that species, as well as the incentive to preserve these documents over time (McClenachan et al., 2015).

Archaeological sources relevant to fisheries include rock art, such as carvings and paintings that show species that were present or captured, gear such as spears, weirs, and traps that help to characterize fishing effort, and kitchen middens, or refuse heaps associated with past or recent coastal settlements that document consumption. Zooarchaeological data, or the analysis of animal remains, reflect human consumption of marine resources over the timeframe of human occupation, which typically spans hundreds to thousands of years. Archaeology provides particular insights into rates of extraction or depletion of marine species, and can help to document changes in the availability of marine resources over time (Rick & Lockwood, 2013). Like archival sources, biases in zooarchaeological

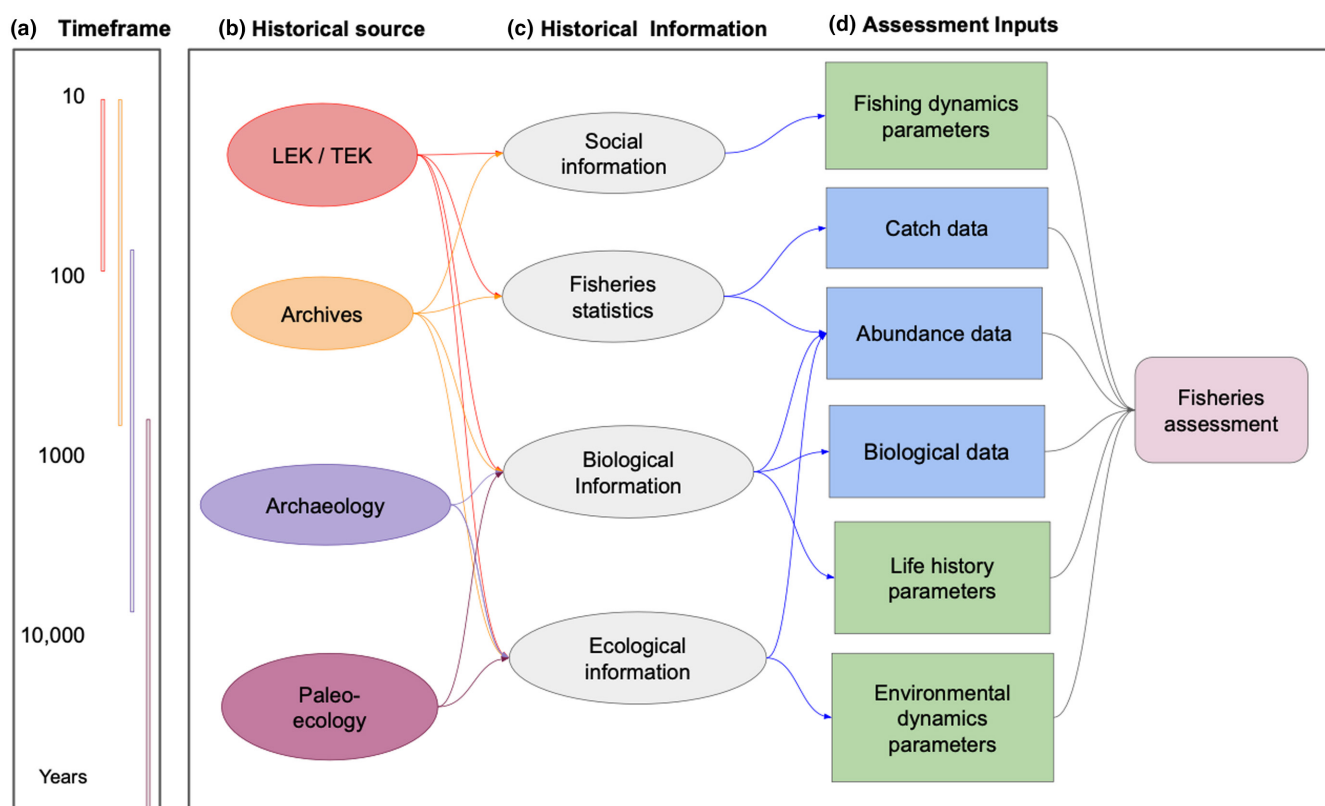


FIGURE 1 Pathways for integrating historical information into fisheries assessments. The timeframes (a) over which historical sources (b) are available. Historical information (c) provided by these sources can be input into fisheries assessments (d) as both data (blue boxes) and model parameters (green boxes). See Table 1 for more details about types of historical information available in different historical sources.

data are associated both with human preference and selection of target species, and the preservation of bone and shell materials over time.

Palaeoecological sources provide information on coastal marine environments and species spanning thousands to millions of years. Fossils analysed from sediment cores and samples, surveys of previously submerged ecosystems such as coral reefs, and museum specimens can provide records of change from the prehuman period (tens of thousands of years ago) to present. Palaeoecological data can be biological in the form of animal fossils, or biogeochemical, in the form of chemical signatures that help to document environmental conditions, such as salinity and temperature, over time (Finnegan et al., 2024). Palaeoecological data from sediment cores can document changes over several millennia and therefore—unlike archaeological data—have the capacity to document the status of coastal marine ecosystems prior to human settlement of coastal regions and are not filtered through the lens of human preference. Palaeoecological records also exist for many species, in the form of fossilized bony fish otoliths and teeth, and bones, shark dermal denticles, and a variety of invertebrate skeletal components including mollusc shells, echinoderm feeding appendages and spines and sponge spicules (Cramer et al., 2017; Dillon et al., 2021; Levitan, 1992; O'Dea et al., 2014).

2.2 | Historical information relevant for fisheries

Each of these historical data sources contains relevant information across a range of data types useful to fisheries management (Figure 1c, Table 1). Social information, such as market changes, preferences, or changes to fishing gear or vessels can derive from LEK/TEK, archival, and archaeological sources. For example, LEK from coastal communities has documented the recent history of exploitation of marine fisheries and described changes in fishing gears and distances travelled to fishing grounds (Rubio-Cisneros et al., 2019). TEK can document the location of past harvest, processing, and trade (Menzies, 2015). Archaeological artefacts document past gear, and rock art can demonstrate species preferences. Archival sources also provide information on changes to fisheries technology over time and market changes such as development of demand for a new product, the prices of fish, and changing consumer preferences that would affect demand (Van Houtan et al., 2013; Vermeij et al., 2019).

Fisheries statistics, including catch, effort, and catch per unit effort (CPUE), are also provided by archival sources, and to a lesser degree, LEK/TEK and archaeological sources. This information can be found in government assessments of fisheries, as well as trade records, and landings records of individual vessels or processing facilities. Whaling records are a well-studied example of this type of historical data (Lotze & McClenachan, 2013). While archival information can provide extended records of catch and effort in a particular fishery, LEK can provide individual statistics such as changes in the average or maximum number and size of fish caught daily by

individual fishers (Bravo-Calderon et al., 2021). Archaeological information can document past effort; for example, weirs constructed by Aboriginal people in Australia show the level of effort in pre-European fisheries. Catch reconstructions are an example of the use of a mix of archival data and LEK, and these are sometimes coupled with estimates of the fishing fleet size, which together allow for an understanding of changes to catch rates over time for target species within a particular region or management context (Granados-Dieseldorff et al., 2013; Zeller et al., 2016).

Biological information is perhaps the most common category of information provided by all four historical source types, and includes species compositions, age or sizes, and spatial distribution. LEK has been used to collect biological information such as maximum size, spawning aggregation sites, and relative abundance (Beaudreau & Levin, 2014; Bravo-Calderon et al., 2021). TEK provides valuable insights into changing abundances; for example, oral histories describe abalone existing at such high densities that the sound of their shells hitting one another was audible (Menzies, 2015). Archival sources have demonstrated historical trends in species composition, individual fish size, and spatial distribution (McClenachan, 2009a; Vermeij et al., 2019). Archaeological data can provide information on the mean trophic level of targeted species and both archaeological and palaeoecological data can reveal relative abundance, past distribution, and species age and size across a gradient of fishing intensities (Dillon et al., 2021; Pestle, 2013).

Finally, historical sources provide ecological information such as the ecological interactions among species and changes in environmental conditions (Izzo et al., 2016). TEK can provide insights into species interactions over long time scales. For example, traditional stories of food preparation counter the Western narrative that abalone were recently introduced into Indigenous diets following the extirpation of sea otters and imply that baseline states for kelp forest ecosystems included abundant invertebrate species (Menzies, 2015). Palaeoecological data can reveal changes in ecosystems over long time scales. For example sediment records containing fish bones and scales and chemical proxies of variability in fish populations, have demonstrated relationships between climate and fish abundance spanning millennia (Finney et al., 2010). Analyses of the relative abundance of species across functional groups have also demonstrated key species interactions, contributing to understandings of baseline ecosystem structure and function before fishing (Cramer et al., 2017; Muraoka et al., 2022).

3 | PATHWAYS FOR HISTORICAL INFORMATION TO INFORM FISHERIES DECISION-MAKING

This range of historical information can inform fisheries management via two main pathways that are key to the fisheries management process: indicators and reference points (Figure 2). An indicator is information that managers can use to make decisions, as it measures

or detects a quality or quantity of the stock (i.e. the exploited population) (Cope, 2024). Indicators are generated as part of a fisheries assessment process, which evaluates the abundance, productivity, and options for harvest of a particular fishery. Common examples of indicators are absolute or relative stock size or fishing rate. Indicators provide information on stock status that can be used to make fisheries management decisions when interpreted in relation to management reference points (Cope, 2024). Reference points are benchmarks that are used to interpret indicators within the context of management objectives. Reference points can reflect a variety of benchmarks, including levels of abundance that are desirable (i.e. target reference points) or those that indicate overfishing is occurring and may be accompanied by management actions (i.e. limit reference points).

Historical information can inform indicators via the assessment process by allowing comparison between a past baseline and current conditions. For example, an indicator based on historical information could be an observation that a species' range has decreased, or an evaluation of current biomass as compared to an estimate of unfished biomass (Cope, 2024). (This pathway is discussed in more detail in Section 3.1). The second pathway for historical information to inform management is through defining the reference points that are used to interpret indicators. In particular, the biological potential of a fishery is frequently referenced. While it is increasingly acknowledged that reference points are not static, one commonly used reference point of this type is unfished biomass (B_0) and biological potential can also include abundances, distribution, or individual size without fishing (Clark, 2002; Cope, 2024; Gabriel & Mace, 1999). Historical data, such as information on historical range, unfished biomass, or stock productivity, can alter understandings of biological potential. Historical data can also function to change social preferences that affect reference points. For example, information about past productivity could motivate a community to set recovery targets higher than they would be without this knowledge (This pathway is discussed in more detail in Section 3.2).

3.1 | Historical data inform indicators of stock status

Historical data can be integrated directly into assessments of a particular fish stock (i.e. stock assessment), to inform indicators of stock status. Historical data may be extensions of more conventional sources of stock assessment information like catch, but may also present new types of information that can serve as inputs into integrated fisheries assessments both in the form of data and parameters (Figure 1d). By providing information on biological baselines or historical fishing effects on the population, historical data can provide insights into model specifications and assumptions that address prior gaps in knowledge, thus edifying the assessment of stock health under more realistic conditions and scenarios (Cope, 2024).

The most common data inputs for single-species stock assessments are catch over time, indices of abundance, and biological data, which commonly include length and/or age of individuals in the catch (Figure 2d, blue) (Cope, 2024). One of the more prominent uses of historical information is the reconstruction of historical catch data using archived datasets, historical reports, newspapers, or other published or unpublished documents. These directly reset the time series considered, as well as the understanding of when a relatively stable 'unfished' population may have last existed (with 'unfished' usually indicating pre-industrial or large-scale removals).

Abundance data—either in the form of absolute measures (Alter et al., 2007) of the population size or relative trends in the population over time (Kuwaie et al., 2017)—can be converted to indices that offer insights into how the stock has changed over time (Rosenberg et al., 2005). Historical data sources can also reset the baseline of how large the population may have been, give insights into historical ranges, densities, changes in species compositions, and available habitat, all of which can alter the perception of the status of current stocks. Historical range distribution is an important consideration in determining a stock definition, and large contractions from a historical range can be an indicator of poor stock status. Therefore,

TABLE 1 Types of historical data available across four different types of historical sources.

	Historical data type	LEK/TEK	Archival	Archaeological	Palaeo- ecological
Social information	Markets	X	X		
	Gear/vessels	X	X	X	
	Preferences	X	X	X	
Fisheries statistics	Catch	X	X		
	Effort	X	X		
	Species caught	X	X	X	
Biological information	Ages and/or size	X	X	X	X
	Distribution	X	X	X	X
	Relative abundance	X	X	X	X
Ecological information	Community structure	X	X	X	X
	Species interactions	X			X
	Environmental conditions				X

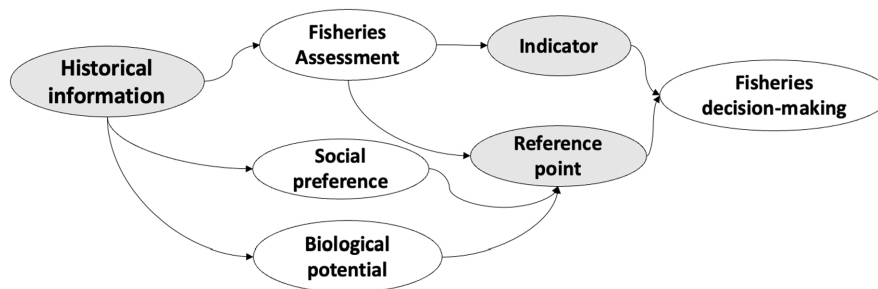


FIGURE 2 Pathways for including historical information in fisheries decision-making. Historical information can inform fisheries assessments that provide indicators of current stock status. They can also inform social or economic preferences and biological potential, both of which contribute to establishing management reference points, which are used to interpret indicators within the context of a particular management framework. Together indicators and reference points inform fisheries decision-making.

understanding the relationship between historical and current stock ranges can dramatically change stock status interpretation and management objectives.

Finally, biological data in general can provide direct insights into demographics and stock status (Hordyk et al., 2016; Thorson & Cope, 2015), and are therefore highly desirable. These include size or age data in the form of compositions, summary statistics (e.g. mean size or age), or even ranges (e.g. reported sizes ranges from 20 to 60 cm in early years, but from 20 to 50 cm in more recent years).

In addition to data inputs, stock assessments also need model parameters that connect biological plausibility and fishery-stock interactions to reconcile and interpret the signals of multiple data types into a cohesive assessment of the stock size or status (Cope, 2024). Common types of model parameters (Figure 1d, green) are life history (e.g. natural mortality, growth, reproduction), fishing dynamics (e.g. fishery selectivity, gear changes) and environmental dynamics (e.g. changes to temperature regimes, species interactions).

Life-history parameters define population productivity and the potential response to fishing, and therefore are fundamental inputs into conventional fisheries assessments (Cope, 2024). Estimating these parameters directly from locally collected data is most desired, but estimates are often based on indirect evidence, borrowed from closely related species, or derived from heavily fished stocks, which biases some estimates (Cope & Hamel, 2022; Hamel & Cope, 2022; Maunder et al., 2023). Changes in life-history parameter values tend to have a major influence on indicators produced by a stock assessment. Therefore, improving the accuracy of life-history estimates with historical information is valuable to this process. Historical data may be able to provide indication of size- or age-composition in an era of light fishing relative to current fishing mortality or intensity, which can inform life-history parameters such as average maximum size (L_{∞}), growth rates, such as how quickly maximum size is obtained (k), and natural mortality (M) (Lee et al., 2020). Understanding if and how life-history parameters may have changed is critical to understanding assumptions about an unfished population structure. It does not exclude the use of more current estimates, but estimates of growth can be

biased in a non-precautionary way if taken from a heavily fished population, as it may assume the populations L_{inf} is smaller, and thus the reduction in mean length is less.

For example, archival records or photographs may provide essential evidence to update estimates of average maximum size under less exploitation. Improved estimates of average maximum size provide better interpretation of the potential reduction of length compositions over time, and thus diminished reproductive potential, such as through the loss of mega-spawners (Froese, 2004). While it is possible to see fish of various sizes within any fishery, it can be rare to see large fish in a heavily fished stock. When large fish are rarely observed, it is unclear whether those few individuals still could have grown larger without fishing. It is also possible that they may be unusually large and not representative of the average. Observations from an earlier time with less exploitation can help clarify the maximum length, and possibly the true average maximum age in the population because less mortality allows for the size and age structure to be broader (Byrd et al., 2022).

Likewise, historical size- or age-composition data may be valuable for improved estimates of natural mortality. The choice of natural mortality parameters can influence an assessment's predictions of what sort of population recovery might happen because of reduced fishing, but it is difficult to directly observe. Assessments that include length- or age-composition of catch generally estimate total mortality (fishing mortality plus natural mortality) using the gradual reduction in frequency of individuals as they get larger or older, unless one is able to measure from an unfished population (Hamel & Cope, 2022). Many assessments calculate fishing mortality, a key metric for management, by subtracting natural mortality from the total mortality. Since natural mortality is difficult to directly measure in an already-fished stock, there are multiple methods for inferring it from other life-history traits (Cope & Hamel, 2022; Maunder et al., 2023), such as average maximum age in the population (i.e. longevity), growth parameters (e.g. L_{∞} and k), and size or age at maturity from less exploited eras. Even if historical data can only provide partial information, trends in those data may provide a more accurate value for natural mortality than using indirect life-history inference.

It is common to assume that model parameters are constant for the entirety or large portions of the time series. Historical information can present evidence as to whether this simplifying assumption is acceptable, and if not, in what direction those changes have occurred. One example is the understanding of fishing dynamics, or how fishing has been conducted over time. For example, fisheries may select larger individuals within a population due to gear, fishing practices, technology or social preference. Stock assessments often represent this 'selectivity' of the fishery with simple assumptions that no individuals below a certain length are caught, while all individuals above that length are, or with a fully specified relationship such as a logistic curve for length (Cadrin & Dickey-Collas, 2015). Selectivity is a parameter with large influence in most stock assessments, and thus, changes in it that are overlooked can create large biases in the results. If selectivity was different in the past, the effect of fishing on the population may be substantially different than assumed under current selectivity, thus affecting the understanding of stock status. Another example is the tracking of expanding and or contracting fished areas (Beaudreau & Whitney, 2016). LEK and archival information can therefore help understand changes in gear, fishing practices, technology and other changes that may have altered how and where the fishery selectively removes fish from the population.

There are many instances where a formal stock assessment using these types of data inputs and model parameters is not available. In these cases, indicators are developed around other available metrics (Cope, 2024). For example, a sampling of the lengths of fish caught may be used to calculate indicators as simple as average length, or as complex as spawning potential ratio (i.e. the amount of eggs produced by a fished stock over its lifespan, relative to that same value for an unfished stock). Historical observations of average maximum length can provide a very useful perspective when interpreting these length-based indicators. Other simple indicators can track relative abundance through such measures as catch per unit effort, or even just periodic interviews of fishers asking how fishing has been (Beaudreau & Levin, 2014; Beaudreau & Whitney, 2016). This historical perspective may be useful even if it may not reflect an unfished condition. For example, a target may be chosen to rebuild a fishery to conditions that were desirable at some point in the not-too-distant past. Additionally, historical data may provide insights into environmental regimes that have changed the productivity of the stock of interest, thus changing the way indicators are interpreted (i.e. there reference points).

3.2 | Historical data inform management reference points

Historical insights can also provide essential information regarding the relevant social, economic, and ecological factors that would affect choices of how to manage a fishery, such as through their influence on the reference points that provide information about

the biological potential of a fishery. Historical data can inform reference points for individual body size and how much of the population would achieve larger sizes in the absence of fishing (often summarized using spawning potential ratios, or SPR). They may also inform reference points including unfished biomass, for example, by demonstrating past abundances above those currently recognized as possible, and optimum yield, for example, by demonstrating the ecological importance of key species prior to intensive fishing. Reference points of biological potential are invaluable for communities and policymakers because they fully illustrate the range of performance that can be achieved by a fishery. For example, harvest control rules are used to adjust management in response to changes in indicators of stock health (Dowling et al., 2015; Punt, 2010). Because a complete harvest control rule requires an understanding of the full range of indicator values, understanding biological potential greatly improves the ability to design effective rules. Reference points based on ecological potential can also factor into fisheries policy, such as the establishment of an optimum yield of 0 for krill along the U.S. West Coast, owing to its importance as forage (PFMC, 2008).

Historical information can also inform reference points through changing or defining social preference. For example, in eastern Indonesian anchovy fisheries, LEK was used to set a reference point within a re-designed fishery management system (Sari et al., 2022). Local fishers remembered that traditional gear had historically been effective in catching enough fish to provide food and income when anchovy populations were higher in the past. Very limited data or management resources existed, and the system was built around the principal community goal to rebuild the anchovy population to levels capable of supporting traditional fishing methods even with large vessels fishing in the area. The policy set a SPR target estimated to achieve this goal, and adjusted the number of licenses for large vessels accordingly.

The use of targets and reference points also provides opportunities to make progress on goals to make fisheries management more ecosystem-based (Link et al., 2020). Models used in this context have had limited practical application because of gaps in our understanding of complex interactions across species and between species and their environment. An alternate and complementary approach consists of relying on empirical observations from times when ecosystems were less impacted (e.g. an ecosystem indicator approach) rather than trying to define those conditions through data-starved models. For example, historical analyses suggest that warming sea surface temperatures in the 1930s affected the abundance, size, and distribution of Pacific cod in the Gulf of Alaska (McClenachan et al., n.d.). Such observations serve to help to understand changes to fisheries productivity under modern warming scenarios. In addition to helping understand potential ecological interactions, historical observations also provide broader reference points of the full ecological potential of multi-species fisheries. Such reference points, like those of biological potential, are invaluable to managers when making decisions across multiple and potentially competing objectives.

4 | CASE STUDIES

4.1 | Caribbean contexts

The Caribbean, with its reliance on commercial, subsistence, and artisanal fisheries, is an ideal geography to integrate historical data in fisheries decision-making. Historical data have particular potential for use in data-limited coral reef fisheries (Friedlander et al., 2015), which characterize many Caribbean fisheries. The Caribbean also has a track record of collaboration between scientists and managers, which is enhanced by the immediacy of conservation needs for strongly interconnected coastal ecosystems (Mumby et al., 2021). Finally, there is an abundance of historical ecological data available for the Caribbean, including LEK, historical archival sources, archaeological middens and palaeoecological data. Here, four Caribbean case studies exemplify the diversity of data that exists and the range of pathways these data can take to be incorporated into unique fisheries management contexts, underscoring the potential of historical data to inform adaptive fisheries management strategies.

4.2 | LEK informs changes in shark distribution and species composition

The value of LEK is demonstrated by the case of coastal sharks in Mexico's Yucatan Peninsula and Caribbean islands. The shift of Mexico's Caribbean islands from one of the least populated territories in Mexico to the most important tourist region of the country in less than five decades rapidly transformed human relationships with coastal ecosystems and fisheries. In this context, LEK, mainly from elder fishers, provides crucial insights into historical changes to shark fisheries important for their management.

LEK has helped to demonstrate how shark exploitation intensified in the late 20th century, resulting in some sharks, rays and sawfishes becoming rare (Bonfil et al., 2018; Rubio-Cisneros et al., 2023). LEK has also revealed how introductions in new fishing gears, such as nylon gillnets, alongside ice production and outboard motors promoted overexploitation of sharks (Marín-Guardado, 2000). Participatory mapping has been essential to understanding spatial changes in the distribution of shark species, and identifying main fishing areas for each species (Martínez-Candelas et al., 2020; Rubio-Cisneros et al., 2019, 2023). This spatial data documenting the historical presence and distribution of sharks in nearshore waters has helped understand of change (Figure 3). Sharks mentioned in these interviews include bull, blacktip tiger, hammerhead, bonnethead, shortfin mako, and whale sharks.

Historical data derived from LEK serve as a valuable tool to establish new baselines for understanding the impact of fishing. One of the key lessons learned is that several big shark species that previously inhabited coastal waters are no longer common, suggesting that ranges have become restricted. Coupled with local monitoring efforts, this historical information on distribution and species

composition allows for a potential indicator-based approach to assess the fisheries current condition (Harford et al., 2021). For example, a standard for 'healthy' species compositions in shark catches could be established based on historical data, and deviations in current species compositions from this indicator could trigger fishery adjustments. These qualitative data could also be refined into semi-quantitative or quantitative indicators, such as quantitative comparisons of historical and modern shark ranges, with the potential to link these indicators to harvest control rules (Dowling et al., 2015). These judgment-based assessments offer an alternative to a formal stock assessment, instead using indicators to measure stock health and guide management decisions. Current shark fisheries management strategies in the Mexican Caribbean include limiting fishing effort, closed seasons, gear restrictions and spatial closures. Baseline information can provide knowledge for decision-makers evaluating the performance of these existing management strategies, and the current condition of the fishery.

This example highlights the urgency of gathering this information from older, experienced fishers, especially in the context of contemporary challenges, like pandemics, hurricanes and fires. These extraordinary events hasten the erosion of cultural heritage, particularly among aging populations. This case study also emphasizes the value of qualitative data, crucial for detecting otherwise unnoticed change. Qualitative data reveal species that were formerly abundant, such as large sharks, and identify the reduced diversity catch as a warning for current management. The case study further reinforces the need to support projects incorporating the human element in natural landscapes, as traditional funding biases toward biological or ecological components of socio-ecological systems (Harford et al., 2021; Figures 4a, 5a).

4.3 | Archival information informs catch history and size structure for goliath grouper

The case of the goliath grouper (*Epinephelus itajara*) demonstrates the value of archival data in fisheries decision-making. This large-bodied predator plays an important role in Caribbean reef ecosystems. In Florida, it was targeted by sport and commercial fisheries for over a century, before closure in 1990 due to a species-at-risk designation in the United States. Most recently, a limited fishery was re-opened in 2023, which has been controversial (Coleman et al., 2023; McClenachan, 2013; O'Hop & Munyandodero, 2016).

Historical archival data offer valuable insights into baseline conditions relevant for modern management decisions. Documents from the 19th-century United States Fish Commission provide observation of commercial fisheries, such as the purchase of 10,000 pounds of goliath grouper from local fishermen in 1895 (Brice, 1897) and the export of catch in the 1920s (Schroeder, 1924). Commercial landings data began in the 1880s when the U.S. Congress tasked the Bureau of Commercial Fisheries with developing an accounting of fisheries in the United States. These early historical records are available for all coasts of the

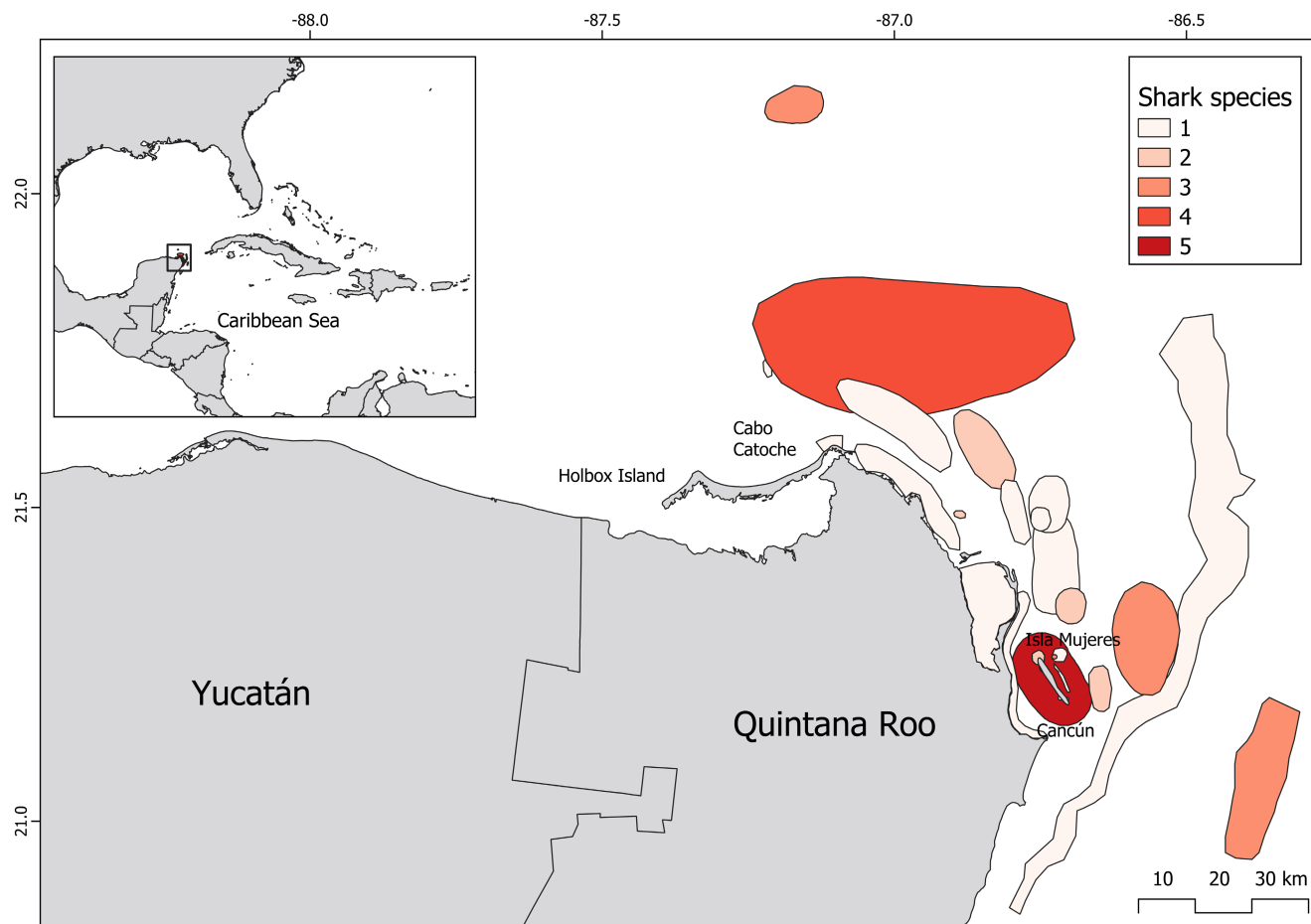


FIGURE 3 Example of historical information on shark diversity and distribution as derived from fishers' local ecological knowledge from Isla Mujeres, Mexico (Data from Rubio-Cisneros et al. 2021).

United States and are indispensable for understanding the status of fisheries before intensive fishing. Archival sources also document the recreational fishery, with newspapers detailing the location and weight of goliath grouper caught in the early 20th century and photographs capturing the size and number of fish caught on charter boats from the 1950s to the present day (Figure 4a,b). Analysis of this archival data revealed a significant decline in maximum size between the 1920s and the 1970s, along with a shift in distribution of large individuals offshore after 1950, a decrease in the proportion of goliath grouper caught, and an 86% decline in CPUE between 1956 and 1985 (McClenachan, 2009b).

As a data-limited fishery with a moratorium on fishing, assessments have been limited by a lack of catch data. However, historical catch data exist, including commercial landings data dating back to 1890. The most recent assessment reconstructed historical catches, drawing on sources including early US Bureau of Commercial Fisheries reports, and incorporated them into the assessment model. Uncertainty in the results suggested that improving the historical catch data, both in quality and in timeframe, was necessary (O'Hop & Munyandodero, 2016).

Additional opportunities exist to use long-term archival data in decision-making for goliath grouper. Given the species' longevity,

historical biological data, such as size compositions of catch, are particularly valuable. Size and age structure are poorly known, with length information a defined priority of the assessment process (O'Hop & Munyandodero, 2016). Historical data sources, such as historical photographs and newspapers, contain information on size (Figure 4a). These could be compared to modern length data, and integrated into assessment models as length compositions, contributing to a growth curve. Differences between historical and modern datasets could be overcome by using a selectivity curve that describes how individual fish are sampled from the population. For example, the assumption could be made that individuals were targeted and displayed as the largest fish likely represent the largest 95% of the population.

Historical size information also offers the possibility to explore or challenge assumptions about life-history parameters used in fisheries models, particularly growth and mortality parameters. For example, maximum size from historical data could be compared to the current estimate of the mean length of the fish in a population or stock would reach if they were to grow indefinitely (L_{∞}). If information from historical photographs routinely showed fish substantially larger than the assumed average maximum length, current assumptions about maximum size would need to be re-evaluated. This is

important because underestimating maximum size and longevity would result in an overestimate of productivity of the stock. Changes in these parameters would change model outputs, with implications of interpreting indicators used to manage the fishery (Figure 5b).

4.4 | Archaeological information informs age structure for queen conch

The queen conch (*Aliger gigas*), a large herbivorous gastropod endemic to the Central Western Atlantic region, has been fished for millennia, and is now one of the most economically important fisheries in the region (Posada et al., 2007; Schapira et al., 2009). Unique management challenges include aspects of conch growth, including sequential and overlapping increases of the shell (two-phase growth, length and lip thickness), and reproductive ecology, requiring minimum densities to be successful (Allee effect) (Stoner & Appeldoorn, 2022; Stoner & Ray-Culp, 2000). Available field surveys, stock assessments, and landings data indicate significant declines in queen conch populations, with associated shifts in size- and age- structure (Marco et al., 2021).

Conch middens provide a window into the history of the fishery, revealing periods of fishing, changes in relative abundance, and details of individual animals harvested, including age, size, and proportion of juveniles and adults across time periods (Figure 4c). Historically, conch were landed whole in close proximity to fishing grounds, with meat removed and shells discarded forming middens that reflect the local population structure over time, as older and deeper layers were covered by more recent ones. Radiocarbon dating has identified midden deposits originating from the 6th to the 16th centuries AD and differentiated pre- and post-colonial settlement from 20th-century deposits, which can be further dated using historical documentation such as aerial photographs (Schapira

et al., 2009; Torres & Sullivan-Sealey, 2002). While the formation of modern middens has declined in the past 30 years, it still occurs in some locations, and along with recent shell discards in the water, facilitate comparisons with older middens (Wilson et al., 2005).

Comparison across time periods has demonstrated significant changes in conch size structure. For example, in Los Roques, Venezuela, the mean size of adults declined across the modern time period (1950–1995), but was stable between the pre-Columbian period (1160–1540 A.D) and the 1950s. Pre-Columbian fishermen collected mostly mature individuals, with an average of 11% of juvenile and subadult individuals present in middens, as compared to modern fisheries, where these immature individuals represented up to 67% of conch landed between 1950 and 1995. (Figure 6; Schapira et al., 2009). A similar pattern occurs in conch shell middens on San Salvador Island, the Bahamas over a similar timeframe (Ruga et al., 2019). Conch middens, with millions of shells representing centuries of harvest, coupled with an understanding of conch life history, provide geographically distinct baselines and patterns of exploitation.

High-quality biological information is available over long periods of time. Accurate dating of midden layers allows baselines of conch population structure to be identified and the intact nature of individual shells within middens allows analyses of changes to relative abundance over time, and shell morphology reveals key life history and demographic information about population status. The high availability of shell middens across the Caribbean enables examination of patterns at various geographic scales relevant to management, from regional to sub-national or the unit of a stock.

Integrating midden data into fisheries decision-making holds high potential and could be done both through development of indicators of stock status, and through improved understandings of biological potential that could lead to updated harvest control rules. First, information on historical size or age structure could

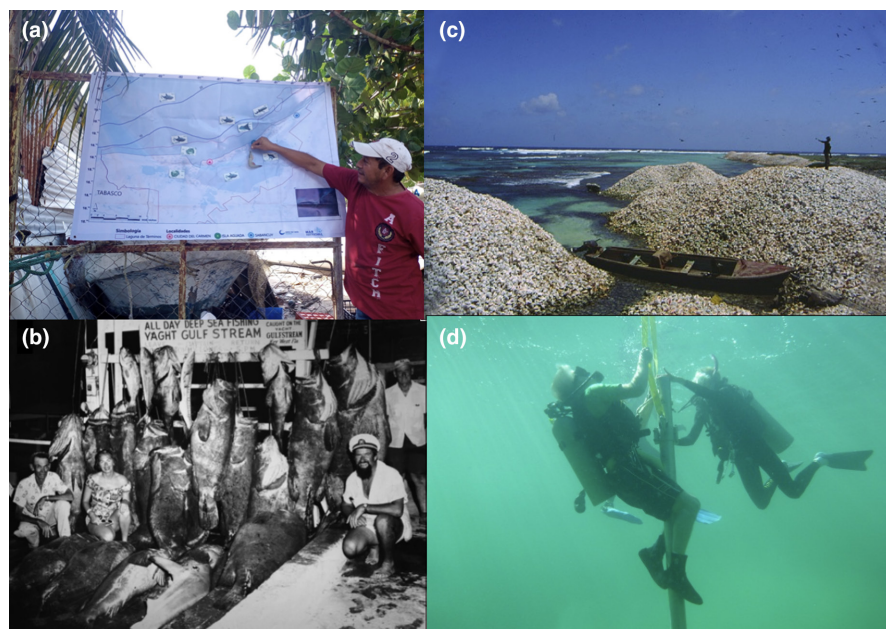


FIGURE 4 Examples of historical data for each of the four case studies described below. (a) Participatory mapping with shark fishers in Mexico (I. Martinez), (b) Photographs of goliath grouper caught on recreational fishing boats in Key West, 1959 (Monroe County Public Library), (c) Queen conch shell midden on the Pedro Cayes, south of Jamaica, 1993 (A. Tewfik), (d) Sediment core extraction in Panama (C. Angioletti).

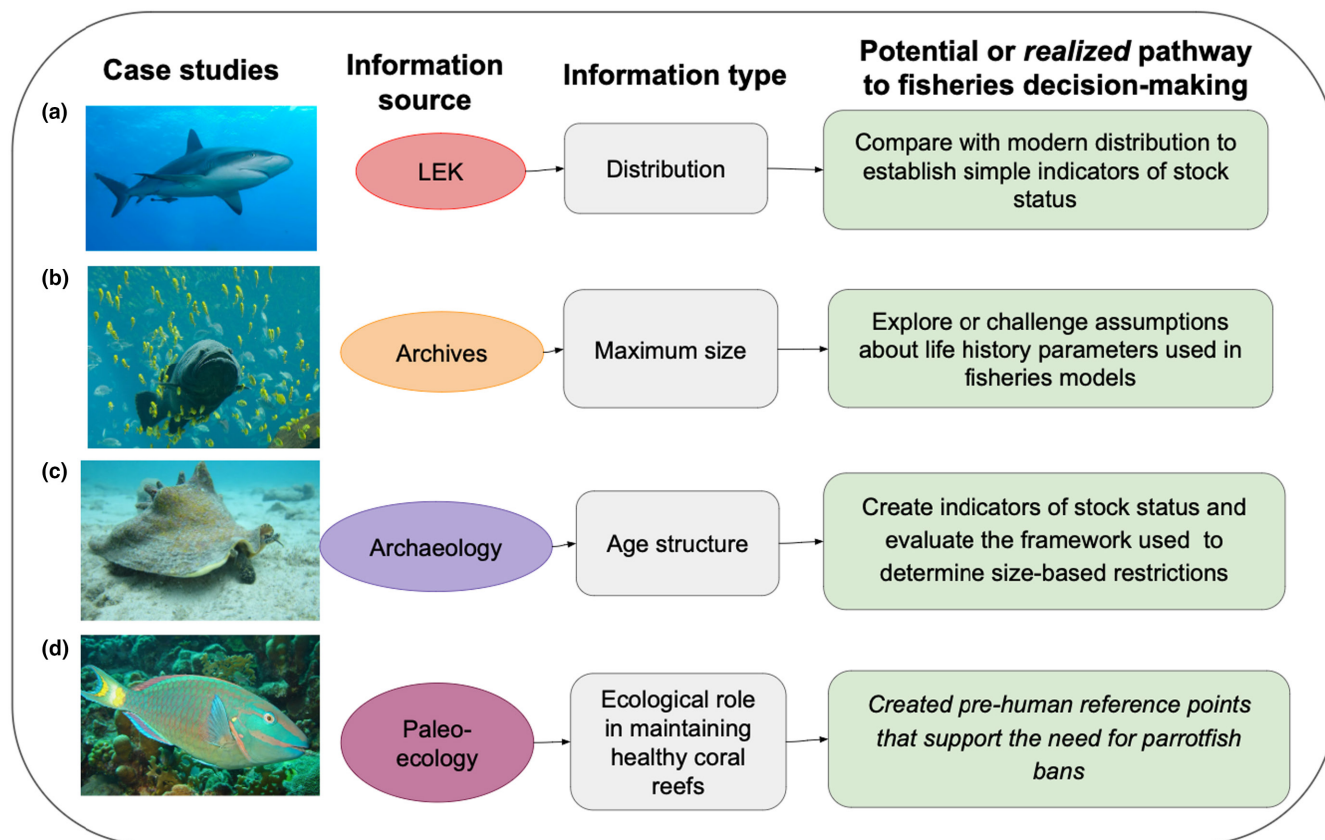


FIGURE 5 Pathways for integrating historical information into fisheries decision-making for four Caribbean case studies (a) reef sharks, (b) goliath grouper, (c) queen conch, (d) parrotfish. Case studies were selected to represent a range of taxa (from large-bodied and long-lived top predators to grazers) and historical data sources. In each case, we describe the available data and actual or potential pathways for integrating the information into assessments or broader decision-making.

be integrated as biological data into population assessments to improve indicators of current stock status. Specifically, historical data on stock structure (range of sizes), mean size (based on shell length), or percentage of mature individuals in a population (based on a minimum shell lip thickness) prior to intensive fishing could be used as indicators of population health and compared to the unfished expectations of each of these variables, all being used to readjust the baseline stock status that can be compared to current metric values. Second, historical data could provide insights into the management framework used to determine fishing restrictions, which are commonly based on minimum shell lengths. However, length cannot be used to identify mature conch, whereas lip thickness is the proven approach. A result of a long-term implementation of a length-based minimum size policy has been a reduction on the mean size of mature conch as size-selective fishing allowed many smaller, slower growing conch to mature (Tewfik et al., 2019). This decline has possible negative impacts on fecundity and recruitment, and also on fisheries productivity as these individuals yield less meat. Conch shell middens that represent a more random pattern of juvenile harvest and mature conch with longer shell lengths would help to improve understandings of the biological potential of the fishery and could motivate a switch to the more appropriate shell lip thickness as a harvest control rule (Tewfik et al., 2019; Figure 5c).

4.5 | Palaeoecological data inform relative abundance and ecological dynamics for parrotfishes

Palaeoecological data can reveal the link between fish community composition and ecosystem functioning, contributing to ecosystem-based fisheries management decisions. Herbivores play a key role in reef ecosystems by controlling the abundance of benthic macroalgae which compete with corals for light and space and can adversely impact coral health (Bozec et al., 2016; Jackson et al., 2001; Steneck et al., 2014). Control of algal abundance via consumption by herbivorous parrotfishes (family Labridae) has been shown to promote coral health and dominance on modern reefs (Adam et al., 2011, 2015; Steneck et al., 2014; Wild et al., 2014). Following the mass die off of the grazing urchin, *Didema antillarum*, the importance of parrotfish herbivory to the maintenance of coral dominance on Caribbean reefs has become elevated (Adam et al., 2015; Hay & Taylor, 1985).

Millennial-scale trends in parrotfish abundance can be tracked via their teeth, which are preserved in reef sediments (Figure 4d). Parrotfish abundance was tracked over the past 3000 years from the relative abundance and accumulation rates of parrotfish teeth fossils found within sediment cores collected below modern reefs in Panama and Belize (Cramer et al., 2017; Muraoka et al., 2022). High-precision U/Th (Uranium/Thorium) dating of coral fragments within these cores allowed these parrotfish abundance proxies to

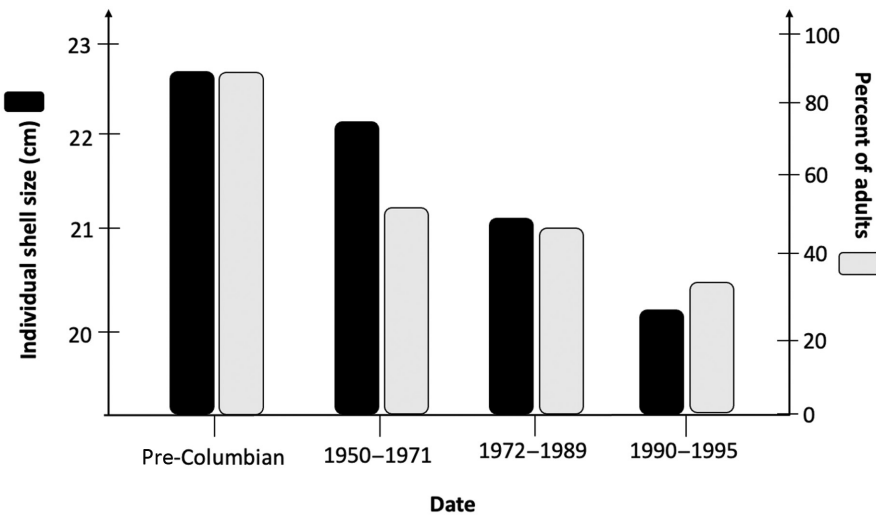


FIGURE 6 A comparison of pre-Columbian and 20th century midden data for queen conch reveals patterns in the size structure (reproduced from data in Schapira et al., 2009). Adults are identified both by length and shell lip thickness.

be tracked on a decadal-scale resolution. In both locations, these data show that the relative abundance of parrotfish teeth peaked in the 1600s–1800s and has since declined, possibly due to post European-contact changes in reef resource exploitation in the Caribbean. Importantly, parrotfish abundance also had a positive causal effect on the accumulation rate of reef sediments, a proxy of overall reef growth rate. This effect was detected in locations with contrasting environmental conditions and human histories (Belize and Panama) indicating that historical overfishing negatively impacted coral resilience on many Caribbean reefs (Cramer et al., 2017; Muraoka et al., 2022).

These historical analyses reveal that current parrotfish abundances are well below their pre-European contact peaks, and that their loss has had ecosystem-wide consequences. This information supports fisheries decision-making. Recognizing the important ecological role of parrotfishes, several Caribbean nations have implemented fishing restrictions or outright bans on the catch of parrotfish as they have become increasingly targeted over the past decades following overfishing of larger predatory reef fish (Belize, 2009; Bozec et al., 2016). Information on historical baselines and ecological importance suggests that these management actions are appropriate.

This case study provides an example of how historical data can inform ecosystem-based fishery management, particularly for habitats such as coral reefs where the dynamics of fish and habitat-forming organisms are tightly coupled. This is also an example of how a fisheries reference point for parrotfish fisheries could consider not just the biological health of a stock as it relates to maximum yield, but also how parrotfish contribute to the functioning of the ecosystem as a whole. Reference points for parrotfish fisheries based on these past ecological relationships would be substantially more conservative than those based on MSY. Based on the clear importance of parrotfish to coral reef ecosystems, management may favour a target that would provide for lower catches and larger

parrotfish populations, akin to the US decision to set a 0 catch for West Coast krill. Efforts to calibrate palaeoecological records with modern survey data could increase the integration of these data into decision-making. For example, quantitative estimates of millennial-scale change in parrotfish abundance would allow for the creation of a reference point based on past abundance, which could be used to establish targets for parrotfish recovery. Efforts that are underway to determine the taxonomic specificity of parrotfish tooth morphotypes may also allow for species-specific estimates of abundance which could assist in historically grounded and taxon-specific assessments for parrotfishes (Figure 5d).

5 | CONCLUSION

5.1 | Broader lessons from case studies

Data-informed management relies on the best available information to make decisions, and across data-limited to data-rich fisheries, managers seek to identify indicators to assess the current status of populations. Our examples highlight that 'data-limited' fisheries may actually have a rich historical set of information, such as the millions of available specimens of conch in the archaeological record or the century long-catch records for goliath grouper. Such historical data can be used to develop indicators; in traditional stock assessment models, they can contribute to both long-term data (e.g. catch) and information to better parameterize population models (e.g. L_{∞}). Historical information can also be valuable to fisheries management outside of the assessment process, by providing information on relevant social, economic, and ecological factors that affect decision-making. For example, palaeoecological data on the role of parrotfish in promoting coral growth support decision-making aimed at restoring this ecological function via fishing bans. Finally, and most broadly, there is a role for historical data in broader cultural

change, shifting and expanding the narrative about what is important for communities in managing their fisheries. For example, the disappearance of formerly abundant coastal shark species can help draw attention to the need to recover these species. Particularly in data-limited contexts, historical data may be the best available information to manage fisheries.

Our examples also highlight that there are multiple types of shifted baselines that each affect fisheries sustainability differently. Unrecognized changes to population abundances are a clear example of shifted baselines, but spatial changes are an often overlooked but essential to understand the status of modern fisheries. Our shark case study demonstrates the ways in which historical information can reveal lost spatial distribution of targeted species; such losses exist broadly among marine fish around the world (Buckley et al., 2017). Changes in individual body size also indicate a changing population demographic structure, highlighted both by our conch and grouper case studies, which together show that historical data, including archives and archaeological middens, may be useful in defining a baseline size structure. These types of changes can also be accompanied by changes in genetic structure, as genetic resilience can be reduced through harvesting that decreases size at maturity (O'Dea et al., 2014). Finally, our parrotfishes case study highlights shifted baselines at the ecosystem level. Changes to the overall community structure and key ecological functions, like grazing and reef growth rates, are important in ecosystem-based management.

Identifying appropriate baselines in a particular management context depends on when impact to that population occurred, with the key being to capture the timing and magnitude of change. Put simply, relevant historical data do not have to be old, and our case studies demonstrate that historical baselines relevant for management can be far more recent than may be assumed. For example, in our conch case study, a baseline of the 1970s may be appropriate for management, as archaeological data show a stable average size before this decade (Figure 6), when both demand and effort were very low. In other cases, the 1990s could be a baseline if change happened more recently. In many marine ecosystems, the rate of change accelerated in the last 30–50 years (Early-Capistrán et al., 2018). Therefore, identifying relevant information to inform historical baselines can mean identifying data sources spanning these more recent decades. In many fisheries contexts, even these more recent data do not exist, so the definition of 'historical' is simply any information that is not currently being considered as part of the management process, but could help provide important context to understanding current conditions.

5.2 | Call to action

This work leads to several key recommendations. These recommendations draw primary from our Caribbean examples, but are broadly applicable across fisheries contexts, depending on each applications specific circumstance.

5.2.1 | Conserve and value existing long-term information that are threatened by loss

The value of long-term records to active management of marine fisheries underscores the importance of conserving these sources of cultural heritage. However, crucial sources like cultural memory, institutional knowledge, and historical records are being lost at a rapid rate, eroding the capacity for safeguarding and incorporating these data into modern management. Archival sources, such as historical photographs and written documents, are vulnerable to both acute climate events and chronic stressors. In the Caribbean for example, hurricanes can destroy valuable documents instantly, while mould and decay can cause them to be eroded more slowly. Protecting archival information requires funding and infrastructure that are often lacking, and inadequate resources lead to an inability to digitize records. At the same time, LEK is eroded as older community members pass away, taking with them their insights into past systems. In particular, COVID impacts on rural fishing communities had large impacts on cultural memory. While published literature has described COVID's economic disruptions (White et al., 2021), more fundamentally, the death of older community members due to COVID rapidly eroded cultural heritage and primary source information that could be key to managing local resources (Rubio-Cisneros et al., 2023). Finally, the loss of coastal archaeological sites due to rapid sea level rise associated with climate change is a key concern.

Supporting the long-term collection and preservation of information is vital. Capturing information from knowledge holders within communities requires both support for recording oral histories, as well as to return this information to the communities, such as through development of education and outreach resources. In the case of our shark example, several such products were produced, including a children's book that narrates the tales of sharks as passed down through generations by the island's elders and a shark-themed bingo game. Additionally, a short documentary focusing on the historical shark fishery practices on the island was produced, which has been showcased to islanders and broader national and international audiences (Robledo, 2023; Rubio-Cisneros et al., 2023).

Collection and storage of archival information also requires support. While there are dangers associated with overreliance on technologies which may not last, the digital age opens a range of new possibilities for preservation, which has additional benefits of sharing this information more widely. For example, the Monroe County Public Library digitized more than 10,000 historical photographs associated with recreational fisheries on a free photo sharing website, making them accessible to community members and researchers around the world (MCPL, n.d.). Citizen science initiatives exist to preserve and share material digitally, and social and digital media are increasingly used for sharing information related to fisheries, which can provide insights into spatiotemporal activity, effort levels, and catches (Lennox et al., 2022). For example, the South Atlantic Fishery Management Council's Citizen Science project developed a protocol for collecting, archiving and analysing historical

photographs to help recreate information on catch and length compositions for recreational fisheries (Byrd et al., 2022).

5.2.2 | Embrace broader definitions of knowledge providers and fisheries assessments

These efforts underscore the need to broaden the definition of knowledge providers to include many who may not consider their expertise in long-term change as relevant to decision-making. Knowledge holders are those with access to long-term information, which includes community elders with knowledge of long-term change in fisheries, archivists who have curated collections of information, and academic and government scientists who have collected or curated long-term data that may be unpublished, in grey literature sources or unpublished student theses. Many fisheries management agencies have historical records on fisheries catch, abundance, and distribution that are stored and in need of digitization.

There is also need to embrace broader definitions of indicators and assessments within the fisheries decision-making process (Cope, 2024). The principle of basing decisions on the best available data supports the use of historical information where these sources can provide information that otherwise does not exist. This need exists in both data-limited and data-rich contexts. For example, long-term catch data represent a form of historical data that is increasingly used in stock assessments. Catch reconstructions were championed by the Sea Around Us Project (Pauly & Zeller, 2016), and typically focused on total catch across commercial, recreational, and subsistence sectors, with outputs highly relevant to management (Zeller et al., 2016). Reconstructing historical catch for individual species, as seen in our goliath grouper case study, is useful and increasingly undertaken within fisheries assessment contexts. Conducting single-species catch reconstructions as part of stock assessments became common in the early 2000s (Karnowski et al., 2014; Ralston et al., 2010) and are a form of historical data use that is valuable and accessible across a range of species. At the same time, broadening the use of historical data beyond catch, to include information on individual body size, range, and ecosystem function could add substantially to fisheries assessment processes.

5.2.3 | Don't delay assessments because data are not perfect

Fisheries scientists aspire to use data collected within designed sampling programs that represent random samples and are otherwise standardized. This practice leads to the perception that assessments are dependent on very specific data quality and quantity. Historical data are often opportunistic and do not meet this standard.

Our examples highlight that indicators used to make decisions in fisheries management can be derived from a range of information sources, and therefore, it is not necessary to delay assessing

stock status until data arrives 'fully formed'. One major advantage of incorporating historical data is that it can provide contrast to current conditions, thus providing informative signals beyond the noise of the samples. And even if the imprecision of the historical data may be high given its opportunistic availability, model sensitivity can be used to ask 'what if' the historical data contains a signal and how that may change current interpretations of important model output. This incorporation of additional baseline considerations support uncertainty characterization and directly feeds into the consideration of risk tolerance (i.e. the willingness to be wrong) for fisheries managers and decision-makers. Constructing plausible alternative models outcomes (i.e. states of nature) using historical allows decision-makers to overlay their willingness to be wrong across the uncertainty in stock status and other derived model outputs (Cope, 2024).

5.2.4 | Bring together relevant stakeholders

Most essentially, this work can only be successful by bringing together relevant stakeholders, including both those with long-term knowledge and those who would benefit by its inclusion in the decision-making process. There are different types of stakeholders that may play a role and incur a benefit at different times. For example, networking between those trained and active in fisheries assessment and management and those with experience accessing, compiling and synthesizing long-term information is critical in the process of connecting data to fisheries decision-making. The NGO community has a role to play. For example, as with the growth of citizen science projects focused on the ocean around the world, NGOs can help to collect fishers' LEK or knowledge of the past using citizen science techniques of information gathering (West & Pateman, 2016). Finally, community members, or fishers who might benefit from increased catch and more sustainable harvesting of natural resources are important contributors to this process. These objectives are consistent with recent calls for fisheries management to attend to different systems of knowledge that address local objectives, values and circumstances, particularly in light of colonial histories and power structures (Silver et al., 2022).

Traditional fisheries management has yielded mixed results, particularly from ecological and social perspectives. Integrating historical ecology into fisheries management can provide a deeper and more holistic view of the status and potential for marine fisheries. To that end, we call on stakeholders to collect, preserve and share this long-term information, which is essential for sustainable management of marine fisheries around the world.

ACKNOWLEDGMENTS

This project was funded by a grant from the Conservation Paleobiology Network, whose structure facilitated the regular conversations among the author group that led to the ideas expressed in this paper. We are also grateful to Pablo Granados, Rachel Graham, Juan Carlos Pérez Jiménez, and Tali Vardi for their insights that

contributed to some of these early conversations. Funding was provided from the Pew Marine Fellows (LM, 00036365) and Canada Research Chairs programs (LM, 2020-00204), Russell E. Train Education for Nature, WWF; Save Our Seas Foundation and The Rufford Foundation (NR).

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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REFERENCES

- Adam, T. C., Kelley, M., Ruttenberg, B. I., & Burkepile, D. E. (2015). Resource partitioning along multiple niche axes drives functional diversity in parrotfishes on Caribbean coral reefs. *Oecologia*, 179(4), 1173–1185. <https://doi.org/10.1007/s00442-015-3406-3>
- Adam, T. C., Schmitt, R. J., Holbrook, S. J., Brooks, A. J., Edmunds, P. J., Carpenter, R. C., & Bernardi, G. (2011). Herbivory, connectivity, and ecosystem resilience: Response of a coral reef to a large-scale perturbation. *PLoS One*, 6(8), e23717. <https://doi.org/10.1371/journal.pone.0023717>
- Alleway, H. K., & Connell, S. D. (2015). Loss of an ecological baseline through the eradication of oyster reefs from coastal ecosystems and human memory. *Conservation Biology*, 29(3), 795–804. <https://doi.org/10.1111/cobi.12452>
- Alter, S. E., Rynes, E., & Palumbi, S. R. (2007). DNA evidence for historic population size and past ecosystem impacts of gray whales. *Proceedings of the National Academy of Sciences*, 104(38), 15162–15167. <https://doi.org/10.1073/pnas.0706056104>
- Beaudreau, A. H., & Levin, P. S. (2014). Advancing the use of local ecological knowledge for assessing data-poor species in coastal ecosystems. *Ecological Applications*, 24(2), 244–256. <https://doi.org/10.1890/13-0817.1>
- Beaudreau, A. H., & Whitney, E. J. (2016). Historical patterns and drivers of spatial changes in recreational fishing activity in Puget Sound, Washington. *PLoS One*, 11(4), e0152190. <https://doi.org/10.1371/journal.pone.0152190>
- Belize, G. (2009). *Statutory instrument no. 49 of 2009. Fisheries (Nassau grouper and species protection) regulations*.
- Bonfil, R., Ricaño-Soriano, M., Mendoza-Vargas, O. U., Méndez-Loeza, I., Pérez-Jiménez, J. C., Bolaño-Martínez, N., & Palacios-Barreto, P. (2018). Tapping into local ecological knowledge to assess the former importance and current status of sawfishes in Mexico. *Endangered Species Research*, 36(August), 213–228. <https://doi.org/10.3354/esr00899>
- Bozec, Y.-M., O'Farrell, S., Bruggemann, J. H., Luckhurst, B. E., & Mumby, P. J. (2016). Tradeoffs between fisheries harvest and the resilience of coral reefs. *Proceedings of the National Academy of Sciences of the United States of America*, 113(16), 4536–4541. <https://doi.org/10.1073/pnas.1601529113>
- Bravo-Calderon, A., Saenz-Arroyo, A., Fulton, S., Espinoza-Tenorio, A., & Sosa-Cordero, E. (2021). Goliath grouper *Epinephelus itajara* oral history, use, and conservation status in the Mexican Caribbean and Campeche Bank. *Endangered Species Research*, 45, 283–300. <https://doi.org/10.3354/esr01135>
- Brice, J. J. (1897). *Report on the fisheries of Indian River Florida* (U.S. Commission of Fish and Fisheries 22; report of the commissioner for the year ending June 30, 1896).
- Brook, R. K., & McLachlan, S. M. (2008). Trends and prospects for local knowledge in ecological and conservation research and monitoring. *Biodiversity and Conservation*, 17(14), 3501–3512. <https://doi.org/10.1007/s10531-008-9445-x>
- Buckley, S. M., Thurstan, R. H., Tobin, A., & Pandolfi, J. M. (2017). Historical spatial reconstruction of a spawning-aggregation fishery. *Conservation Biology*, 31(6), 1322–1332. <https://doi.org/10.1111/cobi.12940>
- Byrd, J., Collier, W. C., & Iberle, A. (2022). Designing the FISHstory project to support fisheries management. *Fisheries*, 47(11), 492–498. <https://doi.org/10.1002/fsh.10809>
- Cadrin, S. X., & Dickey-Collas, M. (2015). Stock assessment methods for sustainable fisheries. *ICES Journal of Marine Science*, 72(1), 1–6. <https://doi.org/10.1093/icesjms/fsu228>
- Clark, W. G. (2002). F35% revisited ten years later. *North American Journal of Fisheries Management*, 22(1), 251–257. [https://doi.org/10.1577/1548-8675\(2002\)022<0251:FRTYL>2.0.CO;2](https://doi.org/10.1577/1548-8675(2002)022<0251:FRTYL>2.0.CO;2)
- Coleman, F. C., Nunes, J. A. C. C., Bertoni, Á. A., Bueno, L. S., Freitas, M. O., Borgonha, M., Leite, J. R., Lima-Júnior, M. J. C. A., Ferreira, B., Bentes, B., Koenig, C. C., Malinowski, C. R., Sanches, E. G., Hostim-Silva, M., & Sampaio, C. L. S. (2023). Controversial opening of a limited fishery for Atlantic goliath grouper in the United States: Implications for population recovery. *Marine Policy*, 155, 105752. <https://doi.org/10.1016/j.marpol.2023.105752>
- Cope, J. M. (2024). The good practices of practicable alchemy in the stock assessment continuum: Fundamentals and principles of analytical methods to support science-based fisheries management under data and resource limitations. *Fisheries Research*, 270, 106859. <https://doi.org/10.1016/j.fishres.2023.106859>
- Cope, J. M., & Hamel, O. S. (2022). Upgrading from M version 0.2: An application-based method for practical estimation, evaluation and uncertainty characterization of natural mortality. *Fisheries Research*, 256, 106493. <https://doi.org/10.1016/j.fishres.2022.106493>
- Cramer, K. L., O'Dea, A., Clark, T. R., Zhao, J., & Norris, R. D. (2017). Prehistorical and historical declines in Caribbean coral reef accretion rates driven by loss of parrotfish. *Nature Communications*, 8(1), 1. <https://doi.org/10.1038/ncomms14160>
- Del Valle, E., Hayes, P., Martinez, I., Brown, P., & McClenachan, L. (n.d.). A systematic review of global historical marine ecology: Trends, biases, and insights. (In review, *Philosophical Transactions of the Royal Society B*).
- Dillon, E. M., McCauley, D. J., Morales-Saldaña, J. M., Leonard, N. D., Zhao, J., & O'Dea, A. (2021). Fossil dermal denticles reveal the pre-exploitation baseline of a Caribbean coral reef shark community. *Proceedings of the National Academy of Sciences of the United States of America*, 118(29), e2017735118. <https://doi.org/10.1073/pnas.2017735118>
- Dowling, N. A., Dichmont, C. M., Haddon, M., Smith, D. C., Smith, A. D. M., & Sainsbury, K. (2015). Empirical harvest strategies for data-poor fisheries: A review of the literature. *Fisheries Research*, 171, 141–153. <https://doi.org/10.1016/j.fishres.2014.11.005>
- Early-Capistrán, M.-M., Sáenz-Arroyo, A., Cardoso-Mohedano, J.-G., Garibay-Melo, G., Peckham, S. H., & Koch, V. (2018). Reconstructing 290 years of a data-poor fishery through ethnographic and archival research: The East Pacific green turtle (*Chelonia mydas*) in Baja California, Mexico. *Fish and Fisheries*, 19(1), 57–77. <https://doi.org/10.1111/faf.12236>
- Engelhard, G. H., Thurstan, R. H., MacKenzie, B. R., Alleway, H. K., Bannister, R. C. A., Cardinale, M., Clarke, M. W., Currie, J. C., Fortibuoni, T., Holm, P., Holt, S. J., Mazzoldi, C., Pinnegar, J. K., Raicevich, S., Volckaert, F. A. M., Klein, E. S., & Lescauwat, A.-K. (2016). ICES meets marine historical ecology: Placing the history of

- fish and fisheries in current policy context. *ICES Journal of Marine Science*, 73(5), 1386–1403. <https://doi.org/10.1093/icesjms/fsv219>
- Finnegan, S., Harnik, P. G., Lockwood, R., Lotze, H. K., McClenachan, L., & Kahanamoku, S. S. (2024). Using the fossil record to understand extinction risk and inform marine conservation in a changing world. *Annual Review of Marine Science*, 16(1), 307–333. <https://doi.org/10.1146/annurev-marine-021723-095235>
- Finney, B. P., Alheit, J., Emeis, K.-C., Field, D. B., Gutiérrez, D., & Struck, U. (2010). Paleoecological studies on variability in marine fish populations: A long-term perspective on the impacts of climatic change on marine ecosystems. *Journal of Marine Systems*, 79(3–4), 316–326. <https://doi.org/10.1016/j.jmarsys.2008.12.010>
- Friedlander, A. M., Nowlis, J., & Koike, H. (2015). Improving fisheries assessments using historical data. In J. Kittinger, L. McClenachan, L. Bight, & K. Gedan (Eds.), *Marine historical ecology in conservation: Applying the past to manage for the future* (312). University of California Press.
- Froese, R. (2004). Keep it simple: Three indicators to deal with overfishing. *Fish and Fisheries*, 5(1), 86–91. <https://doi.org/10.1111/j.1467-2979.2004.00144.x>
- Gabriel, W. L., & Mace, P. M. (1999). A review of biological reference points in the context of the precautionary approach. (proceedings of the fifth national NMFS stock assessment workshop: Providing scientific advice to implement the precautionary approach under the Magnuson-Stevens fishery conservation and management act. NOAA tech memo NMFS-F/SPO-40, pp. 34–45).
- Granados-Dieseldorff, P., Heyman, W. D., & Azueta, J. (2013). History and co-management of the artisanal mutton snapper (*Lutjanus analis*) spawning aggregation fishery at gladden spit, Belize, 1950–2011. *Fisheries Research*, 147, 213–221. <https://doi.org/10.1016/j.fishres.2013.06.007>
- Hamel, O. S., & Cope, J. M. (2022). Development and considerations for application of a longevity-based prior for the natural mortality rate. *Fisheries Research*, 256, 106477. <https://doi.org/10.1016/j.fishres.2022.106477>
- Harford, W. J., Amoroso, R., Bell, R. J., Caillaux, M., Cope, J. M., Dougherty, D., Dowling, N. A., Hurd, F., Lomonico, S., Nowlis, J., Ovando, D., Parma, A. M., Prince, J. D., & Wilson, J. R. (2021). Multi-indicator harvest strategies for data-limited fisheries: A practitioner guide to learning and design. *Frontiers in Marine Science*, 8. <https://doi.org/10.3389/fmars.2021.757877>
- Hay, M. E., & Taylor, P. R. (1985). Competition between herbivorous fishes and urchins on Caribbean reefs. *Oecologia*, 65(4), 591–598. <https://doi.org/10.1007/BF00379678>
- Hayes, P. W., De Roy, B., Hatch, M., & McClenachan, L. (n.d.). The ecological legacy of Indigenous dispossession: Disruption of ancestral sea gardens by commercial clam fisheries in British Columbia, 1882–1960. (In review *Philosophical Transactions of the Royal Society B*).
- Hordyk, A. R., Ono, K., Prince, J. D., & Walters, C. J. (2016). A simple length-structured model based on life history ratios and incorporating size-dependent selectivity: Application to spawning potential ratios for data-poor stocks. *Canadian Journal of Fisheries and Aquatic Sciences*, 73(12), 1787–1799. <https://doi.org/10.1139/cjfas-2015-0422>
- Izzo, C., Doubleday, Z. A., Grammer, G. L., Gilmore, K. L., Alleway, H. K., Barnes, T. C., Disspain, M. C. F., Giraldo, A. J., Mazloumi, N., & Gillanders, B. M. (2016). Fish as proxies of ecological and environmental change. *Reviews in Fish Biology and Fisheries*, 26(3), 265–286. <https://doi.org/10.1007/s11160-016-9424-3>
- Jackson, J. B. C., Kirby, M. X., Berger, W. H., Bjørndal, K. A., Botsford, L. W., Bourque, B. J., Bradbury, R. H., Cooke, R., Erlandson, J., Estes, J. A., Hughes, T. P., Kidwell, S., Lange, C. B., Lenihan, H. S., Pandolfi, J. M., Peterson, C. H., Steneck, R. S., Tegner, M. J., & Warner, R. R. (2001). Historical overfishing and the recent collapse of coastal ecosystems. *Science*, 293(5530), 629–637. <https://doi.org/10.1126/science.1059199>
- Karnowski, M., Gertseva, V., & Stephen, A. (2014). *Historical reconstruction of Oregon's commercial fisheries landings*. (information reports 2014–2; p. 56). Oregon Department of Fish and Wildlife. https://www.dfw.state.or.us/mrp/publications/docs/ODFW_Info_Rpt%202014-02_Historic_Reconstruction_Oregon_Commercial_Fish_Landings.pdf
- Kuwae, M., Yamamoto, M., Sagawa, T., Ikehara, K., Irino, T., Takemura, K., Takeoka, H., & Sugimoto, T. (2017). Multidecadal, centennial, and millennial variability in sardine and anchovy abundances in the western North Pacific and climate–fish linkages during the late Holocene. *Progress in Oceanography*, 159, 86–98. <https://doi.org/10.1016/j.pocean.2017.09.011>
- Lee, Q., Lee, A., Liu, Z., & Szuwalski, C. S. (2020). Life history changes and fisheries assessment performance: A case study for small yellow croaker. *ICES Journal of Marine Science*, 77(2), 645–654. <https://doi.org/10.1093/icesjms/fsz232>
- Lennox, R. J., Sbragaglia, V., Vollset, K. W., Sortland, L. K., McClenachan, L., Jarić, I., Guckian, M. L., Ferter, K., Danylchuk, A. J., & Cooke, S. J. (2022). Digital fisheries data in the internet age: Emerging tools for research and monitoring using online data in recreational fisheries. *Fish and Fisheries*, 23(4), 926–940.
- Levitán, D. R. (1992). Community structure in time past: Influence of human fishing pressure on algal-urchin interactions. *Ecology*, 73(5), 1597–1605.
- Link, J. S., Huse, G., Gaichas, S., & Marshak, A. R. (2020). Changing how we approach fisheries: A first attempt at an operational framework for ecosystem approaches to fisheries management. *Fish and Fisheries*, 21(2), 393–434. <https://doi.org/10.1111/faf.12438>
- Lotze, H. K., & McClenachan, L. (2013). Marine Historical Ecology: Informing the Future by Learning from the Past. In M. D. Bertness, J. F. Bruno, B. R. Silliman, & J. J. Stachowicz (Eds.), *Marine Community Ecology and Conservation*. Sinauer.
- Marco, J., Valderrama, D., & Rueda, M. (2021). Triple bottom line assessment for the historically underperforming Colombian queen conch fishery. *Marine Policy*, 125, 104257. <https://doi.org/10.1016/j.marpol.2020.104257>
- Marín-Guardado, G. (2000). *Holbox, antropología de la pesca en una isla del Caribe mexicano*. El Colegio de Michoacán AC.
- Martínez-Candelas, I. A., Pérez-Jiménez, J. C., Espinoza-Tenorio, A., McClenachan, L., & Méndez-Loeza, I. (2020). Use of historical data to assess changes in the vulnerability of sharks. *Fisheries Research*, 226, 105526. <https://doi.org/10.1016/j.fishres.2020.105526>
- Maunder, M. N., Hamel, O. S., Lee, H.-H., Piner, K. R., Cope, J. M., Punt, A. E., Ianelli, J. N., Castillo-Jordán, C., Kapur, M. S., & Methot, R. D. (2023). A review of estimation methods for natural mortality and their performance in the context of fishery stock assessment. *Fisheries Research*, 257, 106489. <https://doi.org/10.1016/j.fishres.2022.106489>
- McClenachan, L. (2009a). Documenting loss of large trophy fish from the florida keys with historical photographs. *Conservation Biology*, 23(3), 636–643. <https://doi.org/10.1111/j.1523-1739.2008.01152.x>
- McClenachan, L. (2009b). Historical declines of goliath grouper populations in South Florida, USA. *Endangered Species Research*, 7(3), 175–181. <https://doi.org/10.3354/esr00167>
- McClenachan, L. (2013). Recreation and the “right to fish” movement: Anglers and ecological degradation in the Florida keys. *Environmental History*, 18(1), 76–87.
- McClenachan, L., Addison, J. A., Anderson, B. T., Barbeaux, S., Moore, K., Muir, K., Reedy, K. L., Spies, I., & West, C. (n.d.). The fish that stop: Drivers of historical decline for Pacific cod and implications for modern management in an era of rapidly changing climate. (In review, *Philosophical Transactions of the Royal Society B*).
- McClenachan, L., Cooper, A., McKenzie, M., & Drew, J. (2015). The importance of surprising results and best practices in historical ecology. *Bioscience*, 65, 932–939. <https://doi.org/10.1093/biosci/biv100>

- McClenachan, L., Ferretti, F., & Baum, J. K. (2012). From archives to conservation: Why historical data are needed to set baselines for marine animals and ecosystems. *Conservation Letters*, 5(5), 349–359. <https://doi.org/10.1111/j.1755-263X.2012.00253.x>
- McClenachan, L., & Neal, B. (2023). Forgotten whales, fading codfish: Perceptions of 'natural' ecosystems inform visions of future recovery. *People and Nature*, 5, 699–712. <https://doi.org/10.1002/pan3.10439>
- MCPL. (n.d.). *Dead Fish*. <https://www.flickr.com/photos/keyslibraries/albums/72157607307854787/>
- Menzies, C. R. (2015). Revisiting "Dm Sibilhaa'nm da Laxyuubm Gitxaala (Pickling abalone in Gitxaala territory)": Vindication, appropriation, and archaeology. *BC Studies: The British Columbian Quarterly*, Autumn, 179, 129–153. <https://doi.org/10.14288/BCS.V01187.187220>
- Mumby, P. J., Steneck, R. S., Roff, G., & Paul, V. J. (2021). Marine reserves, fisheries ban, and 20 years of positive change in a coral reef ecosystem. *Conservation Biology*, 35(5), 1473–1483. <https://doi.org/10.1111/cobi.13738>
- Muraoka, W. T., Cramer, K. L., O'Dea, A., Zhao, J., Leonard, N. D., & Norris, R. D. (2022). Historical declines in parrotfish on Belizean coral reefs linked to shifts in reef exploitation following European colonization. *Frontiers in Ecology and Evolution*, 10, 972172.
- O'Dea, A., Shaffer, M. L., Doughty, D. R., Wake, T. A., & Rodriguez, F. A. (2014). Evidence of size-selective evolution in the fighting conch from prehistoric subsistence harvesting. *Proceedings of the Royal Society B: Biological Sciences*, 281(1782), 20140159. <https://doi.org/10.1098/rspb.2014.0159>
- O'Hop, J., & Munyandodero, J. (2016). Southeastern U.S. *Goliath grouper* (stock assessment report 47). SEDAR.
- Pacific Fishery Management Council. (2008). *Management of krill as an essential component of the California current ecosystem: Amendment 12 to the coastal pelagic species fishery management plan*. Pacific Fishery Management Council. <https://www.pcouncil.org/actions/cps-fmp-amendment-12/>
- Pauly, D. (1995). Anecdotes and the shifting baseline syndrome fisheries. *Trends in Ecology & Evolution*, 10(10), 430. [https://doi.org/10.1016/S0169-5347\(00\)89171-5](https://doi.org/10.1016/S0169-5347(00)89171-5)
- Pauly, D., & Zeller, D. (2016). Catch reconstructions reveal that global marine fisheries catches are higher than reported and declining. *Nature Communications*, 7(1), 10244. <https://doi.org/10.1038/ncomms10244>
- Pestle, W. J. (2013). Fishing down a prehistoric Caribbean marine food web: Isotopic evidence from Punta Candelero, Puerto Rico. *The Journal of Island and Coastal Archaeology*, 8(2), 228–254. <https://doi.org/10.1080/15564894.2013.797943>
- Posada, J. M., Stoner, A. W., Sullivan Sealey, K., Antczak, A., Schapira, D., Torres, R., Montaño, I., Ray Culp, M., & Aldana Aranda, D. (2007). Regional initiative for the evaluation of queen conch (*Strombus gigas*) exploitation under an historical perspective. *59th Gulf and Caribbean Fisheries Institute*, 59, 23–30.
- Punt, A. E. (2010). Harvest control rules and fisheries management. In R. Q. Grafton, R. Hilborn, D. Squires, M. Tait, & M. Williams (Eds.), *Marine fisheries conservation and management* (pp. 582–594). Oxford University Press.
- Ralston, S., Pearson, D. E., Field, J. C., & Key, M. (2010). *Documentation of the California Catch Reconstruction Project*. (Technical Memorandum NOAA-TM-NMFS-SWFC; 461; NOAA Technical Memorandum NMFS). NOAA.
- Rick, T. C., & Lockwood, R. (2013). Integrating Paleobiology, archeology, and history to inform biological conservation. *Conservation Biology*, 27(1), 45–54. <https://doi.org/10.1111/j.1523-1739.2012.01920.x>
- Robledo, R. (2023). *Estará documental sobre tiburones, 'Holbox', en Festival de Cineteca*. La Jornada.
- Rosenberg, A. A., Bolster, W. J., Alexander, K. E., Leavenworth, W. B., Cooper, A. B., & McKenzie, M. G. (2005). The history of ocean resources: Modeling cod biomass using historical records. *Frontiers in Ecology and the Environment*, 3(2), 78–84. [https://doi.org/10.1890/1540-9295\(2005\)003\[0078:THOORM\]2.0.CO;2](https://doi.org/10.1890/1540-9295(2005)003[0078:THOORM]2.0.CO;2)
- Rubio-Cisneros, N. T., Martínez-Candelas, I. A., & González-Rojas, J. I. (2021). La historia de la pesca en Isla Mujeres. III Coloquio Internacional Antropología, Historia y Arte en el Cribre. Xalapa, Veracruz, México.
- Rubio-Cisneros, N. T., Martínez-Candelas, I. A., Ordaz-García, D., Pérez-Jiménez, J. C., Jiménez-Cano, N. G., Glover, J. B., Montes-Gonzon, B. K., Ruiz-Ayma, G., & González-Rojas, J. I. (2023). Interdisciplinary science and fishers' local ecological knowledge of sawfishes in the Yucatán peninsula. *Aquatic Conservation: Marine and Freshwater Ecosystems*, 33(9), 897–916. <https://doi.org/10.1002/aqc.3981>
- Rubio-Cisneros, N. T., Moreno-Báez, M., Glover, J., Rissolo, D., Sáenz-Arroyo, A., Götz, C., Salas, S., Andrews, A., Marín, G., Morales-Ojeda, S., Antele, F., & Herrera-Silveira, J. (2019). Poor fisheries data, many fishers, and increasing tourism development: Interdisciplinary views on past and current small-scale fisheries exploitation on Holbox Island. *Marine Policy*, 100, 8–20. <https://doi.org/10.1016/j.marpol.2018.10.003>
- Ruga, M. R., Meyer, D. L., & Huntley, J. W. (2019). Conch fritters through time: Human predation and population demographics of *Lobatus gigas* on San Salvador Island, The Bahamas. *PALAIOS*, 34(8), 383–392. <https://doi.org/10.2110/palo.2018.054>
- Sari, I., White, A., Ichsan, M., Cope, J., Nowlis, J., Rotinsulu, C., Mandagi, S., Menai, E., Henan, Z., Sharma, R., Tuharea, S., Tabalessy, R., & Masengi, M. (2022). Translating the ecosystem approach to fisheries management into practice: Case of anchovy management, Raja Ampat, West Papua, Indonesia. *Marine Policy*, 143(2022), 105162. <https://doi.org/10.1016/j.marpol.2022.105162>
- Schapira, D., Montaño, I. A., Antczak, A., & Posada, J. M. (2009). Using shell middens to assess effects of fishing on queen conch (*Strombus gigas*) populations in Los Roques archipelago National Park, Venezuela. *Marine Biology*, 156(4), 787–795. <https://doi.org/10.1007/s00227-009-1133-1>
- Schijns, R., & Pauly, D. (2022). Management implications of shifting baselines in fish stock assessments. *Fisheries Management and Ecology*, 29(2), 183–195. <https://doi.org/10.1111/fme.12511>
- Schroeder, W. C. (1924). *Fisheries of Key West and the clam industry of southern Florida*. Washington, DC, USA.
- Silver, J. J., Okamoto, D. K., Armitage, D., Alexander, S. M., Clifford Atleo (Kam'ayaam/Chachim'multhnii), Burt, J. M., Russ Jones (Nang Jingwas), Lee, L. C., Muhl, E.-K., Salomon, A. K., & Stoll, J. S. (2022). Fish, people, and systems of power: Understanding and disrupting feedback between colonialism and fisheries science. *The American Naturalist*, 200(1), 168–180. <https://doi.org/10.1086/720152>
- Steneck, R. S., Arnold, S. N., & Mumby, P. J. (2014). Experiment mimics fishing on parrotfish: Insights on coral reef recovery and alternative attractors. *Marine Ecology Progress Series*, 506, 115–127. <https://doi.org/10.3354/meps10764>
- Steneck, R. S., & Pauly, D. (2019). Fishing through the Anthropocene. *Current Biology*, 29(19), R987–R992. <https://doi.org/10.1016/j.cub.2019.07.081>
- Stoner, A. W., & Appeldoorn, R. S. (2022). Synthesis of research on the reproductive biology of queen conch (*Aliger gigas*): Toward the goals of sustainable fisheries and species conservation. *Reviews in Fisheries Science & Aquaculture*, 30(3), 346–390. <https://doi.org/10.1080/23308249.2021.1968789>
- Stoner, A. W., & Ray-Culp, M. (2000). Evidence for Allee effects in an over-harvested marine gastropod: Density-dependent mating and egg production. *Marine Ecology Progress Series*, 202, 297–302. <https://doi.org/10.3354/meps202297>
- Tewfik, A., Babcock, E. A., Appeldoorn, R. S., & Gibson, J. (2019). Declining size of adults and juvenile harvest threatens sustainability of a tropical gastropod, *Lobatus gigas*, fishery. *Aquatic Conservation: Marine*

- and *Freshwater Ecosystems*, 29(10), 1587–1607. <https://doi.org/10.1002/aqc.3147>
- Thorson, J. T., & Cope, J. M. (2015). Catch curve stock-reduction analysis: An alternative solution to the catch equations. *Fisheries Research*, 171, 33–41. <https://doi.org/10.1016/j.fishres.2014.03.024>
- Thurstan, R., Campbell, A. B., & Pandolfi, J. M. (2016). Nineteenth century narratives reveal historic catch rates for Australian snapper (*Pagrus auratus*). *Fish and Fisheries*, 17(1), 210–225. <https://doi.org/10.1111/faf.12103>
- Torres, R. E., & Sullivan-Sealey, K. M. (2002). Shell Midden surveys as source of information about fished queen conch (*Strombus gigas*) populations: A case study in Parque Nacional del Este, Dominican Republic. *53rd Gulf and Caribbean Fisheries Institute*, 53, 143–153.
- Van Houtan, K. S., McClenachan, L., & Kittinger, J. N. (2013). Seafood menus reflect long-term ocean changes. *Frontiers in Ecology and the Environment*, 11(6), 289–290.
- Vermeij, M. J. A., Latijnhouwers, K. R. W., Dilrosun, F., Chamberland, V. F., Dubé, C. E., Buurt, G. V., & Debrot, A. O. (2019). Historical changes (1905–present) in catch size and composition reflect altering fisheries practices on a small Caribbean Island. *PLoS One*, 14(6), e0217589. <https://doi.org/10.1371/journal.pone.0217589>
- West, S. E., & Pateman, R. M. (2016). Recruiting and retaining participants in citizen science: What can Be learned from the volunteering literature? *Citizen Science: Theory and Practice*, 1(2), 15.
- White, E. R., Froehlich, H. E., Gephart, J. A., Cottrell, R. S., Branch, T. A., Agrawal Bejarano, R., & Baum, J. K. (2021). Early effects of COVID-19 on US fisheries and seafood consumption. *Fish and Fisheries*, 22(1), 232–239. <https://doi.org/10.1111/faf.12525>
- Wild, C., Jantzen, C., & Kremb, S. G. (2014). Turf algae-mediated coral damage in coastal reefs of Belize, Central America. *PeerJ*, 2, e571. <https://doi.org/10.7717/peerj.571>
- Wilson, S. K., Street, S., & Sato, T. (2005). Discarded queen conch (*Strombus gigas*) shells as shelter sites for fish. *Marine Biology*, 147(1), 179–188. <https://doi.org/10.1007/s00227-005-1556-2>
- Zeller, D., Palomares, M. L. D., Tavakolie, A., Ang, M., Belhabib, D., Cheung, W. W. L., Lam, V. W. Y., Sy, E., Tsui, G., Zylich, K., & Pauly, D. (2016). Still catching attention: *Sea around us* reconstructed global catch data, their spatial expression and public accessibility. *Marine Policy*, 70, 145–152. <https://doi.org/10.1016/j.marpol.2016.04.046>
- Zu Ermgassen, P. S. E., Spalding, M. D., Blake, B., Coen, L. D., Dumbauld, B., Geiger, S., Grabowski, J. H., Grizzle, R., Luckenbach, M., McGraw, K., Rodney, W., Ruesink, J. L., Powers, S. P., & Brumbaugh, R. (2012). Historical ecology with real numbers: Past and present extent and biomass of an imperilled estuarine habitat. *Proceedings of the Royal Society B: Biological Sciences*, 279(1742), 3393–3400. <https://doi.org/10.1098/rspb.2012.0313>

How to cite this article: McClenachan, L., Cope, J., Martínez-Candelas, I., Nowlis, J., Rubio-Cisneros, N. T., Tewfik, A., & Cramer, K. L. (2024). Pathways for integrating historical information into fisheries decision-making. *Fish and Fisheries*, 00, 1–18. <https://doi.org/10.1111/faf.12854>