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Authors: Mary G. Gleason, Jennifer E. Caselle, Chris Caldow, Russell Galipeau, Walter Heady, et. al.

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Horizon scanning: survey and research priorities for coastal and marine systems of the northern Channel Islands, California

Mary G. Gleason[1,*], Jennifer E. Caselle[2], Chris Caldow[3], Russell Galipeau[4], Walter Heady[1], Corinne Laverty[5], Annie Little[6], David Mazurkiewicz[4], Eamon O'Byrne[1], Dirk Rosen[7], and Stephen Whitaker[4]

[1]*The Nature Conservancy, 201 Mission St., San Francisco, CA*
[2] *Marine Science Institute, University of California, Santa Barbara, CA 93106*
[3]*Channel Islands National Marine Sanctuary, University of California, Santa Barbara, Ocean Science Education Building 514, MC 6155, Santa Barbara, CA 93106-6155*
[4]*Channel Islands National Park, 1901 Spinnaker Dr., Ventura, CA 93001*
[5]*Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007*
[6]*United States Fish and Wildlife Service, 1901 Spinnaker Dr., Ventura, CA 93001*
[7]*Marine Applied Research and Exploration, 1230 Brickyard Cove Rd. #101, Richmond, CA 94801*

Abstract.—Historical marine ecology provides information on past ocean conditions and community structure that can inform current conservation and management. In an era of rapid global ocean changes, it is critical that managers and scientists ensure sufficient documentation of past and present conditions of resources they manage or study. Documenting, archiving, and preserving historic and contemporary data will provide their colleagues in the future with more information to make robust science-based management decisions. Using a workshop approach, we identified research and archiving priorities to enhance documentation of the past and present conditions of coastal and marine ecosystems of the northern Channel Islands in California. We identified a variety of historical data types (e.g., archeological data, oral histories, environmental records, imagery) that should be preserved and analyzed to better understand past coastal and marine ecosystems around the northern Channel Islands. Continuing with long-term monitoring programs is also important for establishing baselines to inform contemporary management decisions and compare with future conditions. Herein, we underscore the role that individual scientists and managers working in the northern Channel Islands must play in documenting their work, archiving data, and preserving specimens in museums and institutions. Our case study for the northern Channel Islands provides a guide for how scientists should be documenting past and present conditions for marine resources around the world. Robust documentation of such conditions will give future scientists, managers, and other stakeholders the information needed to navigate what are sure to be increasingly complex management challenges.

Resumen.—La ecología marina histórica proporciona información sobre las condiciones oceánicas y la estructura de las comunidades del pasado, brindando información acerca de la conservación y la gestión actual. En una era de cambios rápidos oceánicos globales, es esencial que los responsables del manejo y los científicos garanticen la suficiente información sobre las condiciones pasadas y presentes de los recursos que manejan o estudian. Documentar, archivar y preservar los datos históricos y contemporáneos proporcionará a futuros colegas mayor información para tomar decisiones de gestión sólidas, basadas en la ciencia. Mediante un taller, identificamos las prioridades a investigar y archivar para reforzar la documentación de las condiciones pasadas y presentes de los ecosistemas costeros y marinos de las Islas del Canal (Channel Islands) del norte de California. Identificamos una variedad de tipos de datos históricos (por ejemplo, datos arqueológicos, historias orales, registros ambientales, imágenes) que se deben preservar y analizar para comprender mejor los antiguos ecosistemas costeros y marinos de las Islas del Canal del norte. También es importante continuar con los programas de monitoreo a largo plazo que ayuden a establecer los fundamentos para informar las decisiones de gestión contemporáneas y compararlas con las condiciones futuras. Destacamos el papel que los científicos y administradores que trabajan en las Islas del Canal del norte deben desempeñar a la hora de documentar su trabajo, de archivar datos y de preservar especímenes en museos e instituciones. Nuestro estudio sobre las Islas del Canal del norte proporciona una guía sobre cómo los científicos deben documentar las condiciones pasadas y presentes de los recursos marinos en todo el mundo. La sólida documentación de estas condiciones ofrecerá a los futuros científicos, administradores y a otros interesados la información necesaria para guiarlos en lo que, seguramente, serán desafíos de gestión cada vez más complejos.

*Corresponding author: mgleason@tnc.org

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Coastal and marine ecosystems are being subjected to increasing impacts due to human activities, such as resource extraction, pollution, and anthropogenic climate changes, that pose significant threats to ecological processes, biodiversity, ecosystem health, and food security (Worm et al. 2009, Hoegh-Guldburg and Bruno 2010, Cózar et al. 2014, Greene 2016). Understanding and responding to these impacts represents a significant challenge to the scientific and conservation communities, in part because of unique attributes of the marine environment. The pace of some climate change indicators (e.g., species shifts) may be faster in marine ecosystems, especially in midlatitude upwelling ecosystems, relative to many other systems (Burrows et al. 2011, Doney et al. 2012). Additionally, the scale of chemical and material transport in the ocean is generally quite large (i.e., many kilometers). Because of the fluid nature of marine ecological processes, spatial boundaries are dynamic across time and over many different parameters. The "openness" of marine systems, with species distributions defined by dynamic water bodies and broad dispersal and movement patterns, affects connectivity of populations, genetics, trophic interactions, and the ability to protect and restore those populations (Kinlan and Gaines 2003, Carr et al. 2003). Ownership and access issues are also markedly different in the marine environment than they are on land. Additionally, we know relatively little about marine ecosystems, especially deeper zones, compared to what we know about terrestrial ecosystems. This is because ocean ecosystems are difficult to access, require the development of new tools, and, as a result, are expensive to study. Coastal ecosystems, occupying a relatively narrow zone at the intersection of land and sea, have their own unique conservation challenges and are subject to stressors from both land and sea, as well as looming threats from sea-level rise (Scavia et al. 2002, Sloan et al. 2007, Heberger et al. 2011).

Overcoming the special challenges of research in coastal and marine ecosystems and collecting baseline data and information for informed management are essential. We need information on the current status of resources and the processes affecting them, as well as the natural variability and responses of systems to specific environmental or anthropogenic-based changes. To better equip and inform natural resource decision making today and into the future, Morrison et al. (2017) highlight the accountability that scientists and managers have to ensure that data pertaining to past and present conditions of the resources in their charge are collected and archived. Historical marine ecology provides information on past ocean conditions and community structure that informs our current understanding of conservation status, recovery targets, and management needs (Jackson et al. 2001, Lotze et al. 2006, McClenachan et al. 2012). As memories fade, records are lost, conditions change, and baselines shift, it is important to do what we can now to document and secure information from the past and present. Global change will bring added complexity and challenges to stewardship of the coastal and marine environment, but we suggest that a strong and easily accessible record and documentation of past and current conditions will give stakeholders and decision-makers in the future the kind of valuable information they will need. What future managers will ultimately do with this information from the past is hard to predict and will be context-specific. However, there is a growing understanding that making resource management decisions, such as how to maintain populations or communities in their current state or whether to bring an ecosystem back to an earlier state, will benefit from an understanding of baseline conditions, trajectories of historic change, and the impacts of humans on observed changes (McClenachan et al. 2012, Thurstan et al. 2015).

As a first stage in this process, we undertook an inquiry to examine the current state of documentation of past and present conditions of the coastal and marine ecosystems of the northern Channel Islands of California (USA), an area of high conservation value and of management and scientific interest. Our inquiry focused on 3 questions:

- How can we better document past conditions?
- How can we better document present conditions?
- How can we build support for data collection and archiving that can be used to make more informed management decisions today and into the future?

We conducted our inquiry as part of a broader effort to assess research and archiving needs and opportunities for the California Islands (Morrison et al. 2018). Our assessment presents a case study of, and a template for, how

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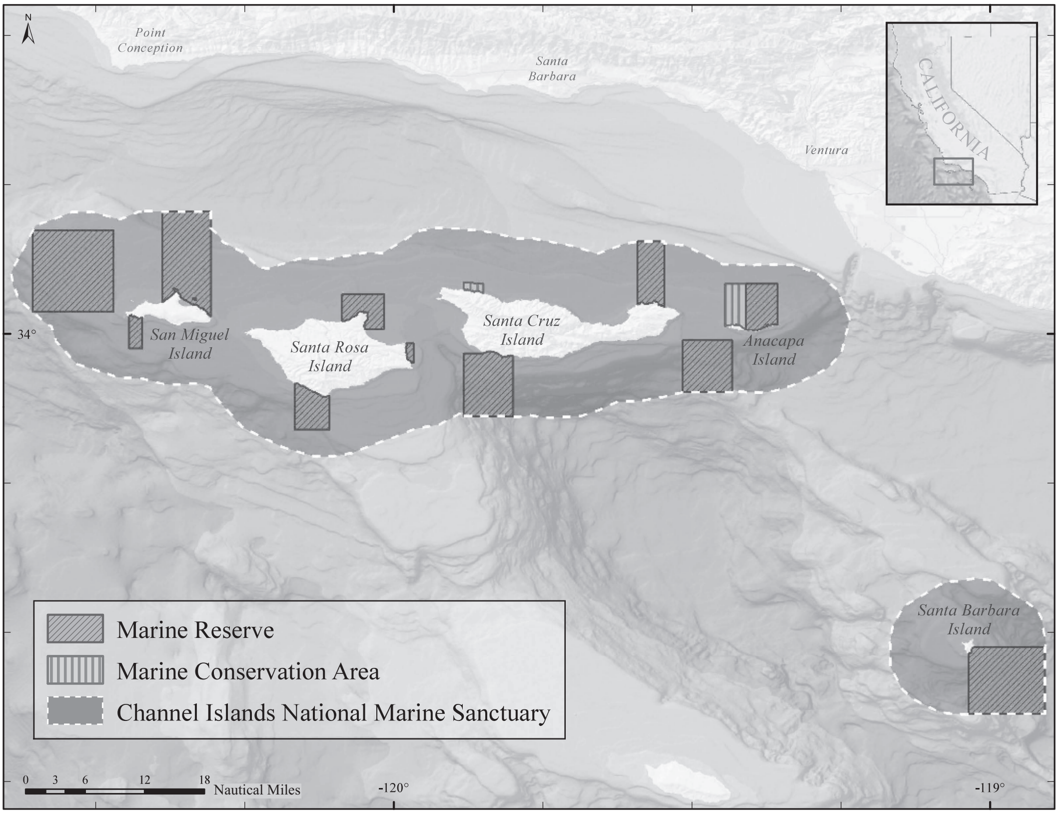

Fig. 1. Map of study region showing the northern Channel Islands and the boundaries of state marine reserves and state marine conservation areas. The dotted line and dark shading delineates the Channel Islands National Marine Sanctuary boundaries.

this type of inquiry can be applied to marine resources elsewhere.

Management Area and Resources of Interest

The Santa Barbara Channel region is highly variable, sitting at the confluence of warm- and cold-water ocean currents, which results in an important biogeographic transition zone for many marine organisms (Hickey 1998, Hamilton et al. 2010). The ocean waters around the northern Channel Islands are some of the most protected in the world, lying within the federal Channel Islands National Marine Sanctuary (henceforth, the “Sanctuary”) and the Channel Islands National Park. In addition to the federal designations, the state of California established a network of 13 marine protected areas (MPAs) in 2003, eleven of which are no-take reserves (Fig. 1; Airamé et al. 2003, Gleason et al. 2013).

While much of the marine environment around the islands is protected from extractive activities, large areas still support recreational and commercial fishing, activities that are likely to grow in importance as human populations increase. In addition, this region experiences impacts from other sources including shipping (e.g., noise, whale strikes, pollution), land-based pollutants carried offshore, offshore oil and gas development, tourism, and climate impacts (e.g., warming water temperatures, ocean acidification, sea level rise).

Study Area Boundary

We defined our study area as the waters around the northern Channel Islands, and we used the federal Sanctuary boundary as the demarcation (Fig. 1). This is akin to using the management unit of an individual island or protected area as a focal area for determining research and documentation priorities for

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terrestrial resources. The Sanctuary encompasses 1110 square nautical miles (1470 square miles or 3807 km^2) of water from mean high tide to 6 nautical miles offshore of Santa Barbara, Anacapa, Santa Cruz, Santa Rosa, and San Miguel Islands. Santa Barbara Island, while geographically grouped with the southern Channel Island archipelago, is included in this overview because of this shared management boundary and research history. We assumed that as we identified questions and information needs related to this jurisdictional unit, the geographic area of interest may scale outward depending on the specific resource or question of interest. For example, connectivity issues in the marine environment, as described above, may lead to conservation strategies that transcend political boundaries. Similarly, conservation of particularly threatened species or habitats might dictate research priorities at spatial scales larger than this study area boundary.

Coastal and Marine Resources

The coastal and marine ecosystems and resources in the northern Channel Islands are important for their biodiversity values and relevance to the people who have lived, worked, and recreated around the islands and their waters both currently and historically. In this ecoregional transition zone, marine biodiversity is quite high, containing species with both northern (cold water) and southern (warm water) affinities. The coastal bluffs and shorelines around the northern Channel Islands include habitats such as coastal scrub, small wetlands, pocket beaches, intertidal rocky habitats, and offshore rocks and islets. Each island supports unique vegetative communities on the coastal margins (such as coastal bluff scrub, coastal sage scrub, and chaparral) and rare endemic plant species; much of the coastal vegetation has been altered by human activities and is in some stage of recovery. Coastal areas provide grounds for colonies of seabirds such as Ashy Storm-Petrel (*Oceanodroma homochroa*), California Brown Pelican (*Pelecanus occidentalis*), Brandt's Cormorant (*Phalacrocorax penicillatus*), Pigeon Guillemot (*Cepphus columba*), Cassin's Auklet (*Ptychoramphus aleuticus*), Scripps's Murrelet (*Synthliboramphus scrippsi*), and others. These areas are also important for marine mammal rookeries and haul-outs for species such as California sea lion (*Zalophus californianus*), northern fur seal (*Callorhinus ursinus*), northern elephant seal (*Mirounga angustirostris*), and others (NCCOS 2005).

Offshore, the marine environment can be characterized by different depth zones (e.g., inner shelf 0–30 m, middle shelf 30–100 m, outer shelf 100–200 m, meso-benthal slope 200–500 m, and bathy-benthal slope >500 m), different substrate types (e.g., silt, sand, cobble, and bedrock), and the presence of submerged aquatic vegetation (e.g., eelgrass and surfgrass) or macroalgae (e.g., kelp forests). The waters in the Sanctuary around the northern Channel Islands range from intertidal to approximately 1600 m deep, with bathymetric complexity in the form of submarine canyons and pinnacles and important deep-sea coral and sponge communities. Similarly, there are different pelagic zones (e.g., bathypelagic, mesopelagic, and epipelagic) characterized by their depth, physical oceanographic parameters, and frontal boundaries. These marine ecosystems support a diverse array of algal, invertebrate, fish, seabird, and marine mammal populations. Important fishery species include spiny lobster (*Panulirus interruptus*), market squid (*Loligo opalescens*), sea cucumbers, urchins, many species of rockfish (*Sebastes* spp.), lingcod (*Ophiodon elongatus*), sanddabs (*Citharichthys* spp.), California sheephead (*Semicossyphus pulcher*), yellowtail (*Seriola dorsalis*), and many others. Marine mammals around the islands include the pinnipeds listed above and many cetacean species such as blue whales (*Balaenoptera musculus*), gray whales (*Eschrichtius robustus*), humpback whales (*Megaptera novaeangliae*), bottlenose dolphin (*Tursiops truncatus*), long-beaked and short-beaked common dolphins (*Delphinus capensis* and *D. delphis*), and many others (NCCOS 2005).

We recognize that many of the resources that are the focus of our inquiry here are linked in complex ways to the natural and cultural resources found in the terrestrial realm of the islands. Inquiries similar to ours were directed to terrestrial flora and fauna and cultural resources of Santa Cruz Island (Boser et al. 2018, Morrison et al. 2018, Randall et al. 2018, Rick et al. 2018) We encourage readers to review those assessments for a multidisciplinary overview of the study area because there were many overlapping interests and complementary sets of recommendations.

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DOCUMENTATION OF THE PAST

Historical ecology approaches have been used to understand long-term change in marine systems (Jackson et al. 2001, Pandolfi et al. 2003, McClenachan 2009) with goals of informing restoration, conservation, and management (Pesch and Garber 2001, VanDyke and Wasson 2005). For example, in California, museum seabird specimens have played a key role in documenting historic population size, changes in diet, community structure, ocean conditions, and pollutants over time (Beissinger and Peery 2007, Osterback et al. 2015). While some of the methods and data sources for historical ecology are similar between terrestrial and coastal or marine systems, there are important differences. For example, specialized tools are often required for accessing underwater environments, so research in marine systems has lagged far behind research in terrestrial systems. Relatively recent advances in SCUBA, remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs), and submarines have made more habitats accessible, and some monitoring now occurs in most marine ecosystems. However, reconstructions of the past in marine systems tend not to be as "deep in time" as terrestrial examples.

EXAMPLES OF THE USE OF HISTORICAL ECOLOGY FROM THE CHANNEL ISLANDS

The Channel Islands and broader Santa Barbara Channel have a long history of environmental change, human occupation, and human exploitation of resources, including 13,000 years of maritime Chumash presence and hundreds of years of Spanish, Asian, and Euro-American presence. The archeological record reflects that history and documents significant changes in flora and fauna in the region that can inform modern-day management (Rick et al. 2008). In the Channel Islands, 2 case studies using different types of data provide examples of how historical information can be used in modern-day management and conservation. Bellquist and Semmens (2016) used fishing records compiled from a regional fishing newspaper (*Western Outdoor News*) to reconstruct changes in size structure of recreationally fished species throughout coastal California, with an emphasis on the northern Channel Islands. The work followed previous studies from Florida that utilized old photographs from fishing piers (McClenachan 2009) and a long time series of fishing records from the International Game Fishing Association (Roberts et al. 2001, Bohnsack 2011) to document temporal declines in fish size and changes in fish community structure and to assess benefits of MPAs to recreational fishing, respectively. Bellquist and Semmens (2016) showed that since 1966, 12 out of 16 species analyzed showed declines in trophy size (size of the largest individuals in a population). Of those 12 species, 9 showed very recent stabilization or increases in trophy size. Importantly, the creation of this database from a nontraditional source overcame current limitations in temporal and spatial resolution with traditional fisheries-dependent and fisheries-independent data collected in California.

A second study (Braje et al. 2017) measured very long-term changes (over 10,000 years) to population abundance and size structure of an ecologically and commercially important fish species, California sheephead (*Semicossyphus pulcher*). Comparing zooarchaeological records from the Channel Islands with contemporary samples and using stable isotope analysis to measure food habits, these authors provide a more accurate baseline of the size and diet of California sheephead prior to the development of a fishery in the early 20th century. They found that the average size of sheephead along the northern Channel Islands today is significantly smaller than in the deep past. This may be due to the targeting of large sheephead by modern commercial and recreational anglers, which has culled many of the largest fish from the modern population. However, the authors also provide evidence for the long-term continuity and stability of sheephead populations in the northern Channel Islands, both in terms of relative abundances and average sizes with fluctuations in time in both metrics, suggesting hope for the restoration of this fishery in the Channel Islands region. This research is a rare example of long-term historical analysis attempting to provide actionable data for modern fisheries management.

Despite a growing interest in historical information and increasing discovery of a variety of nontraditional data types, historical data are still not commonly utilized in marine management or conservation decisions. McClenachan et al. (2012) note several obstacles ranging from

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funding limitations on gathering historical data in the first place to challenges of incorporating nontraditional data into existing quantitative frameworks. Yet, when historical long-term data are incorporated into marine population assessments (e.g., for fisheries or extinction risk assessments), they often point to more severe population declines than assessments without long-term data do (McClenachan et al. 2012). In fact, the problem of shifting baselines in marine ecosystems and populations has been described by many authors (Pauly 1995, Dayton et al. 1998, Jackson et al. 2001, Pinnegar and Engelhard 2008) and has potentially limited management and restoration efforts by identifying rebuilding targets that may be dangerously low or simply underestimating the magnitude of declines. As we move forward collecting and archiving data on marine and coastal ecosystems of the present, attention to the current challenges of incorporating these data into conservation and decision making may help us overcome these limitations in the future. For example, accessibility and documentation (via archiving and good metadata practices) might make data more discoverable to future historical ecologists.

Importance of Historical Information in the Context of Ocean Change

The importance of taking a longer view of our coastal and marine ecosystems, especially in a dynamic area like the northern Channel Islands, cannot be overstated. Recent human-induced climate fluctuations are layered on decadal (e.g., Pacific Decadal Oscillation) and shorter-term (e.g., El Nino Southern Oscillation) time frames. Anthropogenic activities have increased dramatically in the region since the early 19th and 20th centuries with increases in fishing pressure brought by the Chinese and Euro-American fisheries as the native Chumash populations were reduced (Braje et al. 2017). More recently, commercial shipping, invasive species, pollution, disease outbreaks, and tourism have all increased, and all have contributed to largely unstudied impacts on the marine and coastal systems. Several well-documented extirpations of marine species have occurred in the Channel Islands region with varying effects on present-day marine communities. One of the best-documented examples involved the loss of a keystone predator in the system, the southern sea otter (*Enhydra lutris nereis*), because of intensive hunting associated with the fur trade beginning in the early 1800s (Braje et al. 2013). By 1830, southern sea otters were functionally extinct throughout California. After being given protection in 1911 by the International Fur Seal Treaty, southern sea otter populations have increased, albeit slowly (USFWS 2015). Current community structure of rocky reefs and kelp forests (essentially encompassing all modern kelp forest–monitoring time series) almost certainly reflects the loss of this top, keystone predator. However, it has been suggested that southern California kelp forests may be more resilient to change than other kelp forests in the range of the sea otter because of high levels of functional redundancy in predators, including the California sheephead and spiny lobster (Steneck et al. 2002, Graham et al. 2008). Should the sea otter expand its current range to the northern Channel Islands (a small reintroduced population lives at San Nicolas Island), we might expect to see dramatic changes to the kelp forest systems, perhaps a reflection of the historical state.

Another dramatic loss of a suite of species involved a combination of overfishing and disease. Red and black abalone (*Haliotis rufescens* and *H. cracherodii*, respectively) were important food sources for the Chumash people on Santa Cruz Island (Braje et al. 2009). With the loss of their 2 main predators, sea otters as described above and the declining Chumash population, abalone experienced population explosions in the early 1800s (Braje et al. 2009), with black abalone reported to be stacked 5 deep in the intertidal on Santa Cruz Island. Beginning in the 1960s, 5 species of abalone suffered serial depletion in the Channel Islands. The loss has been attributed to a combination of overharvest, disease, and a long-term warming trend leading to poor recruitment (Leet et al. 1992, Engle 1994). One species of abalone, the white abalone (*Haliotis sorenseni*), was the first marine invertebrate on the federal endangered species list. Recently, anecdotal reports of recovery of some species of abalone are encouraging, but to date, the fishery for abalone south of Point Conception (Santa Barbara Co., CA) remains closed. Conservation and management today, and into the future, could benefit from a

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TABLE 1. Types and examples of historical coastal and marine data from the northern Channel Islands.

Source material	Examples
Reconstructed environmental data	Data records (e.g., precipitation) or biotic and abiotic environmental "recorders" (e.g., otoliths, skeletons, shells, sediments)
Archaeological samples	Underwater surveys of ancient submerged terraces; terrestrial middens; stable isotope analysis of feathers or fish bones from cultural and historic nesting or roosting sites
Historical records	Written histories such as ship logbooks; maritime bills of lading; fur trade logs; newspapers and popular magazines
Oral histories	Targeted interviews with scientists, fishermen, and other stakeholders
Scientific surveys	Historic scientific expeditions and surveys; field notes, species lists, and collections from museums and older naturalists; historic seabird surveys; stable isotope analysis of museum specimens; unpublished theses and dissertations; core samples drilled for the offshore oil industry
Imagery or acoustic reconstructions	Kelp canopy estimates from LANDSAT satellites; kelp aerial photography; sediment plumes from aerial imagery; U.S. military imagery and acoustic surveys
Fishing data	Fishery logbooks; newspaper and other media records; photographic databases

better understanding of the long-term context of the region, including both natural and human-induced fluctuations in populations and how marine communities were structured in the past. This does not mean that restoration to some previous state is possible or even desirable. However, knowing the bounds of fluctuations and their relationships to abiotic and biotic factors over long time scales can guide restoration toward realistic endpoints.

Potential Sources of Historical Data for the Northern Channel Islands

The northern Channel Islands provide rich opportunities for exploration and "rediscovery." Workshop participants identified many potential sources of information that could allow for reconstruction of past environmental conditions and human uses of coastal and marine systems.

We grouped these potential sources into 7 categories that span from "deep time," such as information obtained from reconstructed environmental records and archeological surveys, to the more recent past, such as information obtained from historical records, oral histories, scientific surveys, imagery, and fishing data (Table 1). With these types of information sources, it is often possible to reconstruct historic baselines though temporal comparisons, time series analysis, hindcasting, and space-for-time comparisons (Lotze and Worm 2009).

Some of these historic data sources are highly vulnerable to loss. For example, many of the coastal archeological sites around the northern Channel Islands—sites that contain a rich archive of data regarding both marine and terrestrial ecosystems—are experiencing ongoing destruction due to storm surge and sea level rise (Reeder et al. 2012). The knowledge of many late-career scientists who spent decades conducting research in the study area could be lost unless investments are made in interviewing them as part of an oral history project and facilitating the archiving of their field notes. We urge managers and scientists to prioritize data collection from ephemeral sources that are susceptible to degradation or loss.

DOCUMENTATION OF THE PRESENT

Investment in long-term ecological studies and monitoring can have significant benefits in tracking ecosystem changes through time and in informing environmental policy (Hughes et al. 2017). One of the most important actions we can take today to help the conservationists and managers of the future is to comprehensively inventory and document today's marine and coastal ecosystems and make sure those data are archived well into the future. As we considered how we could improve data collection and archiving in the present and for historical ecologists' use in the future, there was broad agreement among workshop participants that completing a baseline on ocean conditions and ensuring stable support for long-term monitoring are critical.

Completing Ocean Baseline and Supporting Long-term Monitoring

There is a high density of academic institutions, state and federal agencies, and nonprofit

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organizations located on the adjacent mainland that have conducted research or monitoring of coastal and marine resources in the northern Channel Islands. In fact, a variety of long-term monitoring programs are already in place (Table 2). Some of the best examples come from the multiple programs that survey kelp forests and rocky intertidal areas. The implementation of MPAs throughout California has provided impetus and funding for continuing and expanding many existing long-term monitoring programs, as well as developing new monitoring in habitats where programs did not already exist (e.g., deep water, sandy beach) or adding alternative types of data to assessments (e.g., social and economic data). In addition to the "benthic" ecological monitoring programs mentioned above, the region hosts some very comprehensive seabird and marine mammal monitoring programs (Table 2). Finally, the area is also well studied from an oceanographic perspective, with many of the programs mentioned above also maintaining instrumentation to measure, for example, temperature, wave exposure, salinity, oxygen, and currents.

Despite a relative wealth of existing data and monitoring programs in the coastal and marine environment, workshop participants identified areas where present-day monitoring or assessment could be added or enhanced. When participants were asked what data the marine scientist or manager of the future would like to see collected now, several areas of inquiry emerged. First, measures of abiotic habitat (e.g., extent, type, quality) are fundamental to understanding variation in biotic communities over space and time. California has made substantial progress in completing benthic habitat maps for the majority of the state using technology such as side-scan and multibeam sonar. Side-scan and multibeam sonar can provide important information on benthic structure, erosion, geomorphological change, and patterns of island subsidence over time. Unfortunately, one of the primary gaps in the statewide mapping process is in the area around the northern Channel Islands. Although substantial progress has been made recently and 70% of the Sanctuary seafloor has been surveyed by high-resolution sonar, only 20% of the area contains an actual habitat map developed by postprocessing those data. The majority of the remaining seafloor mapping gaps occur in shallower areas that are home to some of the most productive and healthy kelp forest and rocky reef communities in the region. Completion of benthic habitat mapping in this area would provide critical information to aid incident response and restoration activities, inform management of protected resources and fisheries, and improve navigational safety. These core products are building blocks for informed survey design, and they are fundamental to understanding species/habitat presence, abundance, and vulnerability.

Similarly, when investigating the drivers of change or spatial variation in biotic communities, understanding anthropogenic activities at relevant spatial and temporal scales is critical. For example, the widespread implementation of MPAs as a spatial management measure should be accompanied by collection of data on fishing effort at similar spatial scales. Similar arguments can be made for spatial data on other human uses including recreational activities, military actions, and energy development. Expansion of long-term monitoring programs into new habitats (e.g., deep water) initiated during the MPA baseline monitoring period should be continued. New technology is continually advancing and one technique in particular, the use of soundscapes and audio recordings, was identified by the group as having potential for use in the Channel Islands. Audio has been used successfully for some time to assess marine cetaceans, but, increasingly, sound is being used to document seabird populations and the "health" of whole ecosystems such as reefs and estuaries (Buxton and Jones 2012, Lillis et al. 2014, Oppel et al. 2014, Harris et al. 2016).

Prioritizing What Needs to be Done Now to Guide Future Management

Ecologists, conservation practitioners, and natural resource managers agree that long-term monitoring of the environment is critical for understanding and making decisions in complex ecological systems (Lindenmayer and Likens 2009). Increasingly, the linkages between humans and ecosystems are also recognized as important aspects to monitor (i.e., social-ecological systems; Folke 2006, Ostrom 2009). However, resources to conduct long-term monitoring are limited. Virtually all long-term environmental and social monitoring programs face funding challenges and, as such, must evaluate where and when to allocate limited resources for maximum benefit.

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TABLE 2. Examples of long-term coastal and marine monitoring programs around the northern Channel Islands.

Monitoring program	Focus and scope	Methods	Frequency/duration	URL or contacts
Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)	Intertidal and shallow subtidal, rocky habitats; fish, invertebrates, and algae; long-term change, ecosystem health, MPA monitoring	Transects and quadrats in intertidal, SCUBA surveys in subtidal; density and biomass of community, basic environmental parameters, process studies on recruitment	Since 1999/annually subtidal, since 1999/biannually intertidal	http://www.piscoweb.org/
Channel Islands National Park Service (CINPS) Kelp Forest Monitoring	Targeted surveys for key kelp forest organisms (fish, invertebrates, and algae); size and abundance; long-term change, ecosystem health, MPA monitoring	SCUBA surveys; basic environmental parameters, process studies on recruitment	Since 1982/annually	https://science.nature.nps.gov/im/units/medn/monitor/kelpforest.cfm
CINPS Rocky Intertidal Monitoring	Targeted surveys for key rocky intertidal algal and invertebrate species and assemblages	Fixed plots and transects; basic environmental parameters	Since 1982/biannually	https://science.nature.nps.gov/im/units/medn/monitor/rockyintertidal.cfm
CINPS Sand Beach Monitoring	Targeted surveys for upper and lower beach invertebrate species	Cores and transects; basic environmental parameters	Since 1994/annually	https://science.nature.nps.gov/im/units/medn/monitor/beacheslagoons.cfm
Santa Barbara Channel Long-Term Ecological Research (SBC-LTER)	Targeted surveys for key kelp forest organisms (fish, invertebrates, and algae); size and abundance; long-term change, relative importance of land and ocean processes in structuring kelp forest ecosystems	SCUBA surveys, basic environmental parameters. Multiple data streams on fishing pressure, primary productivity, water quality, etc.	Ongoing monitoring since 2002/annually, compilations of historic data	http://sbc.lternet.edu/data/
ReefCheck California	Targeted surveys for key kelp forest organisms (fish, invertebrates, and algae); size and abundance; long-term change, ecosystem health, MPA monitoring	SCUBA surveys, citizen science program, highly trained volunteer divers	Since 2006/variable timing	http://reefcheck.org/california/ca-overview
West Coast Canopy-Forming Kelp–West Coast Ocean Data Network	Extents of canopy-forming kelp along the coasts of Washington, Oregon, and California	Aerial photos and digital imagery	Since 1989/roughly annually	https://coast.noaa.gov/dataservices/Metadata/TransformMetadata?u=https://coast.noaa.gov/data/Documents/Metadata/harvest/MarineCadastre/WestCoastCanopyFormingKelp.xml&f=html
Montrose Settlements Restoration Program	Abundance, reproductive success, and restoration of seabirds in the Channel Islands and Baja California Pacific Islands, Mexico	Land, boat, acoustic and aerial surveys for Scripps's Murrelets, Ashy Storm-Petrels, Western Gulls, Cassin's Auklets, Bald Eagles, and Peregrine Falcons. Active habitat restoration work	2002–present; for various species	http://www.montroserestoration.noaa.gov/restoration/seabirds/

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TABLE 2. Continued.

Monitoring program	Focus and scope	Methods	Frequency/duration	URL or contacts
MARE, CA Dept. Fish and Wildlife, The Nature Conservancy, Channel Islands National Marine Sanctuary	Deepwater ecosystems; MPA monitoring	Remotely operated vehicle (ROV) surveys	2003–2009; 2014–2015	http://www.opc.ca.gov/2010/07/rov-based-deep-water-monitoring-of-the-northern-channel-islands-marine-protected-areas/
NOAA NMFS Marine Mammal Program	Marine mammal surveys: ground counts and health and demography studies conducted on San Miguel Island (SMI). Aerial surveys of all northern Channel Islands conducted as part of NOAA stock assessments	Ground observations, tagging, biological samples on SMI only. Aerial photography surveys of all northern islands, California sea lion diets.	Since 1969/annually on SMI. Aerial surveys focused on particular species periodically since the late 1980s.	Dr. Robert Delong and Dr. Sharon Meline (NOAA NMFS) for SMI research. https://www.afsc.noaa.gov/nmml/california/. Mark Lowry (NOAA) for aerial surveys and California sea lion diet studies.
American Cetacean Society LA Chapter	Gray whale census and behavioral monitoring	Land-based surveys from either Long Point or Point Vicente, and sometimes Catalina and Santa Cruz Islands	1979, 1980, 1983–present	http://www.acs-la.org/GWCensus.htm
Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)	Nearshore oceanography; long-term change, ecosystem health	Temperature, salinity, ChlA, waves and currents with ADCP, CTD, thermistors, and CTD casts	From 1999–2010/ continuously for most variables	http://www.piscoweb.org/
California Cooperative Oceanic Fisheries Investigations	Oceanographic data, plankton, marine mammals, and seabirds	Vessel operations including CTD casts, plankton tows, and at-sea sightings data	Since 1949/quarterly	http://www.calcofi.org/data.html
Southern California Coastal Watershed Research Project	Benthic infauna, sediment contaminants	Sediment grabs	Since 1994/every 5 years	http://www.sccwrp.org/Homepage.aspx
NOAA Southwest Fisheries Science Center	Marine mammals and seabirds	At-sea sightings surveys	Annually	https://swfsc.noaa.gov/textblock.aspx?Division=PRD&id=12462&ParentMenuId=147
NOAA Coastal Oceanographic Status and Trends	Contaminants	Collections of mussels	Haphazardly	https://products.coastalscience.noaa.gov/collections/ltmonitoring/nsandt/default.aspx
Plumes and Blooms, UCSB	Oceanography in the Santa Barbara channel; ocean color, productivity	Satellite combined with *in situ* data	Since 1996/monthly	http://www.oceancolor.ucsb.edu/plumes_and_blooms/

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TABLE 2. Continued.

Monitoring program	Focus and scope	Methods	Frequency/duration	URL or contacts
Channel Islands National Park Inventory and Monitoring Data	Seabird abundance, reproductive success, phenology, and population age structure	Boat-, land-, and colony-based surveys. Banding/mark recapture, mistnetting, acoustic surveys	1969–2006 under park program. Some annual monitoring occurred. Species varied by year. Nine species overall within the time frame.	George Hunt, Harry Carter, Bill McIver (USFWS), David Mazurkiewicz (NPS), Josh Adams (USGS), Darrell Whitworth, Frank Gress, CIES, PRBO/Pt. Blue, Smithsonian, BOEM, Laurie Harvey, NFWF, Audubon CA. https://irma.nps.gov/DataStore/ https://www.boem.gov/Pacific-Current-Studies/.
Ocean Acidification Program UCSB/CINPS	Nearshore oceanography for acidification studies	pH, dissolved oxygen; sensors deployed on piers and in the intertidal	Since 2012/continuously for UCSB; NPS intertidal monitoring beginning in 2017	Gretchen Hofmann, UCSB. http://www.hofmannlab.com. Stephen Whitaker (NPS), Jonathan Jones (NPS).
American Trader Trustee Council	Rat eradication and response of nesting seabirds on Anacapa Island	Pre, during, and post rat and seabird monitoring for seabird response	2000–2010/annual monitoring for Scripps's Murrelets. Follow-up single-season survey 2014.	https://www.wildlife.ca.gov/OSPR/NRDA/american-trader. CDFW, USFWS, Darrell Whitworth, Harry Carter, NOAA, Island Conservation.

The benefits of long-term monitoring programs and the value of the data might not be realized until well into the future. Building monitoring programs that can address both present-day and future needs is a difficult but important undertaking. As a general rule, developing criteria for data collection investments can help to clarify needs and increase the future utility of monitoring programs.

Given the many ongoing monitoring programs in existence in the Channel Islands region, potential criteria could be established to guide and prioritize monitoring investments. These criteria should include (1) the length of existing time series, (2) filling key gaps, both disciplinary and geographic (e.g., nearshore benthic habitat mapping, human use patterns, deep water habitats), (3) monitoring of new stressors and emerging issues (e.g., climate change, ocean acidification, plastic pollution, marine diseases, invasive species), and (4) incorporation of new and cost-effective technologies (e.g., monitoring soundscapes with autonomous recording units, eDNA for biodiversity monitoring, satellite imagery, new underwater visual technologies, drones and UAVs, and the use of citizen science).

Other general features of successful monitoring programs include the ability to adapt. Long-term monitoring programs are often plagued by poor planning from the outset and a lack of tractable questions. Lindenmayer and Likens (2009) suggest a framework for adaptive monitoring that stresses asking clear, tractable questions, developing solid, defensible statistical and data collection methodologies, and most importantly iterating the process, thereby allowing for learning and adaptation. In the context of the northern Channel Islands, with its large number of ongoing monitoring programs, not only consistency in methods but also foresight and flexibility to react to changing conditions will be critical to gathering useful information.

In addition to monitoring programs, it is also critical that individual scientists and managers take every opportunity to responsibly document their work, archive their data, and preserve specimens in museums and institutions. If this were a regular practice and expectation for all scientists, over time we would do a better job of accumulating information about the systems of today. Some key institutions that currently house coastal and

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marine specimens from the Channel Islands include the Santa Barbara Museum of Natural History, Los Angeles County Museum, University of California (e.g., Jepson Herbaria), California Academy of Sciences, San Francisco Maritime Museum, Western Foundation of Vertebrate Zoology, Smithsonian Institution, NOAA National Centers for Coastal Ocean Science, and others. Reviewing the myriad data-archiving resources available to marine scientists is beyond the scope of this paper, but funding agencies and foundations as well as scientific publishing enterprises are increasingly requiring data to be made discoverable and accessible through links to data repositories when available (Table 2).

Coordination and Collaboration

Two important themes that emerged from the workshop were (1) the need for increased coordination and collaboration among groups doing ocean-related work and (2) the importance of building and maintaining public support for research and monitoring. As mentioned above, the Santa Barbara Channel region is relatively data rich compared to many marine regions of the world, and while efforts have been made to coordinate research capacity and emerging data streams, more can be done. Currently, the Sanctuary's Research Activities Panel acts as an informal clearinghouse for marine research in the Sanctuary, meeting at least once a year and gathering many local researchers for roundtable discussions of findings. Data documentation and discovery has also improved substantially over the past decade with most long-term monitoring programs hosting and serving data via internet accessible portals (see links in Table 2). Some next steps might include the development of joint databases or repositories such as the Sanctuary Integrated Monitoring Network (SiMON) portal or the inclusion of more disparate types of data into the Southern California Ocean Observing System (SCOOS).

While data availability in the future is key to guiding conservation and management, the idea of having informed and invested stakeholders who support continued conservation and science was viewed as equally important by the workshop group. The public has already invested in the Channel Islands via managing agencies such as the Sanctuary, the National Park Service, the U.S. Fish and Wildlife Service, and the California Department of Fish and Wildlife; what is needed is to ensure that those investments last into the future. The northern Channel Islands are a special place to many generations of stakeholders because the islands are close to large population centers; they present iconic land- and seascapes and have a rich cultural and natural history. Suggestions for building public support for research and monitoring include durable outreach that tells compelling stories of how research has contributed to ecosystem improvement, especially stories that can counter the narrative that monitoring is boring and expensive (Suarez and Tsutsui 2004). Involvement of citizens in research and monitoring programs can also help to build a strong and educated constituency (Bonney et al. 2009). Citizen science is a growing enterprise, and several programs operate in the Channel Islands, including Reef Check California, which utilizes recreational scuba divers to monitor kelp forests (Freiwald et al. 2018). Coordination at all levels, from data collection, archiving, and analysis to outreach and public involvement will increase the effectiveness of management and conservation in the region.

Concluding Remarks

Scientists and managers of today have an opportunity and a responsibility to leave a legacy of solid information, data, and collections to inform coastal and marine conservation and management into the future. The workshop participants had many ideas for how to help the scientist or manager of the future who will look back at our time to understand the ecosystems, culture, management context, and decisions of our day. A handful of "no-regrets" strategies surfaced that, if implemented, would provide a strong foundation upon which scientists, conservationists, and managers of the future could use to understand the ecosystems of our time. These recommendations include the following imperatives:

> Use hindcasting, modeling, and historic data to better understand the past coastal and marine conditions and ecosystems around the northern Channel Islands, how those ecosystems have changed over time, and how resilient they were in the past to climate change, harvest, and species introductions or removals.

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Complete and archive today's "baseline" information including filling key gaps like mapping the seafloor, surveying deeper unexplored sites, mapping human uses around the islands, interviewing key stakeholders, and preserving specimens to leave future scientists a thorough and useful record. We also need to make sure that we are adaptively managing our monitoring programs and using the data to drive management and resource protection as new threats arise (e.g., invasive species, plastics, ocean acidification).

Promote a sense of individual scientists' responsibility to document, archive, and preserve data and specimens to make sure our colleagues in the future will be able to locate and capitalize on collections, materials, and data from our time. By working with oral historians and museum curators, we could collect and preserve the scientific stories and specimens of our time. Such an archiving system can also help connect researchers and resource managers via joint data needs.

Document today's management decisions and their rationale, so that future generations understand the management context of our time and why we made the management decisions we did. This includes documenting smaller decisions (not necessarily captured in the public record) and even recording when we decided *not* to take an action (e.g., to reduce populations or remove an invasive species).

Break down silos across disciplines (terrestrial/marine, benthic/pelagic, ecology/archeology, etc.) to ensure that we are telling the whole story and are able to understand complex dynamics in our changing world. Particularly as ocean temperatures, chemistry, currents, and species distributions change, we will need to understand the impacts of those changes across many systems and over time.

Build a constituency of public support for and investment in scientific monitoring, research, and data collection through education, citizen science, and outreach to the many people who have enjoyed the northern Channel Islands for generations. There are limited funds for data collection and archiving, and we need to identify new ways to engage the public in this important work.

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LITERATURE CITED

AIRAMÉ, S., J.E. DUGAN, K.D. LAFFERTY, H. LESLIE, D.A. MCARDLE, AND R.R. WARNER. 2003. Applying ecological criteria to marine reserve design: a case study from the California Channel Islands. Ecological Applications 13:S170–S184.

BEISSINGER, S.R., AND M.Z. PEERY. 2007. Reconstructing the historic demography of an endangered seabird. Ecology 88:296–305.

BELLQUIST, L., AND B.X. SEMMENS. 2016. Temporal and spatial dynamics of 'trophy'-sized demersal fishes off the California (USA) coast, 1966 to 2013. Marine Ecology Progress Series 547:1–18. https://doi.org/10.3354/meps11667

BOHNSACK, J.A. 2011. Impacts of Florida coastal protected areas on recreational world records for spotted seatrout, red drum, black drum, and common snook. Bulletin of Marine Science 87:939–970.

BONNEY, R., C.B. COOPER, J. DICKINSON, S. KELLING, T. PHILLIPS, K.V. ROSENBERG, AND J. SHIRK. 2009. Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience 59: 977–984.

BOSER, C.L., T.S. SILLETT, P.W. COLLINS, K.R. FAULKNER, W.C. FUNK, C.K. GHALAMBOR, L. LAUGHRIN, G.B. PAULY, J.M. ROBERTSON, R. SHEA, AND W. VICKERS. 2018. Equipping tomorrow's historical ecologist: priorities for documenting conditions of the terrestrial fauna of Santa Cruz Island, California. Western North American Naturalist 78:879–887.

BRAJE, T.J., J.M. ERLANDSON, AND T.C. RICK. 2013. Red abalone, sea otters, and kelp forest ecosystems on Historic Period San Miguel Island, California. Pages 85–96 *in* A. Morrison and D. Addison, editors, Historical ecology and marine resource use in the Indo-Pacific regions. Australian National University, Canberra, Australia.

BRAJE, T.J., J.M. ERLANDSON, T.C. RICK, P.K. DAYTON, AND M.B.A. HATCH. 2009. Fishing from past to present: long-term continuity and resilience of red abalone fisheries on California's Northern Channel Islands. Ecological Applications 19:906–919.

BRAJE, T.J., T.C. RICK, P. SZPAK, S.D. NEWSOME, J.M. MCCAIN, E.A. ELLIOTT SMITH, M. GLASSOW, AND S.L. HAMILTON. 2017. Historical ecology and the conservation of large, hermaphroditic fishes in Pacific Coast kelp forest ecosystems. Science Advances 3:e1601759.

BURROWS, M.T., D.S. SCHOEMAN, L.B. BUCKLEY, P. MOORE, E.S. POLOCZANSKA, K.M. BRANDER, C. BROWN, J.F. BRUNO, C.M. DUARTE, B.S. HALPERN, ET AL. 2011. The pace of shifting climate in marine and terrestrial ecosystems. Science 334:652–655.

BUXTON, R.T., AND I.L. JONES. 2012. Measuring nocturnal seabird activity and status using acoustic recording

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devices: applications for island restoration. Journal of Field Ornithology 83:47–60.

CARR, M.H., J.E. NEIGEL, J.A. ESTES, S. ANDELMAN, R.R. WARNER, AND J.L. LARGIER. 2003. Comparing marine and terrestrial ecosystems: implications for the design of coastal marine reserves. Ecological Applications 13:S90–S107.

CÓZAR, A., F. ECHEVARRÍA, J.I. GONZÁLEZ-GORDILLO, X. IRIGOIEN, B. ÚBEDA, S. HERNÁNDEZ-LEÓN, Á.T. PALMA, S. NAVARRO, J. GARCÍA-DE-LOMAS, A. RUIZ, ET AL. 2014. Plastic debris in the open ocean. Proceedings of the National Academy of Sciences 111: 10239–10244.

DAYTON, P.K., M.J. TEGNER, P.B. EDWARDS, AND K.L. RISER. 1998. Sliding baselines, ghosts, and reduced expectations in kelp forest communities. Ecological Applications 8:309–322.

DONEY, S.C., M. RUCKELSHAUS, J.E. DUFFY, J.P. BARRY, F. CHAN, C.A. ENGLISH, H.M. GALINDO, J.M. GREBMEIER, A.B. HOLLOWED, N. KNOWLTON, ET AL. 2012. Climate change impacts on marine ecosystems. Annual Review of Marine Science 4:11–37.

ENGLE, J.M. 1994. Perspectives on the structure and dynamics of nearshore marine assemblages of the California Channel Islands. Pages 13–26 *in* W.L. Halvorson and G.J. Maender, editors, Proceedings of the Fourth California Islands Symposium. Santa Barbara Museum of Natural History, Santa Barbara, CA.

FOLKE, C. 2006. Resilience: the emergence of a perspective for social-ecological systems analyses. Global Environmental Change 16:253–267.

FREIWALD, J., R. MEYER, J.E. CASELLE, C.A. BLANCHETTE, K. HOVEL, D. NEILSON, J. DUGAN, J. ALTSTATT, K. NIELSEN, AND J. BURSEK. 2018. Citizen science monitoring of marine protected areas: case studies and recommendations for integration into monitoring programs. Marine Ecology 39:e12470.

GLEASON, M., E. FOX, S. ASHCRAFT, J. VASQUES, E. WHITEMAN, P. SERPA, E. SAARMAN, M. CALDWELL, A. FRIMODIG, AND M. MILLER-HENSON, ET AL. 2013. Designing a network of marine protected areas in California: achievements, costs, lessons learned, and challenges ahead. Ocean and Coastal Management 74:90–101.

GRAHAM, M.H., B. HALPERN, AND M. CARR. 2008. Diversity and dynamics of Californian subtidal kelp forests. Pages 103–134 *in* T.R. McClanahan and G.M. Branch, editors, Food webs and the dynamics of marine reefs. Oxford University Press, New York, NY.

GREENE, C. 2016. North America's iconic marine species at risk due to unprecedented ocean warming. Oceanography 29:14–17.

HAMILTON, S.L., J.E. CASELLE, D.P. MALONE, AND M.H. CARR. 2010. Marine reserves special feature: incorporating biogeography into evaluations of the Channel Islands marine reserve network. Proceedings of the National Academy of Sciences 107:18272–18277.

HARRIS, S.A., N.T. SHEARS, AND C.A. RADFORD. 2016. Ecoacoustic indices as proxies for biodiversity on temperate reefs. Methods in Ecology and Evolution 7:713–724.

HEBERGER, M., H. COOLEY, P. HERRERA, P.H. GLEICK, AND E. MOORE. 2011. Potential impacts of increased coastal flooding in California due to sea-level rise. Climatic Change 109:S229–S249.

HICKEY, B.M. 1998. Coastal oceanography of western North America from the tip of Baja California to Vancouver Island. Sea 11:345–393.

HOEGH-GULDBERG, O., AND J.F. BRUNO. 2010. The impact of climate change on the world's marine ecosystems. Science 328:1523–1528.

HUGHES, B.B., R. BEAS-LUNA, A.K. BARNER, K. BREWITT, D.R. BRUMBAUGH, E.B. CERNY-CHIPMAN, S.L. CLOSE, K.E. COBLENTZ, K.L. DENESERA, S.T. DROBNITCH, ET AL. 2017. Long-term studies contribute disproportionately to ecology and policy. BioScience 67:271–281.

JACKSON, J.B.C., M.X. KIRBY, W.H. BERGER, K.A. BJORNDAL, L.W. BOTSFORD, B.J. BOURQUE, R.H. BRADBURY, R. COOKE, J. ERLANDSON, J.A. ESTES, ET AL. 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293:629–637.

KINLAN, B.P., AND S.D. GAINES. 2003. Progagule dispersal in marine and terrestrial environments: a community perspective. Ecology 84:2007–2020.

LEET, W.S., C.M. DEWEES, AND C.W. HAUGHEN. 1992. California living marine resources and their utilization. California Sea Grant. 257 pp.

LILLIS, A., D.B. EGGLESTON, AND D.R. BOHNENSTIEHL. 2014. Estuarine soundscapes: distinct acoustic characteristics of oyster reefs compared to soft-bottom habitats. Marine Ecology Progress Series 505:1–17.

LINDENMAYER, D.B., AND G.E. LIKENS. 2009. Adaptive monitoring: a new paradigm for long-term research and monitoring. Trends in Ecology and Evolution 24:482–486.

LOTZE, H.K., H.S. LENIHAN, B.J. BOURQUE, R.H. BRADBURY, R.G. COOKE, M.C. KAY, S.M. KIDWELL, M.X. KIRBY, C.H. PETERSON, AND J.B.C. JACKSON. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806–1809.

LOTZE, H.K., AND B. WORM. 2009. Historical baselines for large marine animals. Trends in Ecology and Evolution 24:254–262.

MCCLENACHAN, L. 2009. Documenting loss of large trophy fish from the Florida Keys with historical photographs. Conservation Biology 23:636–643.

MCCLENACHAN, L., F. FERRETTI, AND J.K. BAUM. 2012. From archives to conservation: why historical data are needed to set baselines for marine animals and ecosystems. Conservation Letters 5:349–359.

MORRISON, S.A., T.S. SILLETT, W.C. FUNK, C.K. GHALAMBOR, AND T.C. RICK. 2017. Equipping the 22nd-century historical ecologist. Trends in Ecology and Evolution 32:578–588.

MORRISON, S.A., T.S. SILLETT, W.C. FUNK, C.K. GHALAMBOR, AND T.C. RICK. 2018. California island rediscovery: building an archive to improve conservation today and equip the historical ecologist of tomorrow. Western North American Naturalist 78:837–851.

[NCCOS] NOAA NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE. 2005. A biogeographic assessment of the Channel Islands National Marine Sanctuary: a review of boundary expansion concepts for NOAA's national marine sanctuary program. Prepared by NCCOS's Biogeography Team in cooperation with the National Marine Sanctuary Program. Silver Spring, MD. NOAA Technical Memorandum NOS NCCOS 21. 215 pp.

OPPEL S., S. HERVÍAS, N. OLIVEIRA, T. PIPA, C. SILVA, P. GERALDES, M. GOH, E. IMMLER, AND M. MCKOWN. 2014. Estimating population size of a nocturnal

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burrow-nesting seabird using acoustic monitoring and habitat mapping. Nature Conservation 7:1–13. https://doi.org/10.3897/natureconservation.7.6890

OSTERBACK, A.K., D.M. FRECHETTE, S.A. HAYES, S.A. SHAFFER, AND J.W. MOORE. 2015. Long-term shifts in anthropogenic subsidies to gulls and implications for an imperiled fish. Biological Conservation 191: 606–613.

OSTROM, E. 2009. A general framework for analyzing sustainability of social-ecological systems. Science 325: 419–422.

PANDOLFI, J.M., R.H. BRADBURY, E. SALA, T.P. HUGHES, K.A. BJORNDAL, R.G. COOKE, D. MCARDLE, L. MCCLENACHAN, M.J.H. NEWMAN, G. PAREDES, ET AL. 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science 301:955–958.

PAULY, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution. 10:430.

PESCH, C.E., AND J. GARBER. 2001. Historical analysis, a valuable tool in community-based environmental protection. Marine Pollution Bulletin 42:339–349.

PINNEGAR, J.K., AND G.H. ENGELHARD. 2008. The 'shifting baseline' phenomenon: a global perspective. Reviews in Fish Biology and Fisheries 18:1–16.

RANDALL, J.M., K. MCEACHERN, J. KNAPP, P. POWER, S. JUNAK, K. GILL, D. KNAPP, AND M. GUILLIAMS. 2018. Informing our successors: what botanical information for Santa Cruz Island will researchers and conservation managers in the century ahead need the most? Western North American Naturalist 78:888–901.

REEDER, L.A., T.C. RICK, AND J.M. ERLANDSON. 2012. Our disappearing past: a GIS analysis of the vulnerability of coastal archaeological resources in California's Santa Barbara Channel region. Journal of Coastal Conservation 16:187–197.

RICK, T.C., T.J. BRAJE, J.M. ERLANDSON, K.M. GILL, L. KIRN, AND L. MCLAREN-DEWEY. 2018. Horizon scanning: survey and research priorities for cultural, historical, and paleobiological resources of Santa Cruz Island, California. Western North American Naturalist 78:852–863.

RICK, T.C., J.M. ERLANDSON, T.J. BRAJE, J.A. ESTES, M.H. GRAHAM, AND R.L. VELLANOWETH. 2008. Historical ecology and human impacts on coastal ecosystems of Santa Barbara Channel Region, California. *In:* T.C. Rick and J.M. Erlandson, editors, Human impacts on ancient marine ecosystems: a global perspective. University of California Press, Berkeley, CA.

ROBERTS, C.M., J.A. BOHNSACK, F. GELL, J.P. HAWKINS, AND R. GOODRIDGE. 2001. Effects of marine reserves on adjacent fisheries. Science 294:1920–1923.

SCAVIA, D., J.C. FIELD, D.F. BOESCH, R.W. BUDDEMEIER, V. BURKETT, D.R. CAYAN, M. FOGARTY, M.A. HARWELL, R.W. HOWARTH, C. MASON, ET AL. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25:149–164.

SLOAN, N.A., K. VANCE-BORLAND, AND G.C. RAY. 2007. Fallen between the cracks: conservation linking land and sea. Conservation Biology 21:897–898.

STENECK, R.S., M.H. GRAHAM, B.J. BOURQUE, D. CORBETT, J.M. ERLANDSON, J.A. ESTES, AND M.J. TEGNER. 2002. Kelp forest ecosystems: biodiversity, stability, resilience, and future. Environmental Conservation 29:436–459.

SUAREZ, A.V., AND N.D. TSUTSUI. 2004. The value of museum specimens for research and society. BioScience 54:66–74.

THURSTAN, R.H., L. MCCLENACHAN, L.B. CROWDER, J.A. DREW, J.N. KITTINGER, P.S. LEVIN, C.M. ROBERTS, AND J.M. PANDOLFI. 2015. Filling historical data gaps to foster solutions in marine conservation. Ocean and Coastal Management 115:31–40.

[USFWS] UNITED STATES FISH AND WILDLIFE SERVICE. 2015. Southern sea otter (*Enhydra lutris nereis*) 5-year review: summary and evaluation. Ventura Fish and Wildlife Office, Ventura, CA.

VAN DYKE, E., AND K. WASSON. 2005. Historical ecology of a central California estuary: 150 years of habitat change. Estuaries 28:173–189.

WORM, B., R. HILBORN, J.K. BAUM, T.A. BRANCH, J.S. COLLIE, C. COSTELLO, M.J. FOGARTY, E.A. FULTON, J.A. HUTCHINGS, S. JENNINGS, ET AL. 2009. Rebuilding global fisheries. Science 325:578–585.

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