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Cordell Bank National Marine Sanctuary 202__ Condition Report: Status and Trends 2009–2021

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Cordell Bank National Marine Sanctuary

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Office of National Marine Sanctuaries

The Office of National Marine Sanctuaries (ONMS), part of the National Oceanic and Atmospheric Administration (NOAA), serves as the trustee for a system of underwater parks encompassing more than 620,000 square miles of ocean and Great Lakes waters. The 15 national marine sanctuaries and two marine national monuments within the National Marine Sanctuary System represent areas of America's ocean and Great Lakes environment that are of special national significance. Within their waters, giant humpback whales breed and calve their young, coral colonies flourish, and shipwrecks tell stories of our maritime history. Habitats include beautiful coral reefs, lush kelp forests, whale migration corridors, spectacular deep-sea canyons, and underwater archaeological sites. These special places also provide homes to thousands of unique or endangered species and are important to America's cultural heritage.

Sanctuaries range in size from less than one square mile to more than 582,000 square miles and serve as natural classrooms, cherished recreational spots, and are home to valuable commercial industries.

Cordell Bank National Marine Sanctuary

Cordell Bank National Marine Sanctuary is a productive marine ecosystem off the coast of northern California. With its southernmost boundary located 42 miles north of San Francisco, the sanctuary is entirely offshore, with the eastern boundary six miles from shore and the western boundary 30 miles offshore. In total, the sanctuary protects an area of 1,286 square miles. The centerpiece of the sanctuary is Cordell Bank, a four-and-a-half mile by nine-and-a-half mile rocky undersea feature located 22 miles west of the Point Reyes headlands. The bank sits at the edge of the continental shelf and rises abruptly from the soft sediments of the shelf to within 115 feet of the ocean surface. Other significant features of the sanctuary include Bodega Canyon and the deep slope habitat, and the continental shelf. The combination of ocean conditions and undersea topography creates a rich and diverse marine community in the sanctuary. The prevailing California Current flows southward along the coast, and the annual upwelling of nutrient-rich deep ocean water supports the sanctuary's rich biological community of fishes, invertebrates, marine mammals, and seabirds.

Framework for Condition Reports

Sanctuary condition reports are used by NOAA to assess the condition and trends of national marine sanctuary resources and ecosystem services. Condition reports provide a standardized summary of resources in NOAA's sanctuaries, driving forces and pressures on those resources, and current conditions and trends for resources and ecosystem services. These reports also describe existing management responses to pressures that threaten the integrity of the marine environment. Condition reports include information on the status and trends of water quality, habitat, living resources, maritime heritage resources, and the human activities that affect them. They present responses to a set of questions posed to all sanctuaries (Appendix A). The reports also rate the status and trends of ecosystem services (Appendix B). Resource and ecosystem service status are assigned ratings ranging from good to poor, and the timelines used for comparison vary from topic to topic. Trends in the status of resources and ecosystem services are also reported, and unless otherwise specified, are generally based on observed changes in status since the prior condition report.

Sanctuary condition reports are structured around two frameworks: 1) a series of questions posed to all national marine sanctuaries; and 2) a management-logic model called the Driving forces (Drivers)-Pressure-State-Ecosystem Services-Response (DPSER) framework (detailed below). The questions are derived from a conceptual, generic model of a marine ecosystem. The DPSER framework defines the structure of the condition reports themselves.

Although the National Marine Sanctuary System's 15 national marine sanctuaries and two marine national monuments are diverse in many ways, including size, location, and resources, condition reports allow ONMS to consistently analyze the status and trends of abiotic and biotic factors in each site's ecosystem to inform place-based management. To that end, each unit in the sanctuary system is asked to answer the same set of questions, located in Appendix A. Additional details on the evolution of the condition report process are below.

DPSER Framework

In 2019, ONMS began restructuring sanctuary condition reports based on a model that describes the interactions between driving societal forces (Driving forces), resulting threats (Pressures), their influence on resource conditions (State), the impact to derived societal benefits (Ecosystem services), and management responses (Response) to control or improve them. The DPSER framework recognizes that human activities, the primary target of management actions, are linked to demographic, economic, social, and/or institutional values and conditions (collectively called drivers). Changes in these drivers affect the nature and level of pressures placed on both natural and heritage resources, which determines their condition (e.g., the quality of natural resources or aesthetic value). This, in turn, affects the availability of benefits that humans receive from the resources (ecosystem services[1]), which prompts targeted management responses intended to prevent, reduce, or mitigate undesirable changes (see Figure FCR.1).

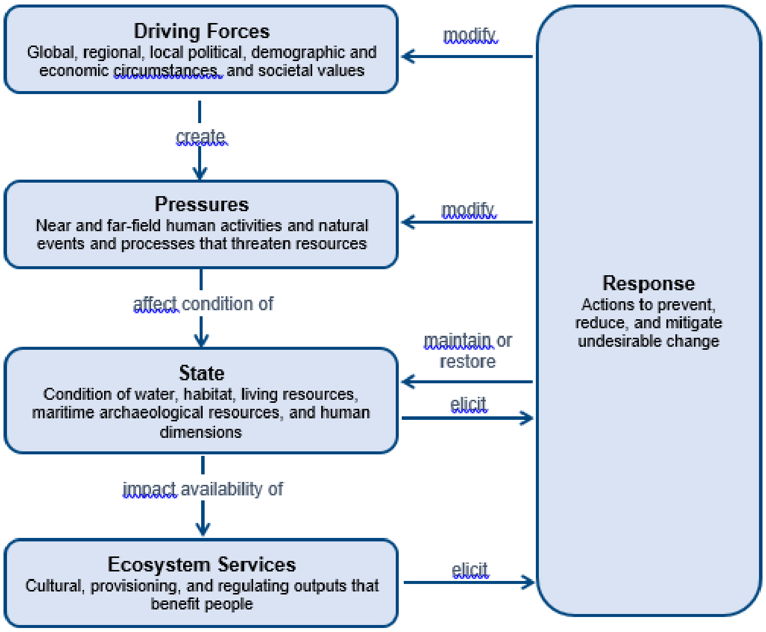

Figure FCR.1. This diagram of the DPSER framework illustrates the functional connections between compartments and the targets of management responses designed to modify driving forces, pressures, and resource conditions. Image: NOAA

Commented [1]: Note for graphic designer, in the Pressures box "Near and far field" needs to be changed "Local and non-local"

[1] For the purposes of this report, ecosystem services are defined as benefits that humans desire from the environment (e.g., recreation, food). They are what link humans to ecosystems, can be goods (e.g., food) or services (e.g., coastal protection), are valued to varying degrees by various types of users, and can be regulated directly by the environment or managed by controlling human activities or ecosystem components (e.g., restoring habitats). Whether or not specific services are rendered can be evaluated directly or indirectly based on attributes of the natural ecosystem that people care about. For example, recreational scuba divers care about water clarity and visibility in coral reef ecosystems. These are attributes that can be measured and factored into status and trend ratings to assess ecosystem services.

About This Report

The purpose of a condition report is to use the best available science and most recent data to assess the status and trends of various parts of the sanctuary's ecosystem. The first condition report for CBNMS was released in 2009 (Office of National Marine Sanctuaries [ONMS], 2009); ratings from that report are provided in Appendix C. This updated condition report marks a second comprehensive description of the status and trends of sanctuary resources and ecosystem services. The findings in this condition report document status and trends in water quality, habitat, living resources, maritime heritage resources, and ecosystem services from 2009–2021, unless otherwise noted. The report helps identify gaps in current monitoring efforts, as well as causal factors that may require monitoring, and potential remediation through management actions in coming years. The data discussed will not only enable sanctuary resource managers and stakeholders to acknowledge and have a shared perspective on prior changes in resource status, but will also inform management efforts to address challenges stemming from pressures, such as increasing coastal populations and climate change.

The findings in this condition report will provide critical support for identifying high-priority sanctuary management actions and will specifically help to shape updates to the CBNMS management plan. The management plan helps guide future work and resource allocation decisions at CBNMS by describing strategies and activities designed to address priority issues and advance core sanctuary programs. The next update to the sanctuary management plan will begin in 2023, building on the 2014 management plan, which contains a number of actions to address issues and concerns (ONMS, 2014). The process will involve significant public input, agency consultation, and environmental compliance work, and, depending on the complexity of actions proposed, may take one to three years to complete.

The State of Resources section of this document reports the status and trends of water quality, habitat, living resources, and maritime heritage resources from 2009–2019, unless otherwise noted. The State of Ecosystem Services section includes an assessment of human benefits derived from consumptive recreation, non-consumptive recreation, science, education, heritage, sense of place, commercial harvest, subsistence harvest, and collection of ornamentals within the sanctuary.

In order to rate the status and trends of resources, human activities, and ecosystem services, sanctuary staff consulted with a group of non-ONMS experts familiar with resources, activities, and services in the sanctuary. These experts also had knowledge of previous and current scientific efforts in the sanctuary (Appendix D). Evaluations of status and trends were based on the interpretation of quantitative and, when necessary, qualitative assessments, as well as observations of scientists, managers, and users.

Two other important changes to the condition report process since 2008 should be noted. First, in response to feedback provided to ONMS, the process used to generate the current condition report is more quantitatively robust and repeatable. This was achieved by using the NOAA Integrated Ecosystem Assessment framework (National Oceanic and Atmospheric Administration [NOAA], 2020), which takes a literature-based approach to developing indicators for key components of the ecosystem. Status and trend assessments can then be made for the selected indicators over time. This approach ensures that, whenever possible, the expert community has quantitative data representative of core ecosystem components available to them as they contribute to assessment ratings. These indicators continue to be tracked over time, and updated time series data can be used in subsequent assessments.

The second improvement pertains to communication of confidence, which was not done in a consistent way in earlier reports. Determination of confidence is now based on an evaluation of the quality and quantity of data used to determine the rating (e.g., peer-reviewed literature, expert opinion) and the level of agreement among experts (Appendix D). The new approach allows for a consistent and standardized characterization of confidence. The symbols used for status and trend ratings have been modified to depict levels of confidence as judged by the expert panel.

This condition report meets the aforementioned standardized format and framework prescribed for all ONMS condition reports. To the extent possible, authors have attempted to make each section's narrative consistent and comparable in terms of content, detail, and length; however, it is important to understand that each section contains different types and amounts of information given the realities and confines of datasets and expert opinions that were available during this process. In addition, this report is the result of a multi-year, collaborative effort across multiple authors, contributors, and reviewers and thus contains stylistic writing differences across some sections. These differences do not detract from the validity or quality of this report but, rather, reflect the diversity of voices and cultures involved in report generation. Finally, ratings reflect the collective interpretation of sanctuary staff and outside experts based on their knowledge and perception of local conditions. When the group could not agree on a rating, sanctuary staff determined the final rating with an acknowledgement of the differences in opinion noted in the report. The interpretation, ratings, and text in this condition report are final and the responsibility of ONMS. To emphasize this important point, authorship of the report is attributed to ONMS; subject matter experts are not authors, though their efforts and affiliations are acknowledged in the report. This report has been peer reviewed and complies with the White House Office of Management and Budget's peer review standards, as outlined in the Final Information Quality Bulletin for Peer Review (White House Office of Management and Budget, 2004).

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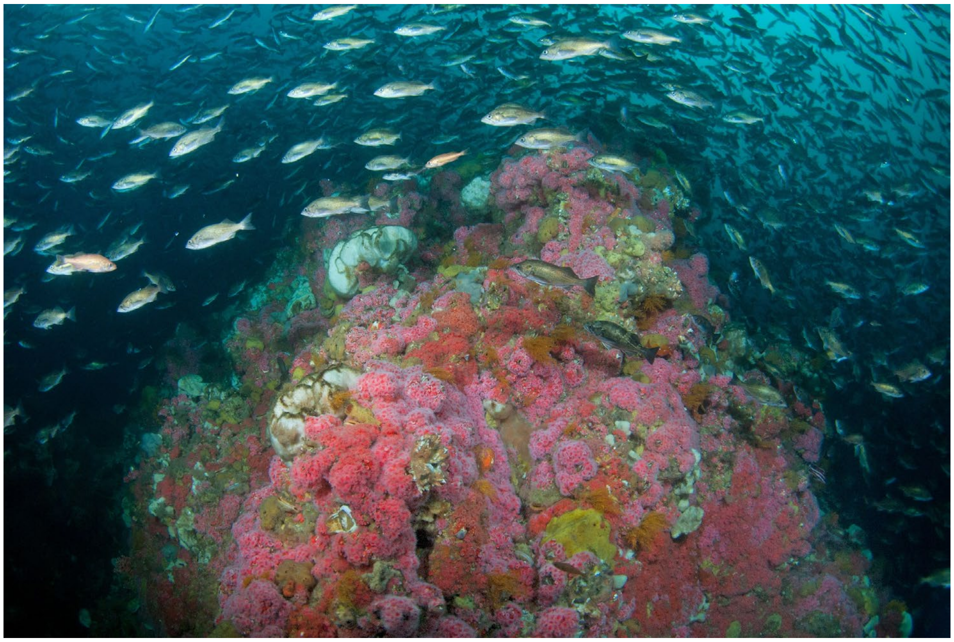
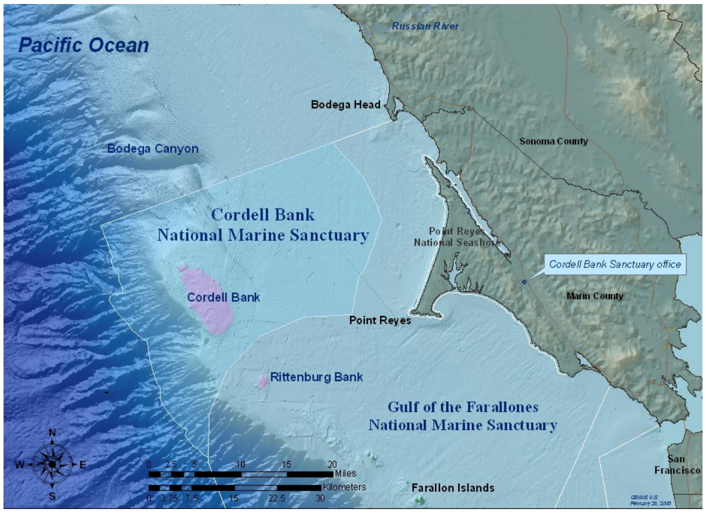
Sanctuary Setting

Overview

Cordell Bank National Marine Sanctuary (CBNMS) is part of the national marine sanctuary system – a network of underwater parks encompassing more than 620,000 square miles of marine and Great Lakes waters. As a result of its unique features and exceptional biodiversity (Figure SS.1), CBNMS was designated in 1989; and was expanded to its current size of 1,286 square miles in 2015. It is administered by the National Oceanic and Atmospheric Administration (NOAA). With its southernmost boundary located 42 miles north of San Francisco, the sanctuary is entirely offshore, with the eastern boundary six miles from shore and the western boundary 30 miles offshore. (Figure SS.2). Seafloor features, such as the rocky Cordell Bank, deep Bodega Canyon, steep slope, and continental shelf habitats, combined with significant upwelling ocean conditions, create an extremely productive marine environment in CBNMS with a wide array of diverse species that contribute to the sanctuary's unique biodiversity.



[Figure SS.1](#). Cordell Bank is a colorful feature in the sanctuary, a rocky bank rising up from the seafloor with its shallowest depths hosting a wide array of invertebrates and providing habitat for rockfish.
Credit: Robert Lee, Bay Area Underwater Explorers
Alt text: A colorful rock covered in pink, yellow, white invertebrates surrounded by blue water and schooling rockfish



[Figure S.S.2a](#). Cordell Bank National Marine Sanctuary boundaries prior to its expansion in 2015.
Credit: NOAA
Alt text: a map showing the location of Cordell Bank National Marine Sanctuary prior to the expansion in 2015

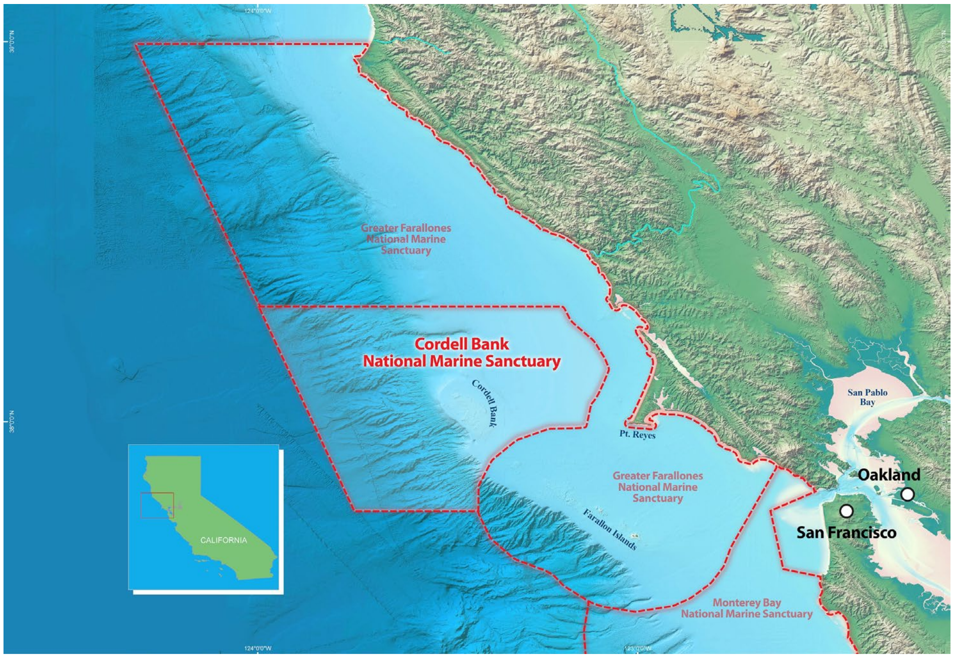


Figure SS.2b.The sanctuary is offshore of the Marin/Sonoma coast and surrounded on three sides by Greater Farallones National Marine Sanctuary.
Credit: NOAA
Alt text: a map showing the location of Cordell Bank National Marine Sanctuary.

Discovery and Designation

Cordell Bank was first noted on charts in the 1800's (Figure SS.3) and was relatively unexplored and unknown until the 1970's when a group of scuba divers from Cordell Expeditions explored and photographed the bank. Through these efforts, images of the biological diversity of Cordell Bank were first made available to the public and these efforts were instrumental in designating the site as a National Marine Sanctuary in 1989 (Figure SS.4). In 2015, NOAA completed a two-year public process that resulted in the expansion of the sanctuary (and neighboring Greater Farallones National Marine Sanctuary), more than doubling its size and including deep water features such as Bodega Canyon and the western region of the continental slope. In addition to the Cordell Expeditions divers that were instrumental in the original designation of the sanctuary, local coastal constituents supported the expansion of the sanctuary to encompass surrounding ecological features linked to the bank.

The Sanctuary Doubles in Size ***(<<GRAY TEXT WILL BE A TEXT BOX>>)***

In 2015, Cordell Bank National Marine Sanctuary expanded from its original 529 square miles to 1,286 square miles. The expansion added sanctuary protection west and north of the original boundaries to the deeper slope and canyon habitats and the highly productive region of Bodega Canyon. The neighboring Greater Farallones National Marine Sanctuary expanded during this process as well, effectively surrounding Cordell Bank National Marine Sanctuary on three sides. In 2021, both sanctuaries were combined administratively to be managed together as one team supporting management of both national marine sanctuaries.

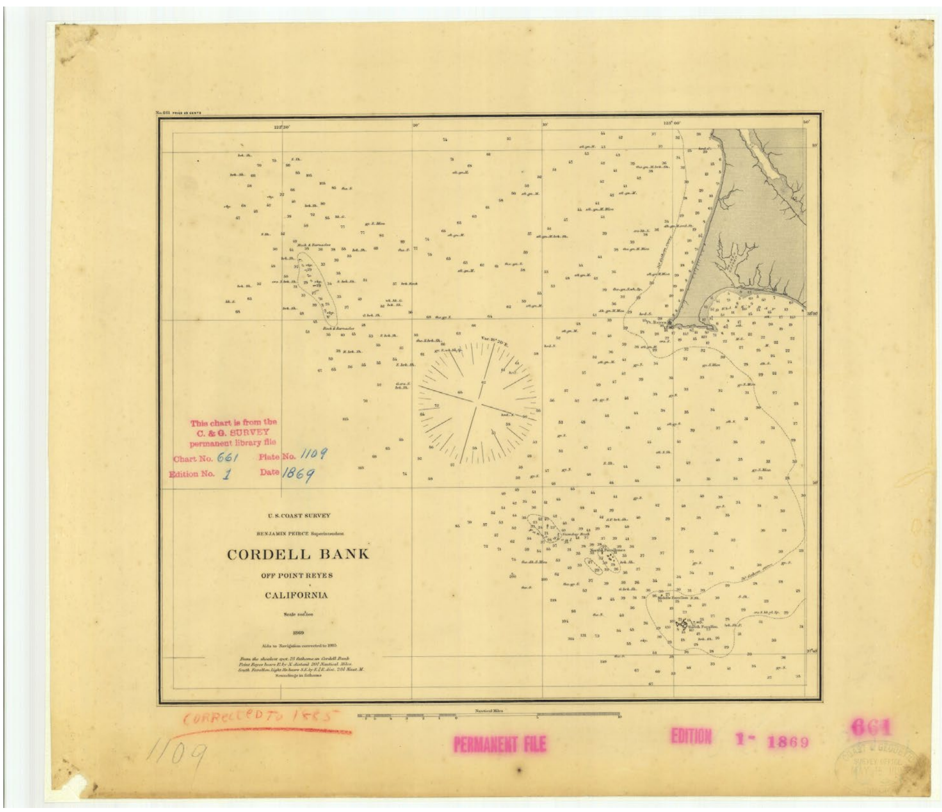


Figure SS.3. *A nautical chart from 1869 showing the feature of Cordell Bank offshore of Point Reyes.*
Credit: NOAA

Alt text: A photo of a map from 1869 showing the outline of Cordell Bank on the seafloor off of Point Reyes.


Scientists to study 'lost island'
Cordell Bank off Point Reyes
The many riches
An amazing island underneath the sea
Cordell Bank divers find
Visit to a long-lost island
EMPHASIS
Cordell Bank surprises explorers
Mystery sea mount
Lush Sea World Rises From Obscurity
Undersea mountain reveals ancient clues
Cordell Bank Dive Was Well Wort
mysterious island beneath Pacific

[Figure SS.4](#). *Through the efforts of Cordell Expeditions, images of the biological diversity of Cordell Bank were available to the public for the first time.*
Credit: Cordell Expeditions
Alt text: An assemblage of black and white clippings from newspapers highlighting Cordell Expeditions.

Oceanographic Setting

Ocean Seasons
Three oceanographic seasons influence the sanctuary. Although there is variability in when these seasons occur, they can generally be described as upwelling season in the spring and early summer (April–June), relaxation in the late summer and fall (July–September), and the storm season in winter (December–February) (Garcia-Reyes and Largier, 2012).

Upwelling Season
CBNMS is located in one of the world's four major coastal upwelling systems. During the upwelling season (April–June), strong northwest winds and the southward flowing California Current System combine with the earth's rotation to drive surface waters away from the shore (Figure SS.5). These surface waters are replaced by an upwelling of nutrient-rich deeper water from offshore which spurs phytoplankton growth, which in turn supports zooplankton and fuels higher levels of the food web. While upwelled waters are rich in nutrients, they are also lower in oxygen and are more acidic than surface waters, which also influences the ecological community of the sanctuary. Upwelling is a major oceanographic and ecological process in the sanctuary and is responsible for the incredible productivity of the ocean in this region. The productivity driven by upwelling influences many aspects of the sanctuary's ecosystem, from the timing and success of seabird nesting (Piatt et al., 2020, Jahncke et al., 2008) to the presence of migratory species. Species such as blue and humpback whales travel from Mexico and Central America to feed in the sanctuary while seabirds arrive from as far as Papahānaumokuākea Marine National Monument in the Northwest Hawaiian Islands, (Hyrenbach et al., 2006), New Zealand (Shaffer et al., 2006), and South America (Felis et al., 2019) to take advantage of upwelling-driven blooms of prey.

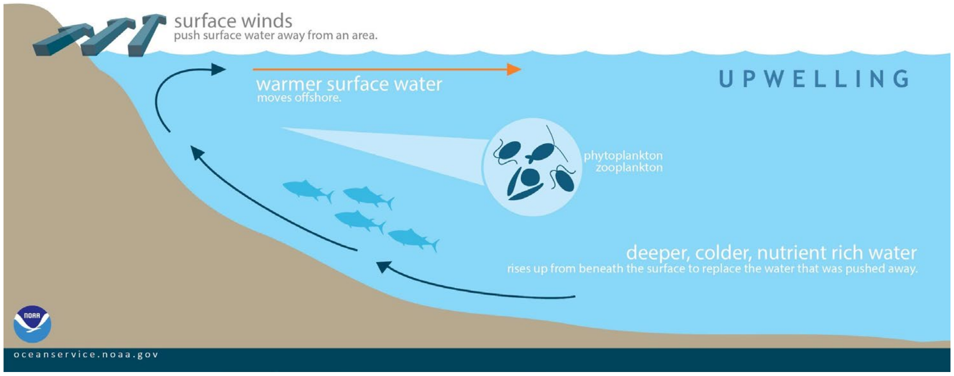


Figure SS.5. Spring/summer upwelling is the primary influence on productivity in the waters throughout Cordell Bank National Marine Sanctuary and beyond.
Credit: NOAA
Alt text: an illustration with arrows showing direction of wind and water and nutrients coming up to the shallow water.

Relaxation Season

During the late summer and fall (July–September), persistent coastal winds weaken and the sea surface becomes calmer. Surface currents during this time period are mostly northward and water temperatures increase. During this time, many migratory animals are in the area feeding on an abundance of prey.

Winter Storm Season

The winter storm season (December–February) is dominated by rough seas and greater mixing of ocean water. Strong winter storms originating in the Gulf of Alaska cause turbulent conditions that break down stratified ocean layers in the upper water column, homogenizing temperature, salinity, and the distribution of nutrients. The northward-flowing Davidson Current has a stronger influence on circulation during this time period. Most migrant species are on their breeding grounds at this time, although some individuals may remain (e.g., humpback whales, Haver et al., 2020)

Geology and Habitat

The Cordell Bank sanctuary is situated on the Pacific Plate, with its eastern boundary 7.5 miles (12 km) west of the convergence zone of two of the Earth's major tectonic plates: the Pacific and North American Plates. Cordell Bank is the most prominent geological feature in the sanctuary. Sediments surrounding the base of Cordell Bank on the continental shelf are composed predominantly of younger silt and sand deposits that originated from rivers and coastal erosion. These sediments continue to shift and break down due to energetic seafloor ocean currents.

Bodega Canyon, with the head around 1,640 ft and reaching a maximum depth of nearly two miles at the western end, transports sediment from the continental shelf to the deep sea.

Habitat

The main habitats in the sanctuary include soft sediment on the continental shelf, continental slope, deep canyons, rocky bank, and water column and pelagic habitat. The continental shelf covers 356 square miles and is primarily soft sediment including sand and mud with isolated rock piles and outcroppings ranging from 230-656 feet deep (Figure SS.6). The deep slope (1,894 square miles) and canyons contain some steep walls and hard substrate, but also large areas of soft sediment. The continental slope covers 894 square miles and is primarily mud bottom with some rock outcrops, steep rock walls, deep slope, and canyons down to depths of 11,614 feet. The main feature the sanctuary was designated to protect, and its namesake, is an offshore rocky bank roughly four miles wide by nine miles long covering an area of approximately 36 square miles. The bank emerges from the soft sediments of the continental shelf, with the upper pinnacles reaching to within 115 feet of the ocean's surface (Figure SS.7). Shelf depths at the base of the bank are between 300 and 400 feet. The bank has a diversity of benthic habitats that include high relief rock pinnacles, flat rock, boulders, cobble, sand, and mud. The pelagic zone, or open ocean water column, is the largest habitat type by volume in the sanctuary. The pelagic zone is subject to seasonal and annual variations in physical parameters like turbidity, temperature, and salinity, as well as stratification. Larger scale oceanographic events, combined with local conditions, make the water column a dynamic habitat.

Figure SS.6. Hake and fragile pink urchins are found on soft bottom habitats along the continental shelf and slope.
Credit: NOAA/MARE
Alt text: A blue gray hake fish sitting on the soft muddy seafloor with fragile pink urchins and two green dots indicating lasers for measuring.

Figure SS.7. The pinnacles of Cordell Bank harbor an abundance of life and provide structure for schooling rockfishes.
Credit: Clinton Bauder/Bay Area Underwater Explorers
Alt text: A pink and yellow invertebrate covered rocky pinnacle is lit up and gray brown widow rockfish swim densely above it.

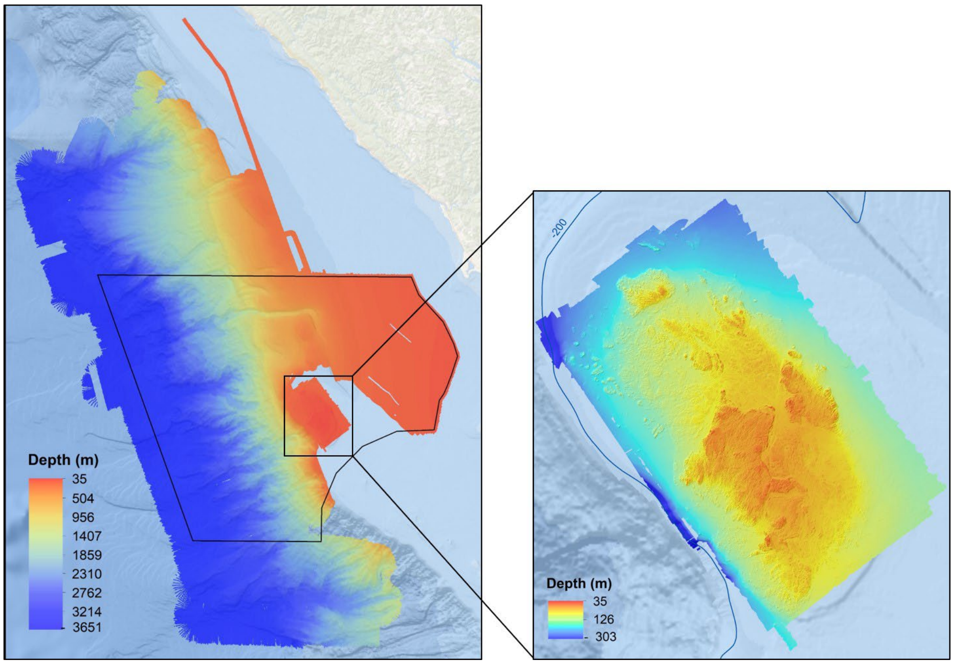


Figure SS.8. Bathymetry of Cordell Bank based on high resolution multibeam echosounder data. Red represents the shallowest depths, blue represents the deepest depths.
Source: CBNMS.
Alt text: Bathymetric map of the sanctuary. Warmer colors, like red and orange, indicate shallower depth and cooler colors, like blue, indicate deeper depths.

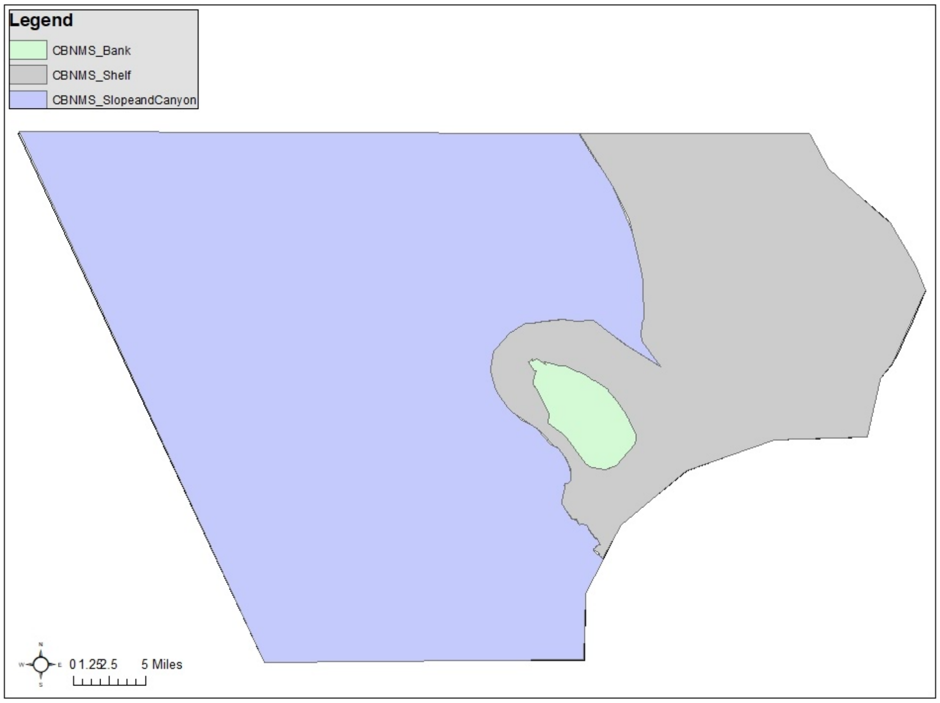


Figure SS.9. CBNMS is predominantly slope and canyon habitat followed by shelf habitat and the bank making up the smallest type of habitat in the sanctuary.
Credit: CBNMS
Alt text: Outline of the CBNMS in purple indicating slope and canyon habitat (most abundant), shelf habitat (gray color) the next most abundant, and the bank (green color) being the least amount of habitat in the sanctuary.

Living Resources

Benthic invertebrates
A dense cover of benthic organisms carpets the shallower rock surfaces of Cordell Bank. The high light penetration in this offshore environment allows for algal photosynthesis in far deeper water than in similar nearshore habitats along the mainland coast. The abundant food supply drifting over the bank, combined with a hard substrate for larval settlement and attachment, provide ideal conditions that support a rich assemblage of benthic invertebrates (Figure SS.10). Ridges are thickly covered with sponges, anemones, hard hydrocorals, soft gorgonian corals, hydroids, tunicates, crabs, sea cucumbers, and snails.

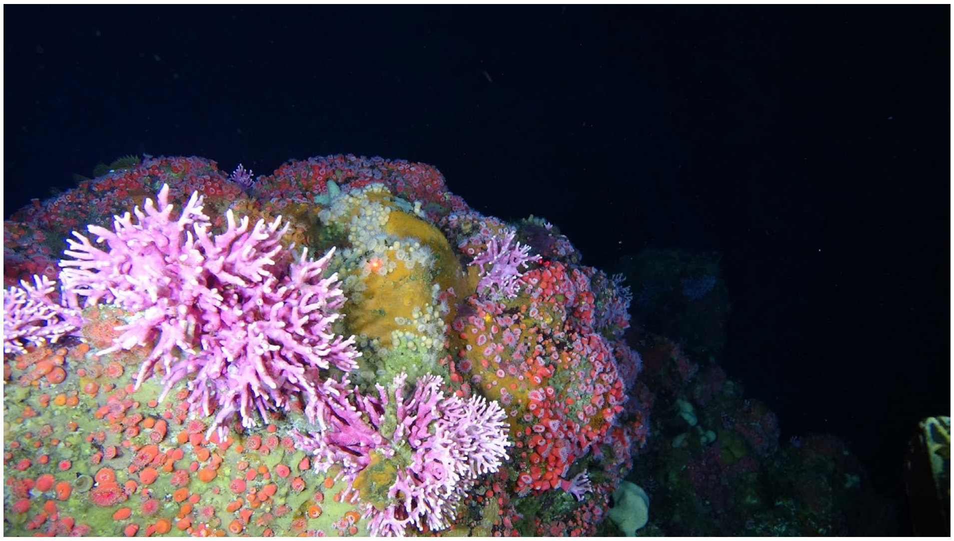


Figure SS.10. Dense invertebrate cover of hydrocorals, sponges, and anemones, carpet the shallow areas on Cordell Bank.
Photo: CBNMS
Alt text: Colorful pink hydrocoral, strawberry anemones and other invertebrates cover a rock.

Soft sediment habitats also support a thriving community of benthic invertebrates. Adapted to life in and on a shifting substrate, these animals are either buried in the sediment, like polychaete worms and clams, or are mobile on the surface, such as sea stars and Dungeness crabs (*Cancer magister*) (Figure SS.11). The sea whip (*Balticina californica*) is one common soft bottom resident that extends into the water column providing structure for fishes and other invertebrates on the flat, mostly featureless bottom of the continental shelf.


Figure SS.11. Dungeness crabs occupy the soft sediment habitats on the continental shelf habitats and are an important commercial species in the region.
Photo: NOAA/MARE
Alt Text: A Dungeness crab sits on the soft seafloor

Zooplankton

Zooplankton is an important component of the open ocean ecosystem at Cordell Bank. Copepods and pteropods are tiny but significant food items for other species. Gelatinous zooplankton include moon jellies (*Aurelia aurita*) and sea nettles (*Chrysaora fuscescens*), which are an important prey species for sea turtles, as well as less common animals such as hydromedusae, ctenophores, siphonophores, pteropods, and heteropods. Fish and invertebrate larvae also comprise a large component of the plankton community.

Krill

Two species of krill (*Thysanoessa spinifera* and *Euphausia pacifica)* are important trophic links in the Cordell Bank ecosystem (Figure SS.12). These small, shrimp-like crustaceans are foundation species because they are critical prey for many other species on and around the bank. At Cordell Bank, the presence of krill is the primary reason the area is a destination feeding ground for many migratory animals such as Chinook salmon (*Oncorhynchus tshawytscha)*, humpback whales and blue whales. In addition, krill are prey for resident species like yellowtail rockfish (*S. flavidus*) and Cassin's Auklets (*Ptychoramphus aleuticus*), which nest on the nearby Farallon Islands.

Figure SS.12. *Krill are often found in large, concentrated groups, including dense swarms with as many as 100,000 krill per cubic meter of water.*
Caption: Photo credit: Sophie Webb/ONMS/Point Blue
Alt text: a clear shrimplike looking krill with black beady eyes rests on top of a finger

Fishes

More than 250 species of fish have been documented in CBNMS (CBNMS, unpubl. data, 2021), (Figure SS.13). Cordell Bank is known as a hotspot for adult rockfish, and an abundance of juvenile rockfishes transitioning from a pelagic to benthic stage in their early life history can also be found there. Widow rockfish (*Sebastes entomelas*) and pygmy rockfish (*Sebastes wilsoni*) are two of the most abundant rockfish on the bank, along with young-of-year rockfish, which are important prey for salmon, seabirds, and adult rockfishes. Deep boulder habitat provides a natural refuge for some species recently recovered or recovering from overfishing, such as bocaccio (*Sebastes paucispinis)*, yelloweye rockfish (*S. ruberrimus)*, cowcod (*S. levis*), and

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Commented [2]: CBNMS species database canary rockfish (*S. pinniger)*. Lingcod (*Ophiodon elongatus*) are conspicuous in the wintertime, when they move up onto the bank to lay their eggs. The soft sediment of the shelf is habitat for flatfish such as sanddabs (*Citharichthys* spp.,), Rex sole (*Glytocephalus* zachirus), Dover sole (*Microstomus pacficus*) and skates (*Raja* spp.). In the deeper depths of the sanctuary thornyheads (shortspine *Sebastolobus alascanus*, and longspine thornyheads, *Sebastolobus altivelus*) and sablefish (*Anoplopoma fimbria*) are common. The pelagic habitat has species such as sharks (blue shark *Prionace glauca*, white shark *Carcharodon carcharias,* thresher shark *Alopias vulpinus,* and salmon shark *Lamna ditropis*); jack mackerel (*Trachurus symmetuicus*), pacific mackerel (*Scomber japonicus*) and pacific hake (*Merluccius productus)*. The commercially important northern anchovy (*Engraulis mordax*) and pacific sardine (*Sardinops sagax*) also occupy this habitat. Fishes that inhabit this zone on a seasonal basis, include albacore tuna (*Thunnus alalunga)* and salmon (*Oncorhynchus tshawytscha, O. kisutch*)

Figure SS.13. *China rockfish make use of the living habitat on Cordell Bank for hiding and resting.*
Photo: CBNMS
Alt text: Pink anemones and corals cover the rocky reef with a large white sponge and a china rockfish with yellow and black markings on it.

Sea turtles

The waters off central and northern California, including CBNMS, are critical foraging areas for one of the largest remaining Pacific nesting populations of endangered leatherback sea turtles, which migrate from Indonesia to feeding grounds off the west coast of North America, including CBNMS (Benson et al., 2007a; Benson et al., 2007b). Leatherback turtles feed on seasonally abundant jellyfishes (e.g., *Chrysaora fuscescens, C. colorata,* and *Aurelia spp*.) in the CBNMS area. Scientists believe that spatial and temporal abundance patterns of turtles in this region are driven by upwelling and relaxation events that favor phytoplankton growth and in turn an increased production of gelatinous zooplankton (Benson et al., 2007a).

Seabirds

The waters around Cordell Bank provide critical foraging habitat for many species of seabirds. During the upwelling season, the highest levels of seabird biomass in the central portion of the California Current are found at Cordell Bank, Monterey Bay, and the Farallon Ridge (Ford et al., 2004). Over seventy seabird species have been identified in the sanctuary. The composition of seabirds found at Cordell Bank is a mix of local breeding birds and highly migratory open-ocean species. For example, a large percentage of the world's population of Ashy Storm-Petrels (*Oceanodroma homochroa*) nest on the nearby Farallon Islands and feed in the waters around Cordell Bank (Stallcup, 2004). Cassin's Auklets are also common local breeders (Stallcup, 2004). Black-footed Albatross (*Diomedea nigripes)* nest in the northwestern Hawaiian Islands and travel to Cordell Bank waters to gather food for their chicks before returning to their nests (Hyrenbach et al., 2006) (Figure SS.14). Other migratory species use the productive waters around the bank as a stopover on their annual migration route. For example, tens of thousands of Sooty Shearwaters (*Puffinus griseus*) pass through the sanctuary annually as part of their migration between the west coast of North America and New Zealand.

Figure SS.14. Black-footed albatrosses travel thousands of miles from the northwestern Hawaiian Islands to feed in the waters of Cordell Bank National Marine Sanctuary. Photo: Mojoscoast

Alt text: A black footed albatross with its wings outstretched flies over the ocean.

Marine Mammals

Nineteen species of resident and migratory marine mammals have been observed within the sanctuary (NCCOS, 2007). Pacific white-sided dolphins (*Lagenorhynchus obliquidens)* are frequently sighted in the sanctuary. Other common cetaceans include Dall's porpoise (*Phocoenoides dalli)* and northern right-whale dolphins (*Lissodelphis borealis)*. Humpback whales are present in the sanctuary year-round, but are most abundant in the summer and fall. Blue whales are present in the sanctuary in the summer, fall, and winter. Fin whales are present from at least late summer to spring (Haver et al., 2020). In addition, gray whales pass through the sanctuary on their annual migrations between Arctic feeding grounds and Mexican breeding areas. Other mammals seen in the sanctuary include Risso's dolphins (*Grampus griseus*), killer whales (*Orcinus orca*), California sea lions, northern fur seals (*Callorhinus ursinus*), northern elephant seals (*Mirounga angustirostris*), and Steller sea lions.

Figure SS.15. Cordell Bank National Marine Sanctuary is entirely offshore and contains an abundance of marine life, including humpback whales.
Caption: Credit: Sophie Webb/ONMS/Point Blue
Alt text: A humpback whale breaches out of the water showing most of its body.

Commercial and Recreational Activities
Maritime activities are prominent in the history and development of California's North Coast. From the first indigenous communities to the present, coastal waterways remain an important route of travel and supply. Hunting of marine mammals for meat and fur took place throughout these waters in the 1800's and early 1900's contributing to the declines of many species. Ocean-based industries (e.g., fisheries, export and import, and coastal shipping) continue to be important to the modern economy and the social character of this region.

The Cordell Bank region has historically supported important commercial and recreational fisheries. Commercial fisheries in CBNMS generally target rockfish (*Sebastes spp*.) and other groundfish species, Chinook salmon (*Oncorhynchus tshawytscha*), Dungeness crab (*Cancer magister*) and albacore tuna (*Thunnus alalunga)* (Scholz et al., 2005). Private boats and recreational fishing charters originating from Bodega Bay also visit the waters throughout the Cordell Bank sanctuary, targeting salmon, lingcod, and rockfish.

Wildlife watching trips are infrequent, due to absence of commercial wildlife watching tours available to the public from the sanctuary's closest port, but they can be good opportunities to see blue and humpback whales on their seasonal feeding grounds, as well as uncommon pelagic seabirds.

Maritime Heritage Resources
The ex-USS *Stewart* (DD-224, Figure SS.16) was recently protected by CBNMS due to its inclusion within sanctuary boundaries following the expansion in 2015. Records indicate the ex-USS *Stewart* is about 39 miles west of Bodega Head. The vessel has a significant history as a United States Navy destroyer that served in both World Wars I and II, for which it received two Battle Stars for its service (Rickard, 2019). It was captured during World War II and commissioned into the Japanese Imperial Navy in 1943 and went into service as a *Shokai-Tie* Patrol Boat *No. 102* (Edwards, 2014). Recaptured at the end of the war, *Stewart* was recommissioned into the U.S. Navy in 1945 (Edwards, 2014); later scuttled in Bodega Canyon. There is good historical knowledge and records about this vessel, but no visual confirmation or indication in data collected of the seafloor. While the potential exists for other historic maritime heritage resources, prehistoric and cultural resources to be within or associated with the sanctuary, as of this writing, none are known. The staff has not been able to verify with certainty that additional resources, beyond the ex-USS *Stewart* (DD-224), lie within the sanctuary. Accordingly, assessment of non-substantiated and/or undocumented maritime heritage resources is not included in this condition report.

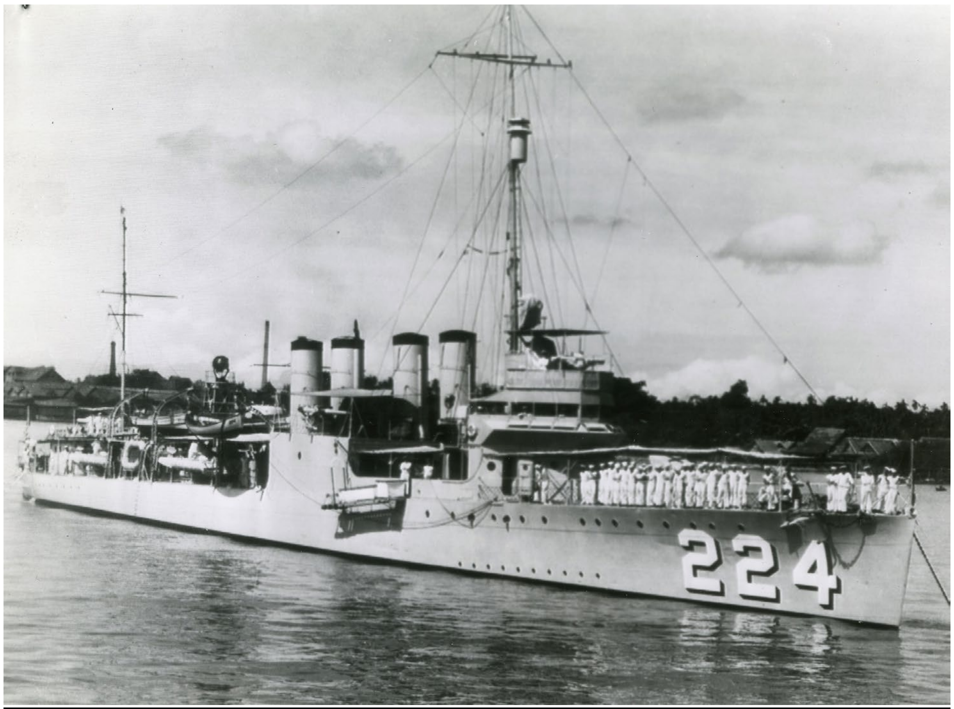

Figure SS.16. USS Stewart (DD-224) circa World War II.
Credit: Robert Schwemmer Maritime Library.
Alt text: A black and white image of a large military vessel on the surface of the water with men in white uniforms and hats at the front of the ship.

Literature Cited (Sanctuary Setting)

Citations: Destroyer History Foundation. (n.d.). USS Stewart. Retrieved June 21, 2021, from https://destroyerhistory.org/flushdeck/ussstewart/

Edwards, P. M. (2014). Between the Lines of World War II: Twenty-One Remarkable People and Events (excerpt). Google Books. Retrieved June 21, 2021, from https://books.google.com/books?id=zaXnzYGuo_4C&pg=PA30&lpg=PA30&dq=Japan+patrol+boat+102&source=bl&ots=SXv8yCDJBX&sig=ACfU3U0QbabQG6j5JWVpf7rP4wokH8fSJQ&hl=en&sa=X&ved=2ahUKEwio_fzp7LHpAhVPsZ4KHQdDAW84ChDoATABegQIChAB#v=onepage&q=Japan%20patrol%20boat%20102&f=false

Haver et al, 2020

Rickard, J. (2019). USS Stewart (DD-224). History of War.org. Retrieved June 21, 2021, from http://www.historyofwar.org/articles/weapons_USS_Stewart_DD224.html

Add to literature cited:
Garcia-Reyes and Largier, 2012

CBNMS unpublished data, 2021. Species database

References from seabirds and sea turtles sections

This is the post-peer review version of the CBNMS Condition Report. It is now locked and a new copy has been created for copy edits.

Drivers

For the purpose of condition reports, drivers, or driving forces, are defined as societal values, policies, and socioeconomic factors that influence human pressures on the ecosystem. By shaping the ways that humans interact with the marine environment, driving forces can result in either positive impacts or negative impacts (pressures) to the condition of resources like water, habitat, living resources, and maritime heritage resources. In turn, the condition, or state, of resources determines the flow of benefits that humans are able to derive from that ecosystem. Accordingly, understanding driving forces can be useful in anticipating, evaluating, and reacting to changes in the condition of resources and ecosystem services.

Whereas pressures on sanctuary resources occur locally, drivers emerge at many different scales, from local to global. A pressure may be affected by one or more drivers, and a driver may also affect multiple pressures. For example, human population growth at all scales can increase demand for seafood and, as a result, fishing pressure. Fishing pressure is also influenced by drivers like fuel prices and ocean policy, and population drivers simultaneously influence other pressures like marine debris, vessel traffic, and discharges. The drivers and pressures may vary from sanctuary to sanctuary. Relevant drivers and associated pressures were identified in consultation with sanctuary staff and based on past experience identifying drivers and pressures at other sanctuary sites. Table D.1 summarizes the drivers that influence pressures at CBNMS and the scale at which they occur.

Table D.1. Drivers and their relationship to pressures that affect CBNMS resources. For each row, the bullets indicate the range of influence of drivers across pressures. For each column, the bullets indicate which drivers affect individual pressures. The geographic scales at which different drivers originate to affect pressures are also shown (G=global, N=national, R=regional, L=local). See text below for explanations of specific drivers and pressures.

		Pressures					
DRIVERS	**Scale**	**Climate Change: Changing Ocean Conditions**	**Fishing**	**Vessel Use: Large Vessel Traffic**	**Vessel Use: Vessel Discharges**	**Vessel Use: Noise**	**Marine Debris**
Population	G, N, R, L	●	●	●	●	●	●
GDP	G, N, R, L	●	●	●	●	●	●
Per-capita Income	G, N, R, L	●	●	●	●	●	●

Fuel Prices	G, N, R, L	●	●	●	●	●	●
Trade Policy	G, N		●	●			
Ocean Policy	N, R, L	●	●	●	●	●	●
Demand for Seafood	G, N, R, L	●	●	●	●	●	●
Demand for Energy	G, N, R, L			●		●	
Regulatory Exemptions	N, L			●	●	●	
U.S. National Security	N			●	●	●	
Societal Values and Conservation Ethic	N, R, L	●	●				●
Environmental Activism	R, L	●	●	●	●	●	●
Technological Advancement	G, N, R, L		●	●		●	●
Tribal Government Relationships	N, R, L	●		●	●	●	●

Frequently, drivers affect pressures by influencing demand for marine-based goods and services like food, energy, recreational opportunities, and transportation. Drivers that influence demand include population, per capita income, trade policy, and societal values and conservation ethic. Other factors that can influence demand may include consumer tastes and preferences. As demand for marine resources increases, higher prices and/or quantity demanded create incentives for higher levels of extraction or use, which can impact the state of resources.

Other drivers influence the supply of or access to marine resources. Examples of these drivers include fuel prices, technological advancement, ocean policy, tribal government relationships, and regulatory exemptions. As production inputs, fuel prices and technology determine the cost and feasibility of exploiting marine resources and, subsequently, levels of activity and use. The other three drivers relevant to CBNMS relate to the governance of marine resources. Ocean policy (e.g., permitting for offshore energy, vessel speed reduction zones, fishing regulations), along with exemptions, may increase or decrease pressures on resources. Tribal government relationships can create cooperative management approaches that can preempt or mitigate pressures (e.g., cooperative fisheries management, preparation of oil spill response plans). Additionally, environmental activism, shaped by preferences, societal values and conservation ethic, can influence levels of ocean use by applying political pressure to ocean policymakers and stakeholders.

Population and Per Capita Income

International and domestic demand for goods and services, at all scales ranging from local to global, is directly tied to changes in population and real per capita income. It is and will remain a ubiquitous, primary driver of pressures on sanctuary resources. The data provided in this section are from the U.S. Census Bureau and U.S. Bureau of Economic Analysis (2020).

Table D.2. Population and mean per capita income in eleven-county study area for CBNMS. The counties included in the study area are Alameda, Contra Costa, Marin, Mendocino, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma. Monetary values are inflation-adjusted to 2020 dollars. Source: US BEA, 2020; Fed Reserve Bank of Minneapolis, 2022.

Year	Mean Per Capita Income	Population	Per Capita Income (% Change)	Population (% Change)
2010	$ 68,059	4,697,828	--	--
2011	$ 70,342	4,750,016	3.35%	1.11%
2012	$ 74,239	4,807,885	5.54%	1.22%
2013	$ 73,959	4,867,808	-0.38%	1.25%
2014	$ 77,836	4,925,586	5.24%	1.19%
2015	$ 84,086	4,979,820	8.03%	1.10%
2016	$ 87,860	5,011,267	4.49%	0.63%
2017	$ 91,748	5,026,510	4.43%	0.30%
2018	$ 96,111	5,023,105	4.76%	-0.07%
2019	$ 99,245	5,003,279	3.26%	-0.39%
2020	$ 106,445	4,960,724	7.26%	-0.85%

From 2010 to 2020, the population in the Cordell Bank study area (includes eleven counties: Alameda, Contra Costa, Marin, Mendocino, Napa, San Francisco, San Mateo, Santa Clara, Santa Cruz, Solano, and Sonoma) grew by 5.6%, which is less than the rate of population increase for the United States (6.5%) and slightly greater than that for California (5.5%). As of 2020, roughly 12.6% of California residents lived in the study area. In addition to being a determinant of demand for marine resources, population can influence land-based pressures on the marine environment, like changes in land use and waste management requirements. Given the decline in study area population in 2018, 2019, 2020, population-driven pressures do not seem to be of immediate concern to the sanctuary on a regional level, although localized population pressures may persist.

From 2010 to 2020, real per capita income in the Cordell Bank study area increased by around 56%, outpacing income growth in the state of California and the United States, which saw increases of roughly 37% and 23%, respectively. With higher real incomes, consumers have greater purchasing power, enabling them to buy more of the products they already purchase and/or substitute preferred, more expensive products for cheaper ones. The expected result of increases in both per capita income and population over the past decade is an increase in pressures on resources in CBNMS, created by higher demand for products and services. Activities required to meet the demand could include fishing, transportation, construction and land development, and visitation, among others.

Fuel Prices

Fuel prices are an important and often immediate driver of many ocean activities. Ocean users consider fuel prices in their decisions about whether and how to conduct activities like commercial fishing, recreational boating, and shipping (e.g., Sumaila et al., 2008; Maloni et al., 2013). Importantly, changes in fuel prices do not impact all fisheries equally. Globally, fisheries targeting crustaceans or flatfish and those employing pots/traps or trawl gear have the highest intensity of fuel use in terms of volume of fuel per live weight landed (Parker & Tyedmers, 2014). The price of retail gasoline in California varied without trend from 2010 to 2020 (Figure D.1, EIA, 2022).

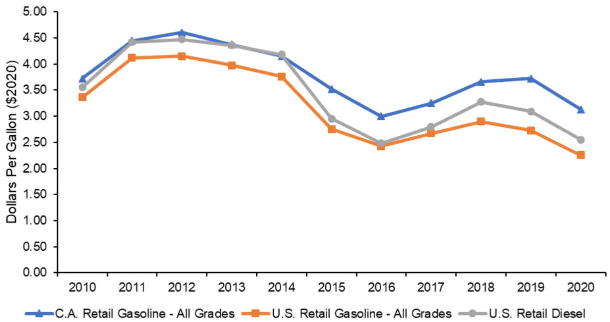

Figure D.1. Prices for California retail gasoline (all grades), US retail gasoline (all grades), and US retail diesel from 2010-2020. Source: Energy Information Administration, 2022.

Trade Policy

As with many industries, U.S. seafood harvesters and producers are impacted by foreign trade policies, like import bans and tariffs, that reduce demand for exports. Since import competition can alter the incentives for resource use, harvesters are also affected by domestic trade policies that affect the competitiveness of U.S. seafood at home (Asche et al., 2022). In 2019, the seafood industry faced a major disruption due to the trade war started with China, which is by far the largest importer and consumer of seafood (Froelich et al., 2020; FAO, 2020). As of spring 2022, the industry continues to be impacted by a Russian ban on all food imports from the U.S. that began in 2014.

Trade policy might also affect pressure on sanctuary resources by influencing the volume of trade flows and shipping activity between ports. Resource impacts related to vessel use are described below.

Ocean Policy

The United States is party to numerous agreements that establish international entities composed of member governments that focus on various topics, ranging from managing shipping (International Maritime Organization [IMO]), global whale stocks (International Whaling Commission), fisheries (International Pacific Halibut Commission, Pacific Salmon Commission, etc.), and oil spill response (CANUSPAC). These international agreements affect local processes, such as the Area to be Avoided designated by the IMO.

The West Coast states have collaborated on ocean policy initiatives since the Tri-State Agreement on Ocean Health was signed in 2006. Since that time, this regional ocean partnership has evolved to better include tribal governments, broaden federal agency representation, and identify a variety of regional priorities. Today, the West Coast Ocean Alliance is focused on: (1) compatible and sustainable ocean uses; (2) effective and transparent decision making; (3) comprehensive ocean and coastal data; and (4) increased understanding of and respect for tribal rights, traditional knowledge, resources, and practices.

The Pacific Fishery Management Council is another partnership of West Coast states that manages federal fisheries for around 119 species in the U.S. EEZ. The Council collaborates with states, tribes, and international forums to develop management measures for recommendation to NMFS (PFMC, 2020a). The California Department of Fish and Wildlife manages fisheries in state waters (1-3 miles offshore) and certain species like Dungeness crab and pink shrimp (CDFW, 2021a).

Demand for Seafood

Seafood is one of the top traded food commodities globally, and the United States is both a top importer and top five exporter of seafood (Froehlich et al., 2020). Global seafood consumption has increased by an estimated average annual rate of 3.1% from 1961 to 2017 (FAO, 2020). Further, consumption in 2030 is predicted to be 18% higher than it was in 2018, with the largest growth rates projected for Latin America (33%), Africa (27%), Oceania (22%), and Asia (19%) (FAO, 2020). Whereas, globally, aquaculture already accounts for over half of seafood produced for human consumption, farmed seafood in the U.S. makes up only 8% of domestic production (FAO, 2020; Froehlich et al., 2020). Offshore farming has been identified as a strategy (e.g., E.O. 13921) to increase U.S. seafood production and reduce reliance on imports, which currently comprise roughly two-thirds of domestic seafood consumption (Gephart et al., 2019).

From 2015 to 2019, the average volume of seafood products exported from the San Francisco US Customs District, which covers all counties adjacent to CBNMS, totaled roughly 55.5 million pounds[1] (NMFS OST, 2022). Over the same period, an average of over 132 million pounds of seafood products were imported[2] through the district (NMFS OST, 2022). Of the top species harvested in CBNMS, market squid has the highest volume of exports from San Francisco, with an average of 26.7 million pounds exported from 2015-2019 (NMFS OST, 2022). For other commercially-important species, the five-year (2015-2019) average exports from San Francisco are approximately 601,000 pounds of sablefish, 364,000 pounds of Dungeness crab, 193,000 of unspecified groundfish, and 170,000 pounds of salmon.[3]

The U.S. seafood industry has been heavily impacted by the COVID-19 pandemic and response. Restaurants and other “away from home” venues account for roughly 65% of consumer seafood expenditures in the U.S., and restaurant orders declined by upwards of 70% beginning in March of 2020 (Love et al., 2020; Froelich et al., 2020). These events resulted in processor closures, shortened fishing seasons, decreased catch, and revenue losses (White et al. 2021). Disruptions in the restaurant market were not felt equally across fisheries, as consumers are more likely to purchase some species in retail stores (e.g., canned tuna, salmon) and others in restaurants (e.g., crab, shrimp, cod) (Love et al., 2020). Frozen and canned seafood products (e.g., sablefish, tuna) were less impacted than fresh seafood products (e.g. halibut) (White et al., 2021).

Consumer tastes and preferences are an important determinant of demand for seafood and, consequently, resource impacts. As a potent example of this, the growing popularity of sushi and sashimi in the late twentieth century led to the industrialization of bluefin tuna fisheries and overfishing of stocks (Longo, 2011). Increasingly, demand for seafood is being driven by perceptions of health risks and benefits and a desire for sustainable products (Lem et al., 2014).

Demand for Energy

The demand for energy, whether from non-renewable or renewable resources, is also a driver. Pressure to increase supplies of energy or energy products (e.g., raw or refined) may place pressures on sanctuary resources through increased development and/or shipping near or through the sanctuary. Development of renewable ocean and wind energy is currently prohibited in CBNMS. Substantial commercial vessel traffic passes through the sanctuary via the northern shipping lane of the San Francisco Bay Traffic Separation Scheme. Large volumes of energy products, including crude oil, refined petroleum products, and coal, are shipped in and out of the Bay Area, which includes the Ports of Oakland and San Francisco and several refineries (SFBCDC, 2020). Expected to be finished in late 2023, the Transmountain Pipeline expansion in Canada would increase the volume of tar sands being shipped to refineries in the Bay (CBD, 2020). Along with infrastructure changes affecting supply, changes in the U.S. and global demand for energy products can impact levels of vessel traffic and associated impacts on sanctuary resources.

Regulatory Exemptions

Federal agencies implement regulatory requirements under their respective statutes and mandates. However, in some cases, individuals, entities, or certain activities are exempt from statutory or regulatory requirements. For example, the Clean Water Act provides a permit exemption for some point source pollution sources. These regulatory exemptions could affect

[1] This may include seafood of foreign origin that has been altered or enhanced in value from the time it was imported.

[2] Imports may include seafood of domestic origin that were processed abroad and returned to the US.

[3] Unless referring to a particular species, seafood trade data are generally available only by species group or product type. For example, salmon exports referenced here include several different species of salmon, many of which are harvested outside the Cordell Bank or Central California region.

the sanctuary through water quality degradation, injury to sanctuary resources or habitats, or other impacts. As outlined in the sanctuary regulations, all activities carried out by the Department of Defense at the time of designation that are necessary for national defense are exempt from prohibition (National Marine Sanctuary Program Regulations, 2009). This exemption does not extend to DOD activities like routine exercises and vessel operations. Other activities exempt from prohibitions include the discharge of materials, like fish or chumming materials, as part of lawful fishing activity and activities necessary for emergency response (National Marine Sanctuary Program Regulations, 2009).

U.S. National Security

The ocean plays a critical role in the mobility and readiness of U.S. armed forces and the preservation of national security. Uncertainty regarding the dynamics of future conflicts requires the U.S. military to train and prepare for a variety of scenarios, especially given emergent technologies. The State Department, Department of Defense, Department of Homeland Security, National Security Administration, Department of Transportation, and others all play key roles in national security. Climate change is also viewed as a national security issue, not only because of its direct effects on military infrastructure via sea level rise, but also because of its potential to exacerbate geopolitical tensions. The increasing intensity and frequency of natural disasters also increases demand for disaster relief, further threatening national security.

The Eleventh Coast Guard District, headquartered in San Francisco Bay, conducts training, search and rescue, and emergency response activities in the sanctuary. The Coast Guard is responsible for enforcing federal laws in U.S. waters, including sanctuary regulations. It is also responsible for vessel traffic management and managing the control and removal of oil and hazardous substances resulting from offshore spills (ONMS, 2014). Although the U.S. Navy no longer has active bases in the San Francisco Bay area, it does conduct operations within or near the sanctuary (ONMS, 2014). The Navy maintains two special-use airspaces in and around the boundaries of CBNMS and GFNMS, and Naval submarines and surface ships routinely transit the area. (ONMS, 2014).

Societal Values and Conservation Ethic

Information on societal values related to conservation can be obtained from various national or local opinion polls. A statewide study conducted in 2021 provides point estimates of Californians' attitudes and perceptions toward the environment (Baldassare et al., 2021). On the topic of offshore energy, around 72% of Californians indicated that they oppose more oil drilling off the coast of the state, while 81% were in favor of offshore wind power and wave energy projects (Baldassare et al., 2021). Almost half of adults reported that ocean and beach pollution along the coast is an issue, with 61% saying that plastics and marine debris are a big problem in the section of coast closest to them (Baldassare et al., 2021). An overwhelming majority of Californians (95%) stated that the conditions of oceans and beaches are either very important or somewhat important to the economy and quality of life in the state (Baldassare et al., 2021). Finally, about three in four respondents are either very or somewhat concerned about the impact of sea level rise on flooding and beach erosion (Baldassare et al., 2021).

A separate 2009 survey of Monterey Bay Area residents provides some indication of Californians' attitudes toward marine protected areas (ACSF, 2009). In 2009, an overwhelming percentage (93%) of respondents expressed support for "the designation of certain areas of U.S. ocean waters as sanctuaries for special management to conserve the marine habitats and cultural features" (ACSF, 2009). A majority (64%) also agreed that "sanctuary managers should have the power to make rules to prohibit human use of the designated sanctuaries," with 30% disagreeing (ACSF, 2009). Over half of residents (58%) support funding the creation and management of MPAs through the general revenue fund from state taxes, but less than half support a tax increase to fund that same goal (ACSF, 2009).

Environmental Activism

As conservation ethics change, levels of environmental activism are likely to change as well. This can affect the implementation of many types of activities and management actions, which can dramatically alter and redistribute pressures.

One focal area for environmental activism near the sanctuary is the issue of ship strikes with large whales and sea turtles. In 2021, two environmental NGOs, the Center for Biological Diversity (CBD) and Friends of the Earth (FoE), sued the USCG and NMFS for failure to meet Endangered Species Act consultation requirements with respect to the impact of ship strikes on ESA-listed species (CBD v. NOAA Fisheries, 2021). The plaintiffs are seeking additional protections for whales and sea turtles through ship strike avoidance measures like temporary vessel speed reductions and/or routing measures (CBD v. NOAA Fisheries, 2021). If successful, the lawsuit would likely affect vessel traffic patterns and associated pressures in Cordell Bank. In 2019, the same two NGOs, along with San Francisco Baykeeper, the Sierra Club, and Communities for a Better Environment, opposed an Army Corps dredging project proposal for San Francisco Bay that would have increased oil tanker traffic through the sanctuary (Communities for a Better Environment et al., 2019; Karras, 2019). The project was terminated in 2020 due to lack of sponsor interest (USACE, 2020).

Technological Advancement

Technology can influence pressures on marine resources in several ways. As mentioned before, technological advancements can lower costs for existing marine-based industries. For example, technologies like electronic navigational aids, acoustic fish-finding equipment, and stronger polymers for line and netting increase fishing efficiency (Marchal et al., 2006). For a given level of human activity or ocean use, technological advancements can also result in lower levels of impact or pressure. Examples of these types of technologies include low-emissions propulsion systems and carbon-capture in shipping, waste management technologies (e.g., marine sanitation devices, bioremediation of wastewater, new materials to replace plastics), and bycatch reduction devices (e.g., turtle excluder devices), among many others. In response to large whale and turtle entanglements in Dungeness crab gear on the West Coast and subsequent fishery closures, there has been considerable interest in developing ropeless crab gear to mitigate entanglement risk. The development of new technologies can also contribute to the growth or emergence of new sectors in the blue economy (e.g., offshore aquaculture, offshore wind), which may even substitute for traditional industries (e.g., wild-capture fisheries, offshore oil). Finally, some technologies may contribute directly to improved resource management outcomes or ecosystem restoration (e.g., “green gravel” for kelp reforestation, drones for monitoring, wave attenuation devices).

Tribal Government Relationships

Federal agencies are required to consult with federally recognized tribes on policies with tribal implications under Executive Order 13175 (2000) and those requirements have been reaffirmed by subsequent presidential memoranda supporting the executive order.

Indigenous peoples on the west coast of North America had many connections to coastal and ocean resources in ancient times. However, at this time, the sanctuary is unaware of any information that suggests historical connections of Indigenous peoples to CBNMS specifically, prior to contemporary usage of motorized fishing vessels. There are possible contemporary connections of Native Americans to CBNMS.

Pressures on the Sanctuary

Human activities and natural processes affect the condition of natural, cultural, and maritime heritage resources in national marine sanctuaries. The following section discusses the nature and extent of the most prominent human influences upon CBNMS, including climate change and ocean acidification, fishing, vessel use, and marine debris.

Climate Change and Ocean Acidification

Located within the California Current System, the sanctuary is exposed to strong seasonal variation in atmospheric and oceanographic conditions defined by upwelling, relaxation, and winter storm conditions. Longer term climatic phenomena influencing the region include global climate change, the El Niño-Southern Oscillation, the Pacific Decadal Oscillation, and the North Pacific Gyre Oscillation – processes that operate on larger spatial and longer decadal scales (CBNMS, 2014; Largier et al., 2010). Climate change has profoundly impacted coastal and marine ecosystems on a global scale, with projected worsening effects on sea level, temperature, ocean chemistry, storm intensity, and ocean current pattern. At a regional scale, climate change is projected to result in significant shifts in the species composition of ecological communities, seasonal flows in freshwater systems, rates of primary productivity, occurrence/persistence of hypoxia, sea level rise, coastal flooding and erosion, and wind-driven circulation patterns by the end of the century (Miller et al., 2013). Climate change is already affecting all aspects of the sanctuary, including but not limited to, water quality, species abundance and distribution, human activities, and ecosystem services (ONMS, 2020a; IPCC, 2022). The climate related pressures of greatest concern are: ocean temperatures, upwelling patterns, ocean acidification, and deoxygenation and hypoxia. These stressors may be co-occurring with each other (Breitburg et al., 2015) and with the other pressures on the sanctuary.

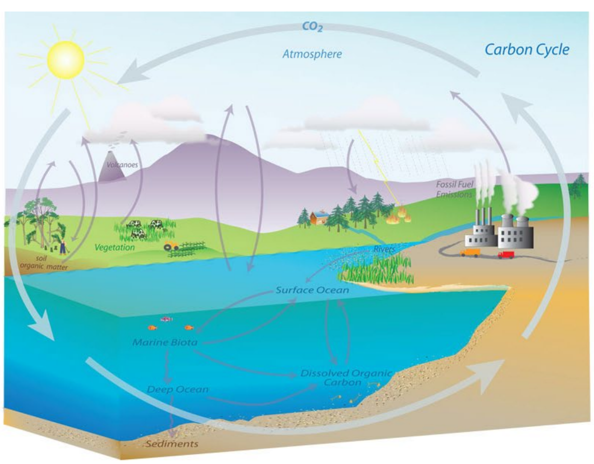

Figure D.2. Carbon cycle. Source: NOAA 2022. (https://www.noaa.gov/education/resource-collections/climate/carbon-cycle)

Greenhouse Gases

Anthropogenic climate change is primarily caused by greenhouse gas emissions. Greenhouse gases (e.g., carbon dioxide, methane) trap heat in the atmosphere; as greenhouse gases increase, so does the amount of heat trapped, which leads to higher air and water temperatures. Since pre-industrial times, global air temperature has increased, on average, by 1.8°F (1°C), and in the last 50 years, this increase has been driven nearly entirely by anthropogenic greenhouse gas emissions (IPCC, 2019). As global temperatures have risen, the ocean has absorbed over 90% of the excess heat, causing the average ocean temperature to increase worldwide (IPCC, 2019). Excess greenhouse gases have also been absorbed by the ocean, resulting in changes in ocean chemistry (Haugan and Drange, 1996; Doney et al., 2009).

CBNMS is affected by global greenhouse gases due to the Earth's closed system, with the main, direct sources of human-based air emissions into the air above the sanctuary stemming from vessel and aircraft engines, shipboard incinerators (ONMS, 2014b), and other motorized equipment that produces exhaust.

Ocean Temperature ,Marine Heatwaves, and Upwelling

Data from NOAA National Centers for Environmental Information show that globally, sea surface temperatures were observed to be above the average starting in 1940; for the forty year period following that, temperature fluctuated annually both above and below average (Figure XX). From 1980 to 2019, globally, annual sea surface temperatures were consistently observed to be above average, in an increasingly warmer trend (NCEI, 2020a). Water temperatures in the region of the sanctuary have risen slightly over the past century (Johnstone & Mantua, 2014; ONMS, 2020a).

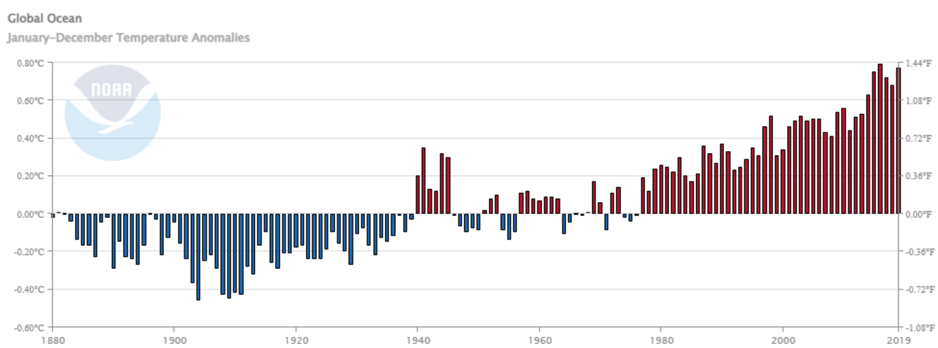

FIGURE D.3. Annual Global Ocean Surface Temperature Anomalies 1880 – 2019. Source: NCEI 2020a.(https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/time-series/globe/ocean/ann/6/1880-2019)

As was described in the Sanctuary Setting chapter, upwelling is a major oceanographic process that results in high productivity, both in the sanctuary and region. Warmer sea surface temperatures could alter circulation patterns which may result in changes to timing and intensity of upwelling seasons and lower productivity (ONMS, 2020a). Warm water events like El Niño events and marine heatwaves can reduce upwelling by creating stratification or force nutrient-rich water closer to shore, away from the majority of the sanctuary (Santora et al., 2020; Jacox et al., 2016). When this occurs, sanctuary waters receive less nutrients, leading to lower biological productivity (Cavole et al., 2016; McGowan et al., 1998). Such changes can lead to cascading effects throughout the food web, potentially affecting zooplankton, krill, fish, seabirds, and marine mammals (Piatt et al., 2020; Cavole et al., 2016; McGowan et al., 1998; Sanford et al., 2019; Di Lorenzo & Mantua, 2016). For example, during past El Niño events and recent marine heatwaves in the California Current, there were shifts in the zooplankton community where smaller, less nutritious species from the south became more dominant and the overall biomass severely declined, as much as 90% (Roemmich & McGowan, 1995; Cavole et al., 2016; McGowan et al., 1998; Fisher et al., 2015; Elliot & Jahncke, 2019; ONMS 2020a).

2014–2016 Heatwave (<<GRAY TEXT WILL BE A TEXT BOX>>)

Marine heatwaves are declared when sea surface temperatures exceed the 90th percentile of the baseline climatology (previous three decades) for at least five consecutive days (Hobday et al., 2016). First detected in 2014, peaking in 2015, and finally dissipating in mid-2016, a marine heatwave in the Pacific Ocean led to water temperatures 1.8–7.2°F (1.0– 4.0°C) above normal (Bond et al., 2015; Gentemenn et al., 2017; Kintisch, 2015). Large numbers of southern species moved north (Sanford et al., 2019; Lonhart et al., 2019); and a large harmful algal bloom (HAB) killed fish, birds, and marine mammals (Cavole et al., 2016), delayed the opening of the Dungeness crab fishery (Cavole et al., 2016; Sanford et al., 2019), and had impacts on prey species that altered the food web (Santora et al., 2020). For example, reductions in krill in offshore areas, such as the sanctuary, forced humpback whales to feed on fish that were closer to shore, resulting in record numbers of whale entanglements in fishing gear across the West Coast in 2015 and 2016 (Santora et al., 2020; ONMS 2020a).

Ocean Acidification

Increased levels of carbon dioxide in the atmosphere have further increased the dissolved carbon dioxide concentration in seawater, reducing the pH value and making the ocean more acidic (ONMS, 2020b); this process is called ocean acidification. The global ocean, on average, has become 30% more acidic since the beginning of the industrial revolution (Haugan & Drange 1996; Doney et al., 2009). Due in part to upwelling, the acidity of U.S. West Coast waters has risen faster than other regions, up to 60% since 1895 (Gruber et al., 2012; Osborne et al., 2020; ONMS, 2020a).

These conditions could be detrimental to many marine organisms, including mollusks, corals, and certain shell-producing plankton which rely on carbonate from seawater to build their shells and other hard parts. The sanctuary is located in an area of persistent high acidity as a result of the productive upwelling in the region (Chan et al., 2017; ONMS, 2020a). Increasingly acidic waters make it difficult for shell-forming animals like Dungeness crab and deep water coral to make and maintain shells and stony skeletons (Keeling et al., 2010). Deep water corals are susceptible as deep waters are naturally more acidic than surface waters and some areas are already acidic enough to slow their growth (Gómez et al., 2018). Further, acidification could reduce larval survival in Dungeness crab (Bednaršek et al., 2020) and krill (McLaskey et al., 2016) while also increasing stress and decreasing larval survival in rockfish and other species without shells (Keller et al., 2010; McClatchie et al., 2010; Munday et al., 2010; Rossi et al., 2016). Krill have reduced reproductive success under acidic conditions (McLaskey et al., 2016) and the shells of pteropods, small sea snails that are important prey for fish such as salmon, thin under acidic conditions (Bednaršek et al., 2017; Bednaršek et al., 2014; ONMS, 2020a).

Fish, birds, mammals, and coral can also be indirectly affected by acidification through adverse impacts on their prey (McLaskey et al., 2016; Bednaršek et al., 2017; Hodgson et al., 2018). More acidic waters as well as warmer waters could adversely affect zooplankton, a critical link in the food web, potentially reducing their numbers. Pteropods, important prey for fish, are susceptible to increasingly acidic waters (Bednaršek et al., 2017) and krill, prey for salmon, seabirds and whales, may experience reduced larval survival as acidity increases (McLaskey et al., 2016). Due to these effects, Dungeness crab may be more negatively affected by reductions of prey driven by acidification than its direct impacts (Hodgson et al., 2018). The effects of ocean acidification on prey species could have consequences for the entire food web from corals to blue whales (Gentemann et al., 2017; Lonhart et al., 2019; McLaskey et al., 2016; ONMS, 2020a).

Ocean acidification, in combination with other local conditions, may also affect historic resources. The historic former U.S. Navy destroyer submerged since 1946 deep within the sanctuary, the ex-Stewart (DD-224), could be threatened by an increasingly acidic ocean, as increasingly acidic waters have the potential to change the corrosion rate (Rockman et al., 2016) of the metal parts and any artifacts on the ship.

Deoxygenation and Hypoxia

As ocean waters warm, their ability to hold oxygen decreases and stratification occurs, which reduces mixing and limits the exchange of oxygen and nutrients (Chan et al., 2017). Ocean deoxygenation, the reduction of oxygen in the ocean, has already led to a 2% decline in global ocean oxygen since 1960 (Stramma & Schmidtko, 2019). Low oxygen conditions, called hypoxia, have become increasingly common in the ocean off California in recent years (Chan et al., 2017; Keller et al., 2015). Ocean oxygen concentrations off California have fallen 20% since 1980 (Bograd et al., 2015; Ito et al., 2017). Dissolved oxygen concentrations are affected by many factors including: water temperature and salinity, light availability, stratification of water layers, tidal and wind mixing, upwelling of deep waters, abundance and decay of organic material, and runoff of high-nutrient waters from land – all phenomena that can fluctuate inter annually with the Pacific Decadal Oscillation and El Niño Southern Oscillation, as well as seasonally. Organisms have high variability in their sensitivity to hypoxia and those in environments that do not typically experience low dissolved oxygen may not be well-adapted to survive and may experience stress or mortality under hypoxic conditions (Vaquer-Sunyer & Duarte, 2008).

Changes in dissolved oxygen can have cascading impacts on the entire ecosystem. Typically, surface waters contain higher levels of dissolved oxygen than subsurface waters due to photosynthesis and diffusion from the oxygen-rich atmosphere. Ocean currents and vertical mixing transport these oxygen-enriched waters throughout the water column. Climate change can cause regional changes in dissolved oxygen by altering water circulation and currents, vertical mixing, air-sea oxygen exchange, and biological production and respiration; these can co-occur with ocean acidification (Largier et al., 2010) and changing temperatures (Breitburg et al., 2015).

Fishing

Commercial[4] and recreational fishing in the sanctuary contribute to the coastal economy, support livelihoods in industries such as seafood and tourism, and provide valuable, nutritional food sources to nearby communities and beyond. Recreational fishing provides health and well-being benefits and sometimes food for anglers. Fishing also occurs within the sanctuary for

Commented [1]: Footnote #6

[4] Defined in National Marine Sanctuary Program regulations at 15 CFR §922.3: "Commercial fishing means any activity that results in the sale or trade for intended profit of fish, shellfish, algae, or corals." Recreational fishing is not defined in the National Marine Sanctuary Program regulations.

research purposes, for example, collecting fisheries-independent data for stock assessments or testing new fishing methods. Information collected through efforts like trawl surveys improve understanding of ecosystem functioning and ultimately management outcomes. All fishing within the sanctuary occurs by boat due the sanctuary's offshore, open ocean location.

Despite the benefits offered by fishing, historical and current fishing practices can negatively impact sanctuary resources such as habitat, water quality, maritime archaeological resources, and/or ecosystem function. For example, the removal of targeted fish species, along with mortality through bycatch, can result in changes in biodiversity and ecosystem health. Catch-and-release fishing (and the release of incidentally-caught species) can result in mortality through barotrauma, increased depredation, hook wounds, and other pathways, as well as sublethal effects like behavioral impairment and decreased feeding success (Campbell et al., 2010). Derelict (lost or discarded) fishing gear can continue to trap and kill marine life for many years. Additionally, certain fishing methods and gears can result in damage to bottom habitats (ONMS, 2020a). Use of mobile fishing gear, such as bottom trawls, has been of particular concern. Bottom trawling disturbs the structure of the seafloor, affects the three dimensional character and availability of fish habitat, changes the composition of biologic communities in the area, disrupts the food web, and results in additional adverse effects (National Research Council, 2002). Habitats may take a long time to recover following these disturbances.

In addition to the drivers previously listed, other influences that could affect fishing include environmental and resource conditions such as the availability of the target species, habitat health, physical ocean conditions, and harmful algal blooms.

Important to note is that Cordell Bank National Marine Sanctuary does not have the authority to manage fisheries. Instead, federal fisheries in CBNMS are managed by NOAA's National Marine Fisheries Service and the Pacific Fisheries Management Council. State fisheries in CBNMS (e.g., Dungeness crab) are managed by the California Department of Fish and Wildlife.

Commercial Harvest

There are a number of wild-caught fish and invertebrate species in CBNMS and the surrounding region. On average from 2015-2019, the top five species-gear groups caught in the sanctuary (by pounds landed) were Dungeness crab, Dover sole-thornyheads-sablefish (trawl), sablefish (non-trawl), market squid, and salmon (see Commercial Harvest section for rankings by species) (CDFW, 2020d). Together, these species-gear groups account for over 80% of the pounds landed commercially in CBNMS from 2015-2019.

From 2015-2019, the top five gear types used for commercial fishing by average pounds landed were trawl gear, pots/traps, set longlines, trolling gear, and purse seines (CDFW, 2020d). Other seines/dip nets and hook and line were commonly employed as well. Commercial fishing vessels come from various parts of the state to fish within the sanctuary. Landings from fish and shellfish caught within the sanctuary mainly occurred at Bodega Bay, Fort Bragg, San Francisco Bay, and Princeton-Half Moon Bay (CDFW, 2020d). On average, about 151 vessels reported catch from the sanctuary from 2010-2020, but that number varies from year to year. In 2010, only 72 vessels reported catch from CBNMS, but in 2013 there were at least 237 vessels using the sanctuary (CDFW, 2020d).

Recreational Fishing

Boats used for recreational fishing within the sanctuary are relatively limited in number; rough ocean conditions can prevent small boats from easily accessing the sanctuary. On average from 2015 to 2019, the top five species groups caught by Commercial Passenger Fishing Vessels

(CPFVs) within the sanctuary were rockfish, whitefish, yellowtail, sanddab, and Dungeness crab. Common gear types used for recreational fishing within the sanctuary include hook and line, trolling gear, and pots and traps.

Vessel Use

The pressures from vessel traffic vary with the size, number, and type of vessels transiting the sanctuary. Vessel impacts include the introduction of contaminants and non-indigenous species, spills, discharge of oil, sewage, non-biodegradable materials, increased ocean noise, anchor damage, vessel collisions, sinking, wildlife disturbance including ship strikes on whales and other species, and air and water pollution via exhaust gas emissions.

The San Francisco Traffic Separation Scheme (TSS) is one of the busiest port systems on the West Coast and includes the ports of San Francisco and Oakland. The TSS supports the economy of the entire region through national and international commerce and trade. The northern traffic lane of the TSS goes through CBNMS. The TSS is used by numerous types of domestic and foreign-flagged vessels, including container ships (some with hazardous materials), tankers, car carriers, as well as an increasing number of cruise liners.
The largest and most numerous vessels that use CBNMS are commercial ships. Nearly 2,000 vessels annually transit through the northern shipping lane (USCG VTS). Commercial ships make about 8,000 annual transits through the San Francisco TSS (which includes lanes within and adjacent to CBNMS). Regulatory and economic changes over time have affected the amount and pattern of shipping traffic passing through the sanctuary (e.g., recent California state regulations required the use of cleaner fuels by ships traversing within 24 nautical miles of the California coast). The size of commercial ships has steadily increased over the last several decades since the sanctuary was designated. Since 1968 Container carrying capacity has increased by 1,200% (reference).

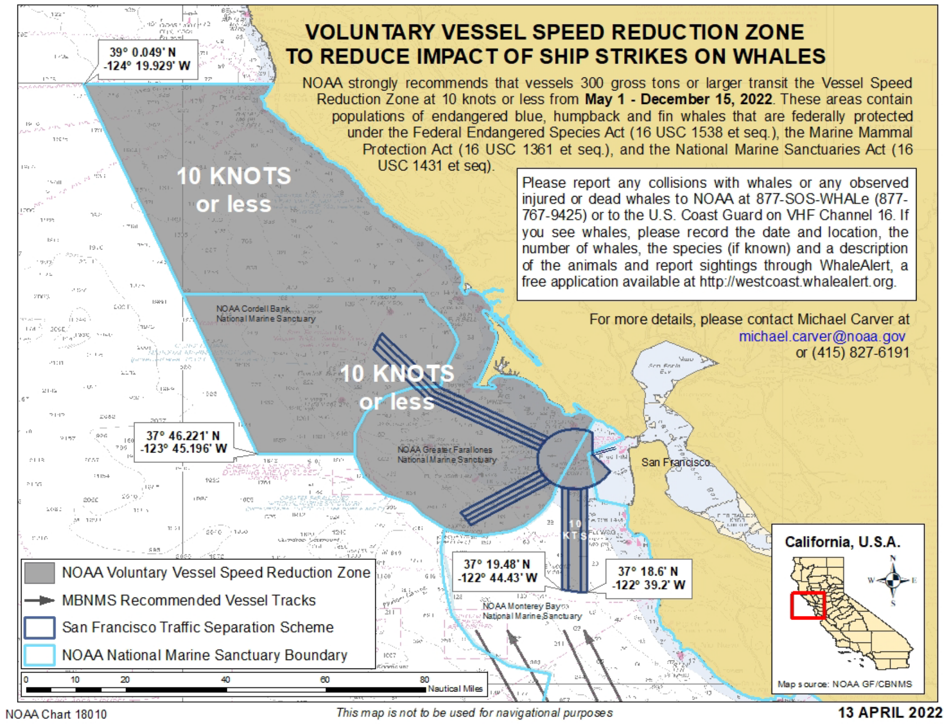

Figure D.4. Map of CBNMS and surrounding area that is used to communicate the voluntary vessel speed reduction zones.

Commented [2]: Placeholder. Will have a new map created to address this.

Other vessel types in the sanctuary include smaller and more regional commercial, recreational, military, research, and fishing vessels.

Noise

The level of noise pollution in the oceans has increased dramatically during the last 50 years, with much of this due to commercial shipping in coastal environments (National Research Council, 2003; Frisk, 2012). Large, ocean-going commercial traffic produces low-frequency noise through cavitation (the bursting of bubbles from their propellers), the flow of water over the hull, as well as other onboard sources such as machinery (McKenna et al., 2013; Richardson et al., 1995). Smaller vessel types usually produce reduced sound levels, measured as energy or pressure, and higher frequency noise (Richardson et al., 1995). Despite these differences McKenna et al. (2017) found that concentrations of smaller vessels can result in significant potential for disturbance of resident marine mammal and seabird species, including disruption of feeding, communication, mating, and predator avoidance. Many marine mammals respond to noise by altering their breathing rates, increasing or reducing their time underwater, changing the depths or speeds of their dives, shielding their young, changing their song durations, and swimming away from the affected area.

The northern shipping lane of the San Francisco Traffic Separation Scheme goes through CBNMS with large ships transiting through it daily. Large vessels were determined to be a primary low frequency anthropogenic noise contributor to the sanctuary soundscape (Haver et al., 2020). In addition, smaller vessels such as commercial and recreational fishing transit through the sanctuary.

Spills

Vessel spills could significantly impact sanctuary resources. Historically, the total number of oil spills in the sanctuary's region from transiting vessels has been small and there were no known spills in the sanctuary from 2009–2021 (see "other stressors" question for data). However, potential impacts could be enormous, given the number and volume of vessels that transit the region and the sensitivity of resources in the area. Given this risk, the sanctuary devotes significant resources to emergency preparedness, enforcement partnerships, and ecosystem monitoring that can help identify events and contribute to damage assessment. Understanding the potential risk is important for the sanctuary to be able to manage effectively.

Cargo, fishing, and passenger vessels can hold substantial quantities of petroleum products in their fuel tanks and are at risk for spills through groundings, collisions, sinkings, and other vessel incidents. Because of the sanctuary's close proximity to the San Francisco TSS, various types of spills, particularly petroleum and other chemicals, are a substantial threat to sanctuary resources. Oil spills directly and adversely impact water quality, plants, animals, and habitats. Oil contamination of marine mammals and seabirds can cause eye irritation, impairment of thermal regulation, loss of buoyancy, toxicity, reproductive abnormalities, and ultimately death. Oil spills can deplete food sources and destroy habitat characteristics essential for survival of vertebrate species. A spill could significantly impact populations and, in a worst-case scenario, extinguish multiple species on a local or regional scale. Oil spills can have lethal as well as long-term, sub-lethal effects on fish (e.g., behavioral changes, reproductive abnormalities) and can also contaminate fish targeted for human consumption. Some sectors of the fishing and shellfishing industries could be shut down for years by an oil spill.

In addition to oil tankers, large cargo vessels are a concern because, in addition to their cargo, they can carry up to one million gallons of bunker fuel, a heavy, viscous fuel similar to crude oil. Within sanctuary waters, disposal of bilge water with any concentration of oil, and disposal or discharge of any harmful substance is prohibited. However, the release of water and other biodegradable effluents incidental to vessel use, including treated effluent from a Type 1 or Type 2 marine sanitation devices, deck wash down, and engine exhaust, is currently allowed. Cruise ships can carry over 3,000 people on board and generate large volumes of waste. The primary pollutants generated by a cruise ship are sewage (also referred to as black water), gray water, oily bilge water, hazardous wastes, and solid wastes and have the potential to severely impact water quality in localized areas if they are not responsibly operated. They also generally incinerate the majority of waste produced.

Sunken vessels residing on the seafloor have the potential to leak oil or other contaminants into the sanctuary. Other than one intentionally scuttled vessel that is suspected to be in the sanctuary, it is unknown if other sunken vessels could be worsening the water quality within CBNMS. Natural seeps exist in the area but are not thought to be a significant contributor to oil secretions into the sanctuary.

Ship Strikes

Whales rely on the highly productive waters of the California Current as part of their migratory routes. Vessels can alter the behavior of marine mammals and seabirds, changing the distribution of the animals or the amount of time that they spend feeding and resting. And in some instances, vessel strikes can injure or kill animals in the sanctuary. Slow-moving animals, like ocean sunfish (*Mola mola*) and whales, are particularly vulnerable to ship strikes as they swim or rest. Ship strikes have increased in recent decades due to increasing shipping traffic, vessel speeds, and whale abundance (Laist et al., 2001, Neilson et al., 2012). Most strikes occur in coastal waters on the continental shelf, where large marine mammals aggregate to feed and vessel traffic is concentrated.

Ship strikes, along with entanglements, are the primary sources of anthropogenic mortality (Carretta et al., 2021). Scientists estimate that the rate of detection and reporting of ship strikes is a small percentage of the actual number of animals struck; about 2% for blue whales and 10% for humpbacks (Carretta et al., 2021). The impact of ship strikes on blue whales is of concern, given their smaller population (1,496 in CA, OR, and WA, Carretta et al., 2021) but humpbacks and fin whales are also at considerable risk. Blue whales remain listed as endangered under the Endangered Species Act, and humpback whales traveling to CBNMS are listed as threatened for the Mexico Distinct Population Segment (DPS) and endangered for the Central America DPS (Carretta et al., 2021).

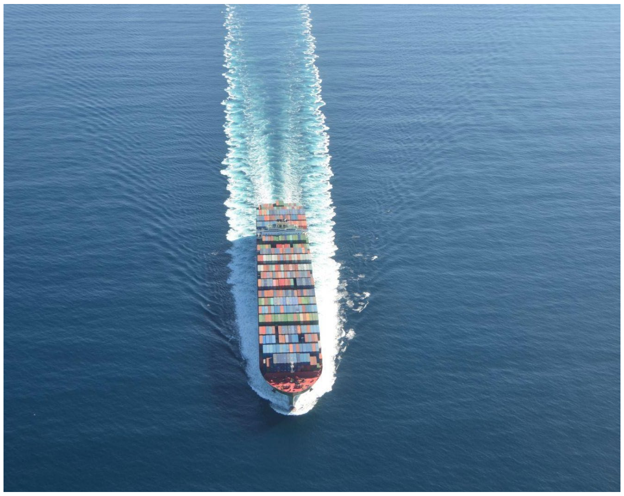

Figure D.5. Container ships such as this one frequently transit through the sanctuary. Photo credit: Jess Morten/NOAA CINMS

Marine Debris

Marine debris in the ocean is a known and growing threat to marine life and biological diversity, even in remote offshore locations like CBNMS.

According to NOAA's Marine Debris Program, marine debris is any persistent, manufactured or processed solid material that is directly or indirectly, intentionally or unintentionally, disposed of or abandoned in the marine environment. The prevalence of debris within the sanctuary is affected by both natural forces (e.g., currents), and human drivers, including population growth, consumer culture, economics, policy, and an increase in coastal development. Marine debris enters the sanctuary from both water and land-based activities, and it is likely accumulating in the water column and benthic habitats. Land-based sources include stormwater runoff, landfills, loss during garbage transport, recreational and commercial activities, and military activities. Ocean-based sources include commercial and recreational fishing, research operations, and cargo containers falling off ships in high seas (Keller et al., 2010).

Marine debris can include a wide variety of objects including lost fishing gear, overboard disposal of passenger and commercial shipboard waste, lost vessel cargo, metal military debris, and essential household goods. Of these types, plastic is the most prevalent type of marine debris found in the ocean. Plastic debris comes in all shapes and sizes, but those that are less than five millimeters in length are called microplastics. Plastics in the marine environment never fully degrade, and recent studies show organisms consume plastic at all levels of the marine food web. Given the quantities of plastic debris floating in the ocean, the potential for ingestion is enormous. The ability for plastics to attract and transport contaminants into the marine food web has been documented (Arthur et al., 2009) and recent research suggests these microplastics can accumulate in seafood (Avio et al., 2017).

Marine mammals and seabirds are known to be affected by marine debris (FSCOP, 2019). Entanglement in marine debris is a severe problem, and it has been linked to measurable population declines for a variety of marine mammals. Marine debris can be ingested, which may result in drowning, starvation, physical trauma, systemic infections, or increased susceptibility to other threats, such as ship strikes (Marine Debris Program, 2014a; 2014b). Surface feeding seabirds common in CBNMS include albatross, shearwaters, fulmars, and storm-petrels, which are highly susceptible to plastic ingestion, with frequency of individuals with plastic in the stomach ranging from 50 to 80% (Nevins et al., 2005). Tagging studies have documented Black-footed Albatross crossing the eastern Pacific to feed in and around Cordell Bank sanctuary (Hyrenbach et al., 2006). Albatross often mistake floating plastic debris for food and ingest large quantities of plastic bottle caps, plastic fragments, discarded cigarette lighters, and plastic toys. When these adults return to their nests to feed their chicks, a high percentage of the meal is composed of plastic.

Evidence from at-sea and benthic surveys in CBNMS suggest that marine debris is widespread in CBNMS (Elliott et al., 2020; Graiff and Lipski, 2019). In addition to altering the structure of habitats within CBNMS, lost or discarded fishing gear can continue to catch and kill fish for years.

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Status and Trends of Drivers and Pressures

This section answers questions related specifically to the drivers and pressures discussed above. The status and trends of sanctuary resources are addressed in the next section. An expert workshop was convened on June 29, 2021 to discuss and determine status and trend ratings in response to a series of standard condition report questions related to human activities occurring in the sanctuary[1] (see Appendix __). Answers are supported by data and the rationale is provided at the end of each section. Where published or additional information exists, the reader is provided appropriate references. Workshop discussions and ratings were based on data available at the time (i.e., through June 2021). However, in select instances, sanctuary staff later incorporated newly available data in order to more accurately describe the current status and trends of resources. Situations where data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text.

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Driver Rating (Question 1)

Question 1: What are the states of influential human drivers and how are they changing?

Not rated

Rationale: ONMS and CBNMS staff decided not to rate the status and trend of influential human drivers at CBNMS. The primary purposes for rating the status and trends of resources are to use condition reports to assess program effectiveness and to influence management of human activities and certain natural resource actions. For the most part, drivers are not manageable, at least not under the authority of the NMSA, nor do most of them originate at scales relevant to management by national marine sanctuaries. While understanding them is important, rating them is not necessary to achieve the goals of the condition report. This information will be addressed in a different chapter in the CBNMS Condition Report.

The primary drivers influencing pressures on CBNMS resources were previously described in the Drivers section of this report. Drivers are the societal values, policies, and socioeconomic factors that influence human pressures on marine ecosystems. Understanding drivers helps to explain the origins of pressures on resources and potentially anticipate future trends for those

[1] Note that a workshop was not convened for the question that asks, What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing? Due to a limited number of experts in the maritime heritage field, archaeological experts with the ONMS Maritime Heritage Program and CBNMS internally evaluated this question. These subject experts have been monitoring existing archaeological sites along the west coast, including CBNMS, since the 1980s.

pressures. Drivers include economic factors, such as income and spending; policies and legal frameworks; demographics, like population levels and urbanization; and societal values, such as levels of conservation awareness, political leanings, or changing opinions about the acceptability of specific behaviors (e.g., littering). All influence pressures on resources by changing the ways that humans interact with the marine environment.

After thoughtful consideration, ONMS and CBNMS staff decided not to rate the status and trend of influential human drivers at CBNMS. The primary purposes for rating the status and trends of resources through this process are to use condition reports to assess program effectiveness and to influence management of human activities and certain natural resource actions, such as restoration. For the most part, drivers are not manageable, at least not under the authority of the NMSA, nor do most of them originate at scales relevant to management by national marine sanctuaries. While understanding them is important, rating them is not necessary to achieve the goals of the condition report. Conversely, the pressures that result from drivers can be managed, either directly by ONMS or through engagement with those who have appropriate authority. Thus, status and trend ratings for pressures (i.e., human activities) and their potential effects on sanctuary resources have been determined and described in Questions 2–5.

Pressure Ratings (Questions 2–5)

Human activities that adversely impact water quality are the focus of Question 2. These include vessel traffic (as a proxy for oil spill risk), known spills, discharges, and emissions.

Question 3 covers human activities that may adversely influence habitats. Some human activities may have structural and non-structural impacts to habitats. For example, fishing activities that physically disrupt the seafloor (e.g., trawling, lost gear) may result in structural impacts to seafloor habitats. Non-structural impacts could include oil spills, anthropogenic sounds, and climate change. For this question, we focus on structural impacts to habitats.

Human activities that have the potential to negatively impact living resources are the focus of Question 4. These include activities that remove plants or animals, as well as activities that have the potential to injure or degrade the condition of living resources.

Activities that influence maritime heritage resource quality are the subject of Question 5. These include activities that diminish resource quality through intentional or inadvertent destruction of maritime heritage resources. Importantly, and unlike most natural resources, maritime archaeological resources are non-renewable. Once degraded or destroyed, their archaeological value is lost forever.

Human activities that influence climate change at a global scale (i.e., those that produce greenhouse gasses) are not discussed in that context in this report. National marine sanctuaries are not charged with controlling this and other issues (e.g., plastic pollution) at such large scales and therefore do not regulate or otherwise control the activities that cause them, at least not for the purpose of reducing their global impact. ONMS does recognize, however, that some activities in national marine sanctuaries that contribute to climate change (e.g., ship and boat traffic, facility construction, and the transport of harvested food and products) also have local and direct impacts on sanctuary resources. For those, we have a responsibility to minimize impacts, and they are considered in this report.

Table S.HA.2.1. 2009 (left) and 2009–2021 (right) status, trend and confidence ratings for the human activities questions.

2009 Condition Report Questions		**2009 Rating**	**2009–2021 Condition Report Questions**		**2009–2021 Condition Report Rating**			
					Status	**Confidence (Status)**	**Trend**	**Confidence (Trend)**
N/A	N/A	N/A	1	Influential Drivers	Not rated			
4	Human activities and water quality	?	2	Human activities and water quality	Good/Fair	High	—	Medium
8	Human activities and habitat	▲	3	Human activities and habitat	Fair	Very high	▲	Very high
14	Human activities and living resources	▲	4	Human activities and living resources	Fair	Very high	▲▼	High
17	Human activities and maritime archaeological resources	?	5	Human activities and maritime heritage resources	Good		?	

Question 2: What are the levels of human activities that may adversely influence water quality and how are they changing?

Status: Good/Fair (high confidence)
Trend: Not Changing (medium confidence)
Status Description: Some potentially harmful activities exist, but they have not been shown to degrade water quality.
Rationale: There are fairly high levels of human activity, mainly vessel traffic, that pose risks to water quality. Varying patterns make it difficult to discern a trend, but fuel carried per vessel is increasing, though spill volumes have decreased. In addition, although there has been increased vessel traffic over several decades, recent air quality regulations have resulted in a change to low sulfur fuel and improved emissions. Overall, the levels of large commercial vessel traffic, as recorded with USCG AIS data, have remained the same during the study period. There were no reported oil spill incidents inside CBNMS, but incidents that occurred nearby had

the potential to affect the sanctuary. Vessel discharges were recorded in the sanctuary, yet are likely underreported. New regulations on sulfur oxide (SOx) emissions resulted in an increase in exhaust gas cleaning systems and a downward trend in emissions over the study period.

Comparison to the 2009 Condition Report

In 2009, the status was good/fair and the trend was undetermined (Table S.HA.1). The rating was based on the presence of some potentially harmful activities, but the level of human activities in CBNMS was considered low. The 2009 condition report also noted uncertainty about the levels of vessel discharges. Over the last decade, our understanding of vessel traffic has grown substantially, largely due to Automatic Identification Systems (AIS), and our awareness of discharges has risen significantly. Our understanding of small traffic still lags, along with our understanding of the scope and scale of illegal vessel discharges.

New Information in the 20__ Condition Report

Information considered for this question included vessel traffic (as a proxy for spill and discharge risks), as well as known spills, discharges, and emissions (Table S.HA.2.2).

Table S.HA.2.2. Status and trends for individual indicators discussed at the June 29, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figures
Vessel Traffic (as proxy for oil spill risk)	BOEM et al., 2021	Pelagic	**Status**: Overall level of large commercial vessel traffic has remained the same **Trend**: Conditions do not appear to be changing	S.HA.2.1
Spills	USCG, NOAA/NCCOS	Pelagic	**Status**: No reported incidents in CBNMS, some nearby **Trend**: Conditions do not appear to be changing	
Discharges	MISLE, NOAA/NCCOS	Pelagic	**Status**: Small and large discharges likely underreported **Trend**: Undetermined trend	
Discharges - exhaust gas cleaning system discharge	EPA, CARB/NA	Pelagic	**Status**: New regulations on SOx emissions, resulted in increased industry use of EGCS systems, and new fuels resulted in decreased use of EGCS. **Trend**: Conditions appear to be improving	
Emissions - Greenhouse gases	NOAA/NOAA	Pelagic	**Status**: GHG are high and affecting water chemistry and temperature **Trend**: Some recent efficiencies, not enough to counteract high levels	

CBNMS has regulations that prohibit discharge of material within sanctuary boundaries, except by lawful fishing. Other agencies also have regulations that apply in CBNMS including USCG regulations on trash disposal and the IMO Ballast Water Management Convention requirements to limit invasive species in ballast water. Because there is limited data on how human activities influence water quality, vessel traffic data were used as a proxy for oil spill and discharge risk. Given the large volume of commercial traffic that transits through the sanctuary, there is a heightened risk for spills and discharges. Large commercial ships use the San Francisco Traffic Separation Scheme (SF TSS), of which the northern lane bisects the sanctuary. This vessel traffic poses threats that include oil spills and other water pollution, air pollution (which can affect water quality, for example, through ocean acidification), container loss, and biological invasions (Jagerbrand et al., 2019, Hassellöv et al., 2013, Ruiz et al., 2000). During the study period the size of commercial ships has increased but the number of ships using all three lanes of the TSS has stayed relatively constant at about 8,000 transits a year, including inbound and outbound transits (Jensen et al., 2015, USCG San Francisco Vessel Traffic Service vessel monitoring data 2017, Bureau of Ocean Energy Management & NOAA, 2021). Over one million miles (898,369 nm) of vessel transits through CBNMS occurred from 2009 to 2020 (Bureau of Ocean Energy Management & NOAA, 2021), and this does not include vessels that are not required to carry AIS (Figure S.HA.2.1). Vessel Management System (VMS) records from NOAA's National Marine Fisheries Service (NMFS) show an increasing trend in the number of fishing vessels in CBNMS carrying VMS over the last decade. We do not have spatial data on vessels not equipped with VMS or AIS beacons.

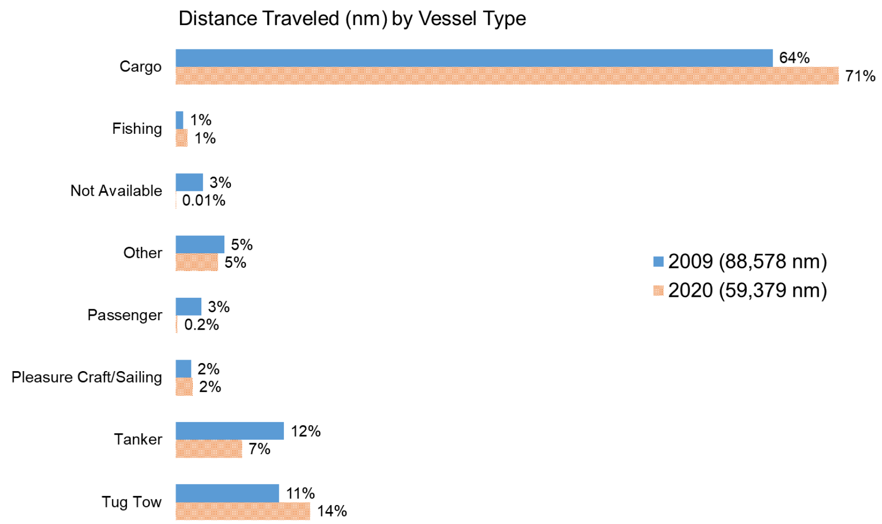

Figure S.HA.2.1. Percent of total distance traveled within CBNMS by each vessel type category in 2009 (total of 88,578 nm) and 2020 (total of nm). "Not available" means the vessel type was not provided in the data. Data source: BOEM, et al., 2021

VMS and AIS   (<<GRAY TEXT WILL BE A TEXT BOX>>)

Vessel Monitoring Systems (VMS) and Automatic Identification System (AIS) are tools for tracking vessels. VMS consists of a NOAA Fisheries type-approved transmitter that automatically determines a vessel's position and transmits it to a communications *service provider. The communications service provider receives the transmission and relays it to NOAA Fisheries. In the Pacific Coast groundfish fishery, the position data is primarily used to monitor fishing activity relative to closed areas. VMS is required on commercial fishing vessels registered for use with a Pacific Coast groundfish limited entry permit in California as well as on any vessel that uses non-groundfish trawl gear to fish within the Exclusive Economic Zone (EEZ); and any vessel that uses open access gear to take, retain, or possess groundfish in the EEZ or land groundfish taken in the EEZ. In addition, VMS is also required on drift gillnet (DGN) vessels participating in Highly Migratory Species fisheries (NOAA 2021a). More simply, VMS is required for any vessel that sells groundfish commercially when it is caught in federal waters. Vessels with federal groundfish limited entry permits are also required to have VMS, regardless of whether in state or federal waters. CBNMS includes only federal waters. Therefore, fisheries active in CBNMS that are required to use VMS include black cod, groundfish trawl, and groundfish caught using pot and trap. Vessels targeting squid or tuna are only required to have VMS if they land groundfish from federal waters at other times of year. For salmon trollers, VMS is only required if they retain incidentally caught groundfish.*

AIS is an on board navigation safety device that transmits and monitors the location and characteristics of large vessels in U.S. and international waters in real-time. In the U.S., the Coast Guard collects AIS data, which can be used for a variety of coastal management purposes. Since 2015, vessels over 65 feet are required to carry AIS.

Cruise ships transiting through the sanctuary are one vessel type of particular concern. Cruise ship arrivals in San Francisco increased from 65 in 2013 to 81 in 2015. Many carry over 3,000 people, generate and incinerate large amounts of waste, and have the potential to severely impact water quality in localized areas if they are not responsibly operated. The main pollutants generated by a cruise ship are sewage (also referred to as black water), gray water, oily bilge water, hazardous wastes, and solid wastes. NOAA prosecuted two related cases involving 190 separate, prohibited discharges from cruise ships during the study period (2015–2017), totaling approximately eight million gallons released in CBNMS and GFNMS of untreated black and gray water, membrane bio-reactor de-sludging, Exhaust Gas Cleaning System (EGCS) effluent, and food waste (NOAA Office of General Counsel, 2021). In 2010, there was also a bilge water discharge nearby in GFNMS. Cases of vessel discharges within and near the sanctuary are likely underreported despite the legal requirement for reporting vessel discharges.

Cargo ships and oil tankers transit through the sanctuary are of concern for spills and discharges. Large cargo ships can carry up to 4 million gallons of fuel oil (NOAA 2016). Oil tanker size varies and these ships can carry between 9-150 million gallons of oil (Washington State Department of Ecology, 1996).

High sulfur fuel used in commercial shipping for much of the 20th century emitted significant amounts of pollution (Figure S.HA.2.2). The pollutants from fuels are redirected from entering the atmosphere to the water column through the use of properly functioning EGCS. In 2009 the California Air Resources Board (CARB) instituted Emission Control Areas (ECA) for ocean-going vessels that mandate the use of low sulfur fuels and restricted the use of EGCS to comply with these standards. In 2015 California ECA areas were expanded to all US waters out to the EEZ. While the net effect of these regulations was a reduction in emissions from ships over the study period; some ships used EGCS illegally; and there is uncertainty as to the scale of EGCS effluent that entered CBNMS. Fuel changes also resulted in reductions to GHG although emissions remain high and are affecting water chemistry (Smith et al., 2014) (Table S.HA.2.3).

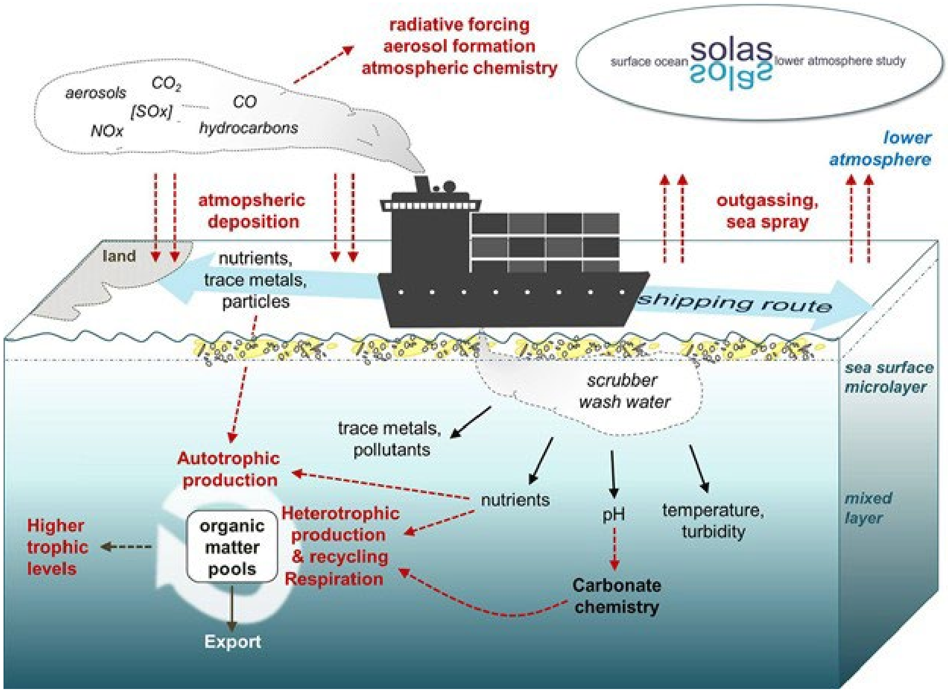

Figure S.HA.2.2. Emissions from both a ship smokestack and scrubber wash water system at the ship-air-water interface and their potential effects on atmospheric chemistry and marine ecosystems in the surface ocean. Figure: Endres et al., 2018.

Table S.HA.2.3. Summary of fuel regulation changes that impacted vessel traffic in CBNMS. Source: Adapted from Moore et al., 2018.

Fuel regulation changes	Date
California Emission Control Areas (ECA) in effect by CARB (1.5%/0.5% Sulfur)	July 1, 2009
California ECA boundary modification by CARB	December 1, 2011
Global fuel standard made more stringent by IMO (3.5% Sulfur)	January 1, 2012
North American ECA in effect by IMO (1.0% Sulfur)	August 1, 2012
California ECA standard made more stringent by CARB (1.0%/0.5% Sulfur)	August 1, 2012
Traffic separation schemes modified by IMO/USCG	June 1, 2013
California ECA standard made more stringent by CARB (0.1%/0.1% Sulfur)	January 1, 2014

North American ECA fuel standard made more stringent by IMO (0.1% Sulfur)	January 1, 2015

Conclusion

Several human activities have the potential to adversely influence water quality. The primary consideration for the good/fair rating and the not changing trend continues to be the level of shipping in the sanctuary as this activity poses a risk for oil spills. Data gaps that were identified include, but are not limited to, volume and impacts of vessel discharges, including black water and gray water discharges, and EGCS effluent.

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Question 3: What are the levels of human activities that may adversely influence habitats and how are they changing?

Status: Fair (very high confidence)
Trend: Improving (very high confidence)
Status Description: Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Rationale: Vessels in and around CBNMS generate noise that can degrade habitat quality for marine species. The soundscape of CBNMS is dominated by ships and baleen whales and is at the threshold of good environmental health, according to European Union standards. Trend data on the CBNMS soundscape are not yet available but globally ocean noise has increased since the 1950s due to larger vessels and more vessel traffic. Bottom trawling occurs in CBNMS, mainly on soft sediment, and marine debris is present in all sanctuary habitats. It is possible that conditions are improving because bottom trawling has decreased during the time frame, but it is also likely that debris and noise in the sanctuary are increasing.

Human activities that degrade habitat quality do so by affecting structural (physical), biological, oceanographic, acoustic, or chemical characteristics of the habitat. Structural impacts, such as removal or mechanical alteration of habitat, can result from various fishing methods. Removal or alteration of critical biological components of habitats can also result from fishing, most notably trawling. Marine debris, particularly in large quantities (e.g., lost nets and other types of fishing gear), can degrade both biological and structural habitat components. Management actions such as no-anchoring prohibitions on Cordell Bank are in place to help protect fragile habitat.

Chemical alterations most commonly occur following spills and can have both acute and chronic impacts. Many of these activities are regulated to limit their impact on protected resources.

Comparison to the 2009 Condition Report

In 2009, this question was rated fair and improving (see Table S.HA.2.1). The report noted that there had been impacts to habitat from bottom contact fishing gear, which supported the fair status. At the time, spatial management zones had recently been implemented by the Pacific Fisheries Management Council that restricted bottom contact fishing in some areas of the sanctuary designated as Essential Fish Habitat or Rockfish Conservation Areas, which pointed to the improving trend.

New Information in the 20__ Condition Report

The indicators evaluated for this question included noise, marine debris, and trawling for commercial fishing and research purposes (Table S.HA.3.1).

Table S.HA.3.1. Status and trends for individual indicators discussed at the June 29, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Noise	OSU, NOAA/Haver et al., 2020, 2021	Pelagic	**Status**: Whales and shipping dominate the soundscape, CBNMS is at the threshold of "good ecosystem status" **Trend**: No long term trend data from NRS yet; overall ocean noise increasing since the 1950's	
Marine Debris	ACCESS/ Point Blue (surface)/ CBNMS/CBNMS (benthic)	Pelagic and Benthic	**Status**: Marine debris found in the surface waters of the sanctuary; and debris on the bottom **Trend**: Undetermined	
Research trawling	NMFS/CCIEA	Benthic	**Status**: Trawling on the shelf and slope at low levels **Trend**: Conditions do not appear to be changing	
Fishing	NMFS/CCIEA	Benthic	**Status**: Trawling on the shelf and slope, less than other areas. Crab effort over time appears to be consistent. **Trend**: Improving (trawling has been decreasing); however recent RCA changes in 2020 increased area open to trawling (trend TBD)	Figure S.HA.3.1; S.HA.3.2
Data Gaps	We have not yet had a chance to analyze all bottom contact fishing activities from the VMS data for trends.			

Many marine organisms, including baleen whales, rely on sound for their life functions and anthropogenic noise can impact their habitat (Hatch et al., 2008, Redfern et al., 2017, Richardson et al., 1995). CBNMS provides habitat for many species of marine mammals, including large baleen whales. Substantial vessel traffic occurs in and out of the San Francisco Bay area, which includes the Port of Oakland, a major port for container vessels. The levels of large commercial vessel traffic, as recorded with USCG AIS data, have remained similar throughout the study period (Jensen, 2015; Moore, 2018; USCG San Francisco, 2017)

CBNMS has a baseline assessment of the soundscape (Haver et al., 2020) but no trend data yet. NOAA does not have a standardized threshold for chronic noise in marine environments, but the European Union has developed a standard where noise at certain frequencies should not exceed 100 decibels over a seasonal time period to be considered in "good ecosystem status". The CBNMS soundscape is at the threshold of "good ecosystem status", according to these thresholds, and falls in the middle of the range compared to other listening station sites around the US (Haver et al., 2021; Tasker et al., 2010; see question 10). Large vessel traffic is the primary source of anthropogenic noise in the sanctuary (Haver et al., 2020). Although we do not have a trend analysis for CBNMS yet, "a growing body of literature suggests that low-frequency, ambient noise levels in the open ocean increased approximately 3.3 dB per decade during the period 1950–2007", a doubling of noise intensity every decade since 1950 (Hatch et al., 2008; Frisk, 2012).

Increases in noise in the Pacific basin over the past several decades have been correlated with increases in shipping volume and size of ships (Vos et al., 2005; McKenna et al., 2012). Therefore, it is likely that noise from commercial shipping has increased in CBNMS in the past half century, with market driven dynamics over the past ten years linked to inter-annual variability, such as recessions and the COVID-19 pandemic.

Marine debris is found in all habitats of the sanctuary. A variety of human activities contribute to marine debris, including fishing, plastic manufacturing, littering, improper trash disposal, and waste water disposal. Data on contributions to sanctuary debris from these activities are not available, but increases in human population and production of goods, without a tangible solution for removing significant amounts of marine debris from the ocean, suggests that the problem is not improving. And, while records for within CBNMS are sparse, along the west coast marine debris accounts for 106 confirmed injuries and deaths to marine mammals from 2011–2015 (Carretta et al., 2017) and 123 deaths from 2014–2018. These numbers are considered a minimum value as the recovery rates of cetacean carcasses are consistently quite low (<1% to 33%) across different species (Carretta et al., 2021)

Bottom contact fishing gear can alter and damage seafloor habitat. The types of fishing that occur in CBNMS and could impact the seafloor include research trawling, commercial trawling, and fixed gear such as for Dungeness crab (see Question 10). Research trawling is conducted by the National Marine Fisheries Service Fisheries Resource and Monitoring (FRAM) division and uses short duration tows to assess the stock of groundfish. Because of their standardized design, the effort has not changed significantly over time (Figure S.HA.3.1). Commercial trawling in CBNMS occurs on the shelf and the slope (Figure S.HA.3.2) at low levels compared to coastwide levels. There is a declining trend during the study period and a shift to areas on the shelf and away from the slope (Figure S.HA.3.2, Figure S.HA.3.3). Fixed gear for Dungeness crab occurs mainly in the eastern portion of the sanctuary. Because of CBNMS' offshore location, less crab fishing occurs here than at other sanctuaries in California. During the study period, the Dungeness crab landings in CBNMS remained fairly constant, except for a peak in 2010-2011 (S.HA.3.6).

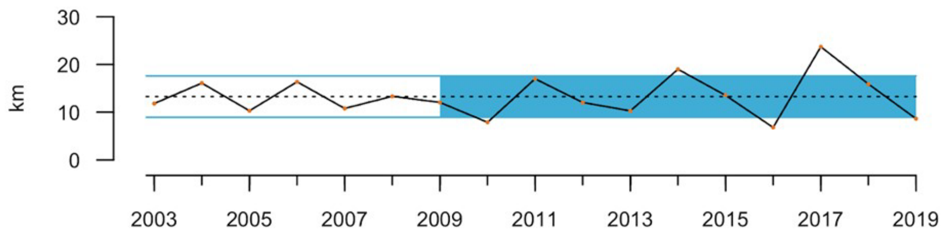

Figure S.HA.3.1. Distance of seafloor contact (in km) by bottom trawl gear from the NWFSC's groundfish survey within the Cordell Bank National Marine Sanctuary. The dashed line is the mean and the solid horizontal lines are ±1 standard deviation (SD) of the full time series. The blue shaded area is the time period evaluated for this report. Source: NMFS

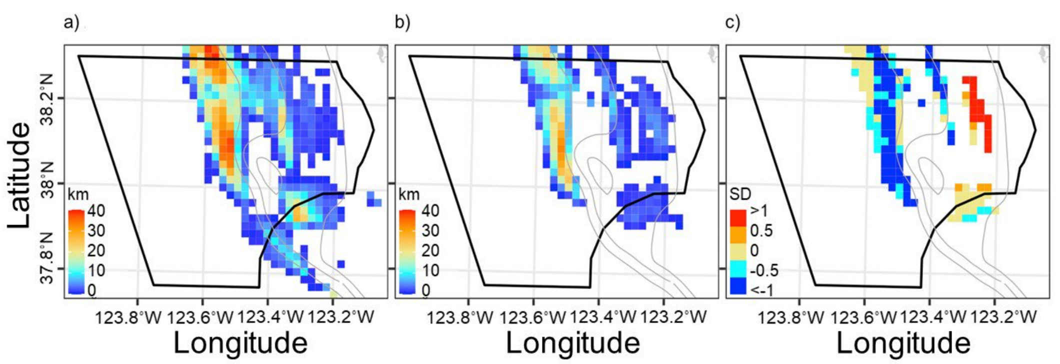

Figure S.HA.3.2. (Also Figure S.Hab.10.1.) Spatial representation of seafloor contact by bottom trawl gear from federal groundfish fisheries operating within CBNMS and nearby areas, calculated from annual distances trawled within each 2x2-km grid cell from 2002–19. Left(a): mean distance trawled annually from 2002 to 2008. Middle(b): mean distance trawled annually from 2009 to 2019. Right(c): normalized trend values from 2009 to 2019 - red grid cell values were >1 standard deviation (SD) above and blue grid cells were > 1 SD below the long-term mean (2002–2019) of that cell. Gray lines represent 100, 200 and 500-m depth contours. Grid cells with < 3 vessels operating within the time period represented have been removed due to confidentiality. Image: Data from NOAA's Northwest Fisheries Science Center's Fisheries Observation Science Program, analyzed by CCIEA. Cordell Bank National Marine Sanctuary showing trawling effort by 1km square blocks over the ten year period from 2011-2020.

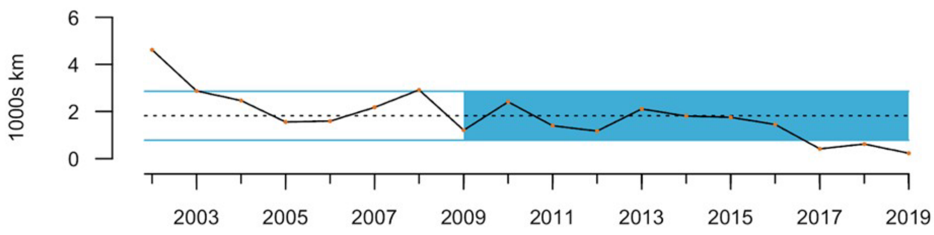

Figure S.HA.3.3. Distance of bottom trawl gear contact with seafloor by limited-entry and catch share permitted groundfish bottom trawl vessels in 1000's of kilometers. The dashed line is the mean and the solid horizontal lines are ±1 standard deviation (SD) of the full time series. The blue shaded area is the time period evaluated for this report.Source: NMFS NWFSC

Figures to be moved to appendix

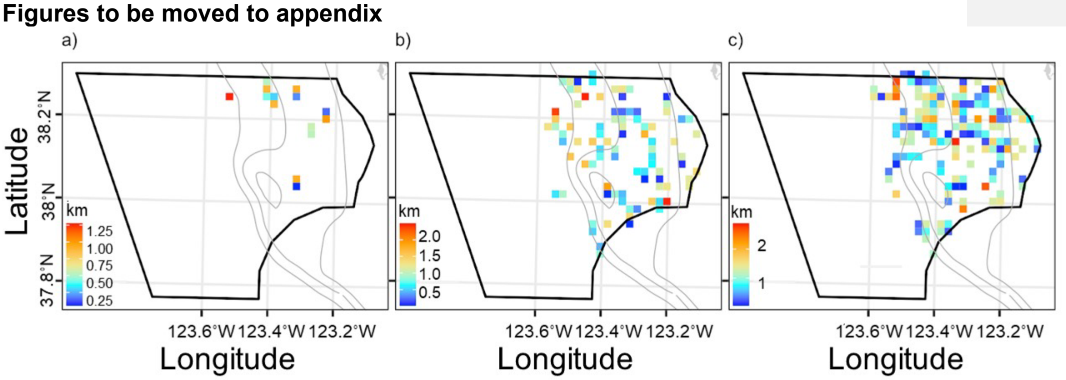

Figure App.E.3.1.. Spatial representation of seafloor contact by bottom trawl gear from NOAA's Northwest Fishery Science Center Groundfish Survey within CBNMS, calculated from annual distances trawled within each 2x2 km grid cell from 2003–2019. Left(a): most recent year's (2019) distance trawled. Middle(b): total sum of distance trawled from 2003–2008. Right(c): total sum of distance trawled from 2009–2019. Gray lines represent 100, 200 and 500-m depth contours. Image: Data from NOAA's Northwest Fisheries Science Center's Fishery Resources, Analysis and Monitoring Program, analyzed by CCIEA. (Also included as Appendix.X.10.7)

Spatial representation of seafloor contact by bottom trawl gear from the NWFSC's groundfish survey within the Cordell Bank National Marine Sanctuary, calculated from annual distances trawled within each 2x2 km grid cell total sum of distance trawled from 2009–2019. Gray lines represent 100, 200 and 500-m depth contours. Source: NOAA's Northwest Fisheries Science Center's Fishery Resources, Analysis and Monitoring Program.

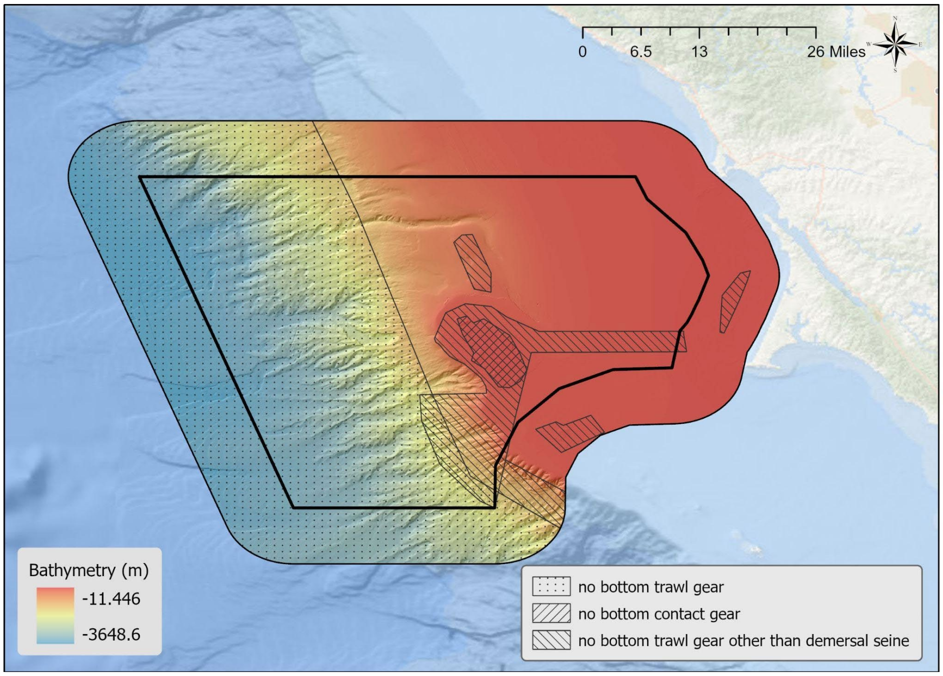

Figure App.E.3.2. Cordell Bank and surrounding area showing bathymetry and the geography of associated fishing regulations. Bathymetry data from NCCOS.

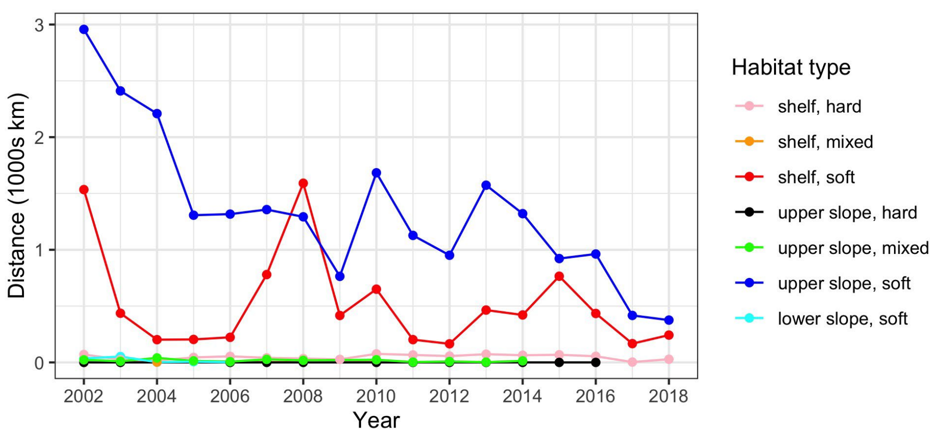

Figure App.E.3.3 (Also App.E.10.3). Distance trawled by federal limited-entry and catch shares groundfish bottom trawl vessels by habitat type. Source: NMFS NWFSC

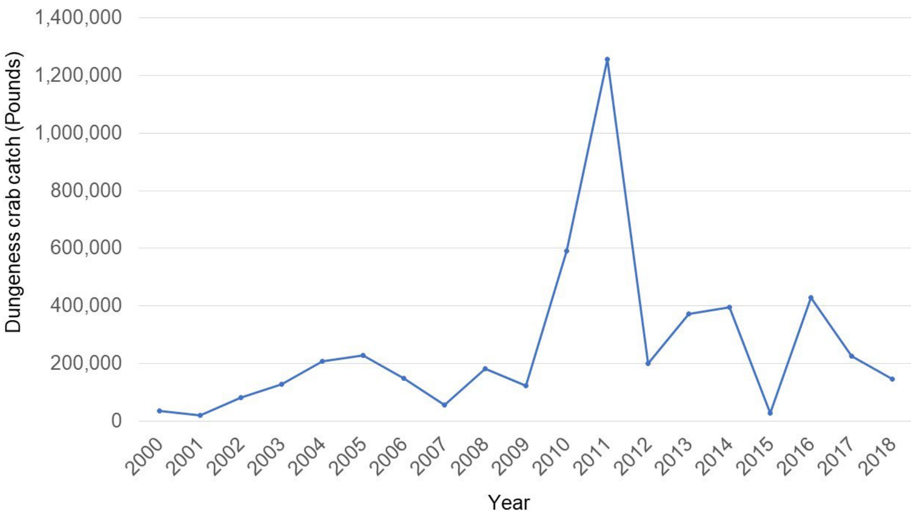

Figure App.E.3.4. Annual Dungeness crab catch in pounds from 2000-2018. Data source: CDFW; Data visualization: ONMS/CBNMS

Conclusion

The rating is fair because CBNMS habitat is impacted by noise, marine debris continues to be documented in the sanctuary and is likely increasing as it accumulates in marine waters, and areas of CBNMS were recently opened to trawling. The improving trend is based on a decrease in bottom trawling during the time frame. The level of noise is a concern but long term monitoring data is not yet available to evaluate the trend for ocean noise in the sanctuary and continued monitoring and analysis in the coming years is needed. More information on bottom contact fishing trends is needed to better assess human activities that may adversely influence habitats. This includes information about the habitat impacts from fishing on the seafloor such as the amount of fixed gear deployed and lost, and the severity and duration of impacts from fixed gear and trawling.

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Question 4: What are the levels of human activities that may adversely influence living resources and how are they changing?[2]

Status: Fair (very high confidence)
Trend: Mixed (high confidence)
Status Description: Selected activities have caused measurable living resource impacts, but effects are localized and not widespread or persistent.
Rationale: Status is fair based on measurable living resource impacts as a result of vessel traffic, fishing, and entanglement. Vessel traffic poses a risk of ship strikes to whales in the sanctuary, especially in high use habitat that includes a heavily trafficked shipping lane. In addition, whales are at risk of entanglements in the region, but the occurrence of entanglements in CBNMS is thought to be low. The trend for CBNMS for entanglement and strandings could not be determined due a lack of temporal data from the sanctuary. Generally, however, vessel speed decreased over the study period. A recent, slight increase in vessels and records from VMS suggest that fishing activity has increased from a low in 2018, but does not show a strong long term trend.

Comparison to 2009 Condition Report
The 2009 rating was fair and improving and was based on selected activities that had resulted in measurable living resource impacts, including fishing and associated habitat disturbance, vessel traffic (discharge, noise, collision), and marine debris (lost gear and plastics) (see Table S.HA.2.1).

New Information in the 20__ Condition Report
Human activities currently considered to pose the greatest threat to living resources in CBNMS are vessel traffic (mostly because of ship strikes), removal by fishing, and commercial fishing with gear that can entangle whales (Table S.HA.4.1). Vessel strikes to baleen whales are thought to be a significant source of mortality and the northern shipping lane of the San Francisco Bay Traffic Separation Scheme goes through CBNMS, funneling large vessel traffic into those lanes and through the sanctuary to vessel routes seaward of the shipping lane. Fishing activity, such as trawling and fixed gear, can reduce target and non-target species. Fishing gear, as well as marine debris and research gear, poses an entanglement risk to whales.

Table S.HA.4.1. Status and trends for individual indicators discussed at the June 29, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/Data visualization	Data Summary	Figures

[2] Experts assigned a trend rating of undetermined at the workshop. However, following the workshop, a new trend "mixed" was introduced to the condition report rating scheme as a result of discussions with experts. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the combination of trends from available data.

Vessel traffic	USCG/NOAA	**Status**: Mean Speed in CBNMS from 2009-2020 has dropped 3.1 knots; the size of ships has increased but the number of ships has stayed relatively constant. **Trend**: Conditions appear to be improving	
Ship Strikes	NMFS/ONMS	**Status:** Ship strikes continue to be a significant cause of human-induced mortality **Trend:** Conditions appear to be worsening	
Whale entanglement	NMFS/NMFS	**Status:** Whale entanglements continue to be a significant cause of human-induced mortality **Trend:** Conditions were worsening but appear to be improving in the last two years.	
Fishing activities	NMFS, CDFW/NCCOS	**Status:** Trolling, trawlers, and fixed gear make up the majority of the fishing activity in CBNMS **Trend:** VMS records indicated an increasing trend in time spent fishing in CBNMS	

Vessel traffic

Vessel traffic has a direct and indirect impact on some living resources in the sanctuary through ship strikes and noise (noise is discussed in Q3 and Q10). Ship strikes continue to be a significant cause of human-induced mortality and injury to baleen whales in CBNMS (Carretta et al., 2021). Blue and humpback whales are still recovering from past impacts (see Q13), and are listed as endangered (blue whales, humpback whale Central American Distinct Population Segment) and threatened (humpback whale Mexico DPS), and are vulnerable to impacts (Carretta et al., 2021). Experts believe that not all whales that are killed by ship strikes are detected, therefore, documented ship strike deaths are considered minimum values. Documented stranded animals appear to be about 2% (blue whales) to 10% (humpback whales) of actual whale vessel strikes because most dead whales will drift offshore or sink (Carretta et al., 2021). The total number of fatal strikes on endangered whales may be much higher than recorded totals, based on modeling estimates (Rockwood et al., 2020a). Cetacean carcass detection is consistently quite low across regions, therefore observed species and numbers are under-representative of true impacts. However, the trend in documented stranded animals appears to be increasing (NOAA, 2021) (Figure S.HA.4.1). The wide-ranging whale populations, uncertainty in where vessel impacts to whales occur vs. where struck whales are observed, and the limitations of data availability, require a broad look at the issue including regional observations.

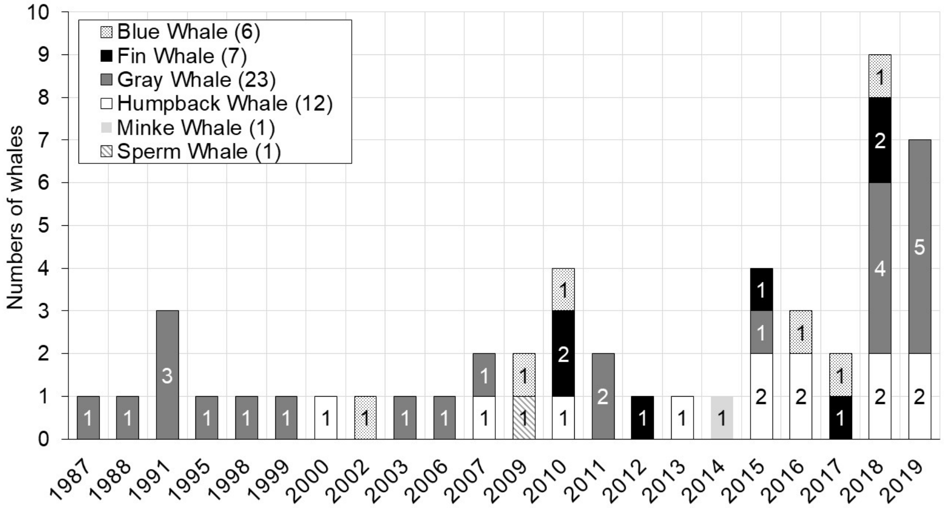

Figure S.HA.4.1. Recorded fatal ship strikes on large whales in San Francisco Bay Counties from 1986–2020 by species. Includes data for Sonoma, Marin, Contra Costa, Alameda, San Francisco, San Mateo and Monterey Counties. Only years with recorded data are shown. Due to COVID-19, 2020 necropsies were limited and therefore cause of death was not reported for 6 large whale strandings in San Francisco Bay Counties after February 2020. Figure: Jess Morten

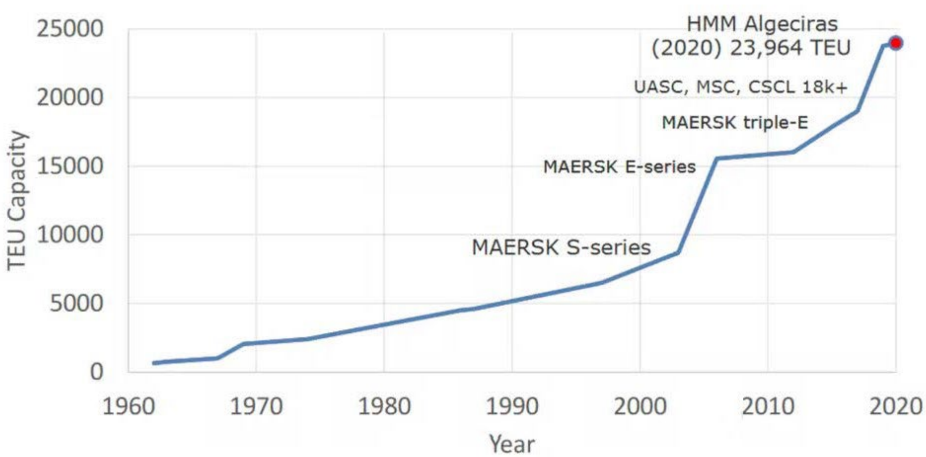

Figure S.HA.4.2. Container carrying capacity of ships globally has grown over 1000% since the 1960's. Source: Boulougouris E., 2021

The risk of fatal ship strikes to whales is influenced by the number, size, and speed of vessels, and how much vessel traffic overlaps with preferred whale habitat. While the number of ships that transit the sanctuary has not changed significantly during the study period, the size of ships has continued to increase (Boulougouris, 2021), increasing the probability of mortality in marine mammals that are struck (Silber et al., 2010) (Figure S.HA.4.2). "Over the last 100 years, the number of large commercial vessels (>100 gross tons) increased from 11,108 to just over 94,000" ([Schoeman et al., 2020](#)) indicating there are more large ships, which are more likely to cause fatal injuries. But large freight vessel speeds in CBNMS decreased by approximately 3 knots between 2009 and 2020 (Moore et al., 2018), from 15.2 knots in 2009 to 12.1 knots in 2020. In 2013, the traffic separation scheme for the entrance to San Francisco was modified to increase navigational safety by lengthening and narrowing the lanes, which also allowed for a decrease in the overlap of ship traffic and preferred whale habitat (Figure S.HA.4.3). However, later modeling work showed that the shift increased the risk of ship strikes in the northern traffic lane by concentrating vessel traffic over key blue whale habitat (Rockwood et al., 2020b). Ship strike risk is also influenced by the distribution of whales and the recovery of whale populations (Redfern et al., 2020).

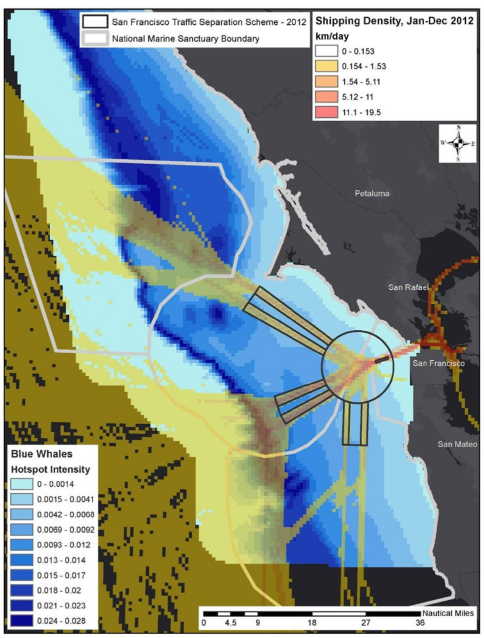

Figure S.HA.4.3. Vessel traffic patterns in 2012 prior to shipping lane changes overlaid on predicted whale density. Whale data: Point Blue; Vessel data: 2012 density data for vessels equal or greater than 80m from Moore, TJ (2018). Map source: Jess Morten/NOAA CBNMS/GFA

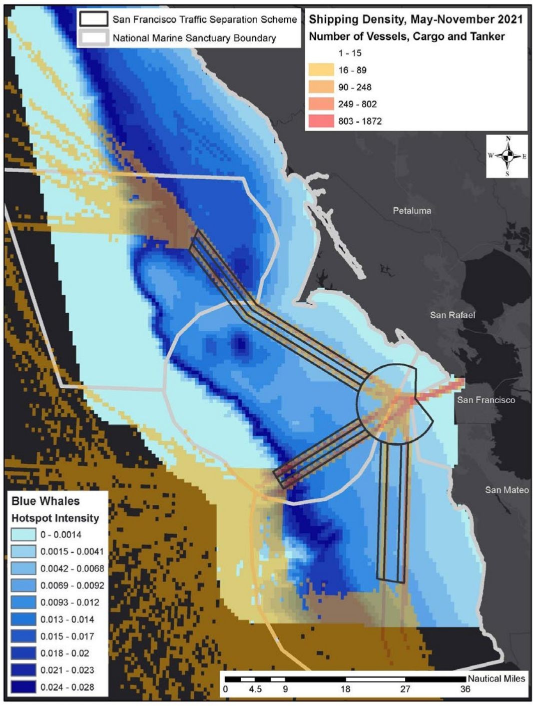

Figure S.HA.4.4. Vessel traffic patterns in 2021 after shipping lane changes were implemented in 2013 overlaid on predicted whale density. Whale data: Point Blue; Vessel data: 2021 vessel density for cargo and tanker vessel types, Gatehouse Marine. Map source: Jess Morten/NOAA CBNMS/GFA

Fishing activity

Recreational and commercial harvesting have direct effects on animal and plant populations, either through the removal or injury of organisms. Some fishing techniques are size-selective, resulting in impacts to particular life stages. In addition, lost fishing gear can cause extended periods of loss for some species through entanglement and “ghost fishing” (the continuous capture and serial mortality of animals by lost gear).

The majority of targeted species caught in CBNMS consists of various species of groundfish, salmon, and crab. Trolling, trawlers, and fixed-gear make up the majority of the fishing activity in CBNMS. NOAA Vessel Management System (see text box in Question 2) records indicate no strong trends, but a slight increase from 2018 to 2020 in the number of vessels and duration of fishing, following a low in 2018. VMS beacons are only carried by certain fisheries and do not reflect all fishing effort in CBNMS, but only those required to carry VMS beacons (50 CFR §660.14, NOAA 2020). Therefore, VMS records are only a subset of the fishing vessels in the sanctuary and do not provide a complete picture of fishing effort or fishing type. Total landings of all species, excluding market squid, have remained fairly constant since 2009. Including market squid, total landings declined significantly from 2009–2020 (p-value = 0.04), but this is driven by a very large squid harvest in 2010 (Figure S.HA.4.5). Fishing activity, based on VMS records, is concentrated in the eastern portion of the sanctuary and along the shelf break north of Cordell Bank (Figure S.HA.4.5).

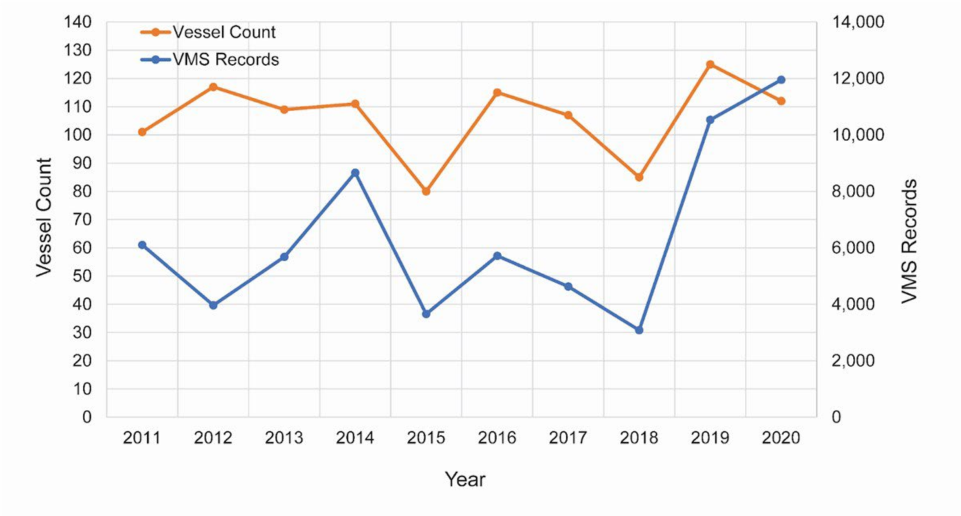

Figure S.HA.4.5. Fishing vessels in CBNMS from 2011 to 2020, based on VMS records. Data source: NOAA; compiled by: NCCOS

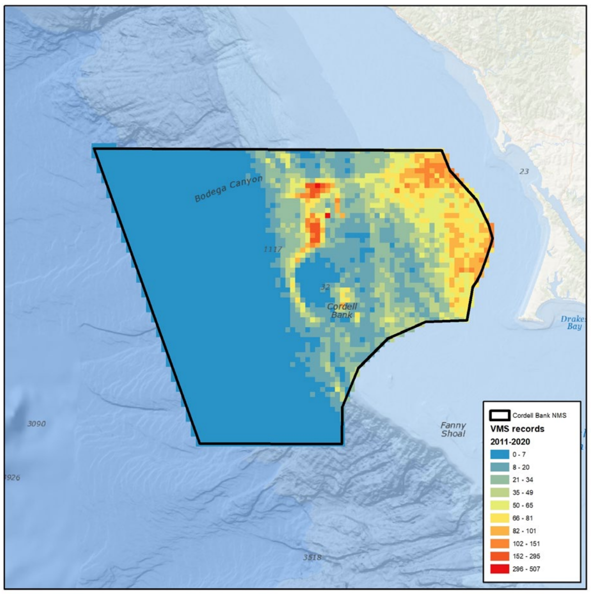

Figure S.HA.4.6. NOAA National Marine Fisheries Service Vessel Management Service Records for CBNMS during the study period, including all vessels with VMS. Data source: NOAA; compiled by: NCCOS

Automatic Identification System (AIS, see text box in Q2) data indicates an increasing number of fishing vessels and the distance traveled within the sanctuary during the study period but this likely reflects more vessels using AIS than previously (Figure S.HA.4.7). AIS carriage requirements for commercial vessels expanded in 2015, with a deadline for installation of working transponders in 2016 for all commercial vessels and passenger and fishing vessels that are 65 ft or more in length. Previously, only vessels 300 GT and larger were required to carry and transmit AIS (33 CFR §164). The increase in carriage requirements biases the data significantly for vessels in this class, as they were not required to carry a transponder before 2016. With this in mind, the data show the number of unique fishing vessels from 2009–2020 was 269, with the most in any one year approximately 85 vessels. The total distance traveled by fishing vessels, a measure of fishing vessel usage of an area, within the sanctuary was 26,682 miles.

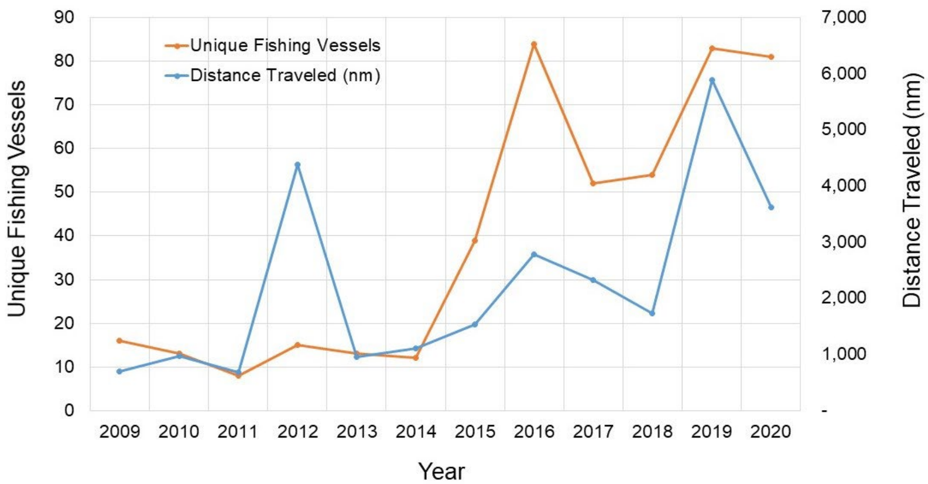

Figure S.HA.4.7. AIS data from vessels identified as fishing vessels from 2009 to 2020. Data includes unique fishing vessels (orange line) and distance traveled (blue line). Source: ?

The fisheries represented by VMS and AIS data are removing targeted species from the sanctuary including groundfish, black cod, salmon, and crab. Although there is limited data available to evaluate the seafloor impacts, the fishing gear may also be impacting benthic invertebrate species. On the soft sediment in the eastern portion of the sanctuary this could include sea pens, infauna (worms and bivalves), crustaceans, sea urchins, sea cucumbers, and sea stars. At the shelf break, the sediment there is like to be a mixture of soft and hard sediment. Species possibly affected by fishing in this area could include corals and sponges, crustaceans, sea stars, urchins, and sea cucumbers, among others. Additionally, non-target species can be caught as bycatch, and foragers in the water column, including whales, dolphins, pinniped, and seabirds, can be impacted by fishing gear and activity. Data was not available to evaluate the level of these impacts.

Whale entanglement

Entanglement in fishing gear, marine debris, and research gear is a significant threat to marine wildlife. Baleen whales are particularly vulnerable to entanglement because of their habitat use and behavior. Humpback whales continue to be the most common species entangled. While during the study period there was only one confirmed entanglement within CBNMS, there were over 118 confirmed entanglements in neighboring GFNMS and MBNMS from 2000–2019, indicating that it is a concern in the region. And in 2020, despite significant efforts to reduce entanglements, there were still 17 confirmed whale entanglements off the coasts of Washington, Oregon, and California, or off the coast of other countries but entangled in U.S. commercial fishing gear. (NOAA, 2021) (Figure S.H.4.8). In addition, unidentified whales represent approximately 15% of entanglement cases along the U.S. West Coast (Carretta et al., 2016). Entanglements are likely underreported as they require opportunistic sightings. During the study period, the 2014–2016 marine heatwave caused a habitat compression for humpback whales that concentrated whales in areas of high use by the Dungeness crab fishery (exacerbated by prey switching and changes to the timing of the fishery, also a result of the marine heatwave) causing an increase in entanglements, (Santora et al., 2020). Additionally, in response to the change in the northern shipping lane in 2013, the commercial fishery for Dungeness crab began placing their pots along the eastern edge of the northbound lane, in a configuration that may increase the risk for whale entanglement (Richard Ogg, personal communication). In recent years, there have been increasing efforts to disentangle humpback whales along the west coast through the Large Whale Entanglement Response Network coordinated by NOAA (NOAA, 2022). In addition, the Risk Assessment and Mitigation Program California Dungeness Crab Fishing Gear Working Group is working to reduce overlap of the Dungeness crab fishery with whales, and to modify fishing gear to reduce the risk of entanglement (OPC, 2018).

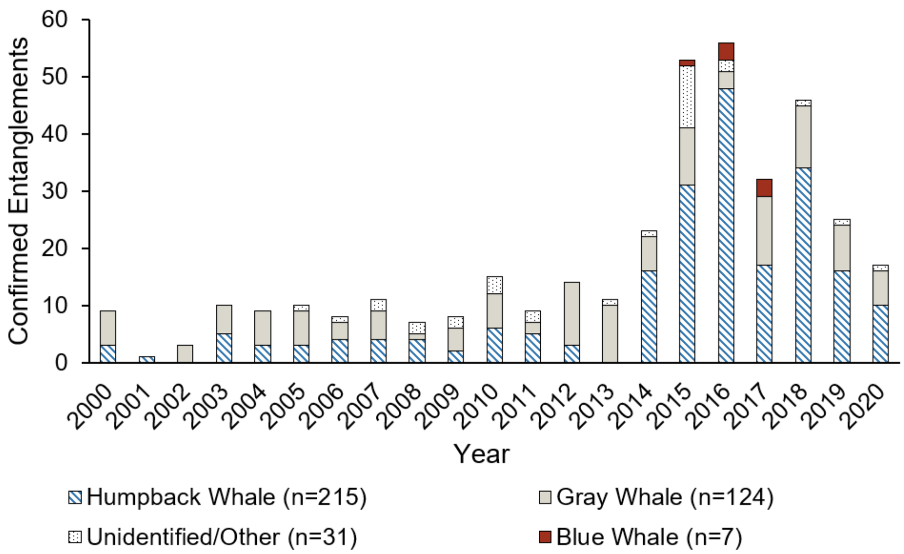

Figure S.HA.4.8. Number of confirmed entanglements by species reported to the West Coast Region each year from 2000 to 2020. Source: [NMFS West Coast Region Marine Mammal Health and Stranding Response Program 2021]

Conclusion

The rating of fair considers whale entanglements in the region, (though most of those observed are outside of CBNMS), and a fairly high risk of ship strikes within the sanctuary due to the high traffic volume, increasing ship size, and a shipping lane that crosses key whale habitat in the sanctuary. The trend was mixed, based on two considerations. First, the spatial coverage of stranding and entanglement data does not allow for an assessment of sanctuary-scale temporal change. Second, reduced impacts to whales from decreased risk of ship strikes as a result of reductions in vessel speed could be offset by a slight but recent increase in fishing vessels and duration of fishing based on VMS records which could increase entanglements and impacts to other living resources such as benthic species, but the result of this dynamic is not yet known. The adjustment of the shipping lanes narrowed the footprint of shipping lanes in some whale habitat, but directed traffic towards a whale hotspot. The adjustment of the shipping lane also changed the distribution of fishing activity, possibly creating more overlap with Dungeness crab gear and whale habitat. Addressing data gaps in fishing activity (including vessel types and locations), whale entanglements, ship strikes, and acoustic impacts will improve the ability to assess human activities, and under what co-occuring environmental stressors (e.g. marine heatwaves) that may adversely influence living resources.

Question 4 Literature Cited

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Shoeman R. 2020 A Global Review of Vessel Collisions With Marine Animals Front. Mar. Sci., 19 May 2020

Silber, G. K., Slutsky, J., and Bettridge, S. (2010). Hydrodynamics of a ship/whale collision. J. Exp. Mar. Bio. Ecol. 391, 10–19

Question 5: What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?[3]

Status: Good
Trend: Undetermined
Status Description: Few or no activities occur at maritime heritage resource sites that are likely to adversely affect their condition.
Rationale: The rating is good because the levels of human activities that may adversely affect the one maritime heritage resource documented to be in the sanctuary, the ex-USS S*tewart* (DD-224), are thought to be minimal. This is due to its isolated, 6,000 foot depth location. For example, commercial fishing bottom trawls do not reach to that depth. There may be deposition of marine debris on the shipwreck and the corrosion rate may be changed by increasingly acidic ocean waters. Natural processes of degradation are likely to pose a larger threat. The trend is undetermined due to a lack of information about changes in human activities that may impact the shipwreck. Note that a confidence score was not assigned to the status or trend rating for this question because subject matter external experts were not consulted on these ratings.

Comparison to the 2009 Condition Report
In the 2009 condition report, both the status and trend ratings for this question were undetermined because at that time, there were no documented underwater maritime archaeological sites within sanctuary boundaries (see Table S.P.2.1).

New Information in the 20__ Condition Report
As a result of sanctuary expansion in 2015, one maritime heritage resource is now known by historical records and news accounts to be located within the sanctuary, the ex-USS *Stewart* (DD-224) (ONMS, 2014a, ONMS, 2014b). The estimated depth, around 6,000 feet below the surface, of this shipwreck precludes direct human activity disturbance such as commercial and

[3] A workshop was not convened for the question that asks, What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing? Archaeological experts with the ONMS Maritime Heritage Program and CBNMS internally evaluated this question. These subject experts have been monitoring existing archaeological sites along the west coast since the 1980s.

Commented [2]: The inclusion of ocean acidification and natural processes seemed out of place here, since it wasn't included in the earlier questions and I thought the introduction of this document explicitly stated these would not be included in the "states of drivers/pressures"

Commented [3]: Ginny - You are right that purely natural processes should not be used as a basis for judgement in ratings, as natural processes are neither good nor bad, they are just nature doing her thing. OA may be a different story, as it is linked to human-accelerated climate change. So it may deserve discussion. Regardless, we often contrast the role of natural degradation with processes influenced by humans. So for me, this description is consistent with what we've seen at other sites and for other questions. Does that make sense?

Commented [4]: Yes that makes sense.

Commented [5]: Flagging this for discussion with Kathy and Steve. How have you dealt with this in other reports?
@kathy.broughton@noaa.gov
@steve.gittings@noaa.gov
Assigned to Kathy Broughton - NOAA Federal

Commented [6]: Dani - take a look at my response to Ginny below and let me know if that helps.

recreational fishing (bottom trawls do not reach this deep), inadvertent damage by recreational divers, looting, or vessel anchorings. There is a possibility of deposition of marine debris on the remains of the ship, as marine debris of different types has been observed throughout the sanctuary. However, the amount of debris, if any, on the shipwreck and any damage such debris might cause to the ship has not been assessed. Also, there are no existing or planned offshore developments, and no military activities are known to exist near the location of this shipwreck. Due to these factors, the rating for this question is good. The trend rating is undetermined due to a lack of information about changes in human activities that may impact the shipwreck.

As described in the pressures section of this report, human activities are contributing to a changing climate and ocean that may also affect submerged maritime heritage resources. The wreck of *DD-224* could be threatened by an increasingly acidic ocean, as this has the potential to change the corrosion rate (Rockman et al., 2016) of metal parts and artifacts on the ship. Corrosion on shipwrecks is affected by a number of variables (Wright, 2016), including metal composition, pH, dissolved oxygen, temperature, salinity, and water movement, among others (North & Macleod, 1987). In addition, *in situ* corrosion analyses on shipwrecks need to consider the effects of microbiologically-influenced corrosion on both the position of an iron or steel archaeological shipwreck site, the locations they colonize, and the prevalent chemical and physical environmental conditions, as these directly influence the species of microorganisms that settle on the shipwreck and microbial metabolic rates (Moore, 2015). Thus, corrosion rates vary for different parts of a shipwreck, based on the variables present. But while ocean acidification will have a detrimental effect on shipwrecks and other underwater cultural heritage sites, the corrosion potential of metal-hulled shipwreck sites needs to be explored as the impacts of ocean acidification on metals and organic materials and implications to artifact stability are not yet well understood (Dunkley, 2015). The depth of the shipwreck suggests that overall microbial activity may be limited and that concretion products formed by calcifying marine organisms around ferrous artifacts and on vessel structures may not be as prevalent as at a shallower site. Cold water temperature likely would preserve organic materials and slow the rate of deterioration (J. Hoyt, personal communication, May 27, 2020).

Commented [7]: Again, I'm confused why ocean acidification is being discussed here and not elsewhere in this document.

Conclusion

The estimated depth of this shipwreck has precluded direct human activities that would disturb it, though there is a possibility of deposition of marine debris on the wreck. While ocean acidification will have a detrimental effect on shipwrecks and other underwater cultural heritage sites, the corrosion potential of metal-hulled shipwreck sites such as this one need to be explored as the impacts on materials and implications to artifact stability are not yet well understood. The wreck of *DD-224* and the effects of disturbance from human activities on it have not been assessed. However, the ocean depth and cold temperature in the wreck area suggest overall microbial activity may be limited, concretion products formed by calcifying marine organisms may not be as prevalent, and cold water temperature may preserve organic materials and slow deterioration. Due to these factors, the rating for this question is good and the trend rating is undetermined due to a lack of baseline information about human activities that may have adversely affected the wreck and changes to those activities.

Question 5 Citations

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Status and Trends of Sanctuary Resources

This section provides summaries of resource status and trends within four areas: water quality, habitat, living resources, and maritime heritage resources. Virtual expert workshops were convened by CBNMS staff on various dates from March–April, 2021 (see Appendices A __ and C) to discuss the series of questions about each resource area. It is important to note that, in general, the assessments of the status and trends of key indicators in CBNMS are for the period from 2009–2021. During the virtual workshops indicators for each topic were presented, accompanied by datasets ONMS had collected prior to the meeting. Attendees were then asked to review the indicators and datasets, identify data gaps or misrepresentations, and suggest any additional datasets that may be relevant. Once all datasets were reviewed, experts were asked to provide status and trend recommendations and supporting arguments. After assigning status and trend ratings, experts were asked to assign a level of confidence for each value by: (1) characterizing the sources of information they used to make judgments; and (2) their agreement with the selected status and trend ratings. The evidence and agreement ratings were then combined to determine the overall confidence ratings. Appendix C provides a detailed description of the report development methods.

Commented [1]: Can be viewed here: https://docs.google.com/document/d/1ao4r6jJ3VjnYQcbaqah0Bf6_nFYD5cVBAFslJaG5IEY/edit

The following responses for each question summarize the key indicators, supporting data sets, and rationale for each status and trend rating. Where published or additional information exists, the reader is provided with appropriate references and web links. Workshop discussions and ratings were based on data available at the time (e.g., through spring 2021). However, in some instances, sanctuary staff later reevaluated and/or incorporated newly available data in order to more accurately describe the current status and trends of resources. Situations where post-workshop rating decisions were made and/or data were used by sanctuary staff to support a rating, but were not presented or discussed during the workshop, are noted in the text.

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Status and Trends of Water Quality (Questions 6–9)

The following provides an assessment of the status and trends of key water quality indicators in CBNMS for the period from 2009–2021.

Question 6 focuses on eutrophic conditions and their influence on primary production in sanctuary waters. Eutrophication is the accelerated production of organic matter, particularly algae, usually caused by an increase in the amount of nutrients (primarily nitrogen and phosphorus) from human sources in surface waters. Eutrophication can impact the condition of sanctuary resources, for example, by promoting nuisance and toxic algal blooms or impacting dissolved oxygen levels.

Question 7 focuses on parameters affecting public health. Human health concerns can arise from water or seafood contamination (bacteria, chemicals, and biotoxins). Indications of health impacts may include fishery closures and shellfish consumption advisories. Such impacts can be devastating, both ecologically and economically, in affected coastal communities.

Question 8 focuses on shifts in water quality due to climate drivers. Climate indicators include indices of large-scale climate patterns, upwelling intensity, water and air temperature, dissolved oxygen, and acidity. Shifts in water temperature can affect species growth rates, phenology, distribution, and susceptibility to disease. Acidification can affect organism survival, growth, and reproduction. Upwelling influences oxygen content and nutrient cycling.

Question 9 assesses biotic and abiotic stressors not addressed in other questions that, individually or in combination, may influence sanctuary water quality. Examples include nonpoint source contaminants and hard-to-quantify stressors that influence the condition of habitats and living resources. Such inputs may include industrial discharges and emissions.

Text box

Trendlines in figures were used as a visual representation during a series of workshops with experts to rate the status and trend of each question. In each figure caption, the fit of each trendline is described. Trendlines do not represent statistical significance.

Table S.WQ.6.1. 2009 Condition Report ratings (left) and 2009–2021 Condition Report ratings (right) status, trend, and confidence ratings for the water quality questions.

2009 Condition Report Questions		2009 Rating	2009–2021 Condition Report Questions		2009–2021 Condition Report Rating			
					Status	Confidence (Status)	Trend	Confidence (Trend)
2	Eutrophic Condition	—	6	Eutrophic Condition	Good	Medium	—	Medium

3	Human Health Risks	—	7	Human Health Risks	Good/Fair	High	▼	Low
1	Multiple Stressors (including climate)	?	8	Climate Drivers	Fair	High	▼	Low
			9	Other Stressors	Good/Fair	Medium	?	Medium

Question 6: What is the eutrophic condition of sanctuary waters and how is it changing?

Status: Good (medium confidence)
Trend: Not changing (medium confidence)
Status Description: Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.
Rationale: Although data are limited and only provide proxy information, there is no clear evidence of eutrophication resulting from anthropogenic sources occurring in the sanctuary. Some data suggest that climate change may influence nutrients; this issue is further discussed in Question 8.

Findings from the 2009 Condition Report
Eutrophication is characterized by an increase in organic productivity and is often caused by an increase in nutrients, which can occur due to natural processes such as upwelling, or anthropogenic causes like run-off. Nutrients can trigger algal blooms, which can result in the production of toxins and low oxygen levels. In 2009, this question was rated as good with a trend of not changing because there was no evidence of eutrophication in the sanctuary or surrounding region; chlorophyll concentrations did not reach levels of concern for eutrophication and there was an absence of HABs (Table S.WQ.6.1).

New Information in the 20__ Condition Report
The current condition report also rated this question as “good” with a trend of “not changing,” based on data on nutrients (indicated as nitrates), chlorophyll concentrations, net primary productivity, and dinoflagellate/diatom ratios (Table S.WQ.6.2).

Table S.WQ.6.2. Status and trends for individual indicators discussed at the March 24, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Nitrates	ACCESS/Point Blue	Pelagic	Status: Variability, concentrations not of concern for eutrophication Trend: Possible declining trend	Figure S.WQ.6.1

Nitrates vs temperature	ACCESS/Point Blue and Garcia-Reyes et al., 2014/Garcia-Reyes et al., 2014	Pelagic	Status: Higher nitrates in cooler water temperatures Trend: No trend	Figure App.EX.6.1, Figure App.EX.6.2, Figure App.EX.6.3,
Chl A - Satellite	NASA Aqua MODIS/Point Blue	Pelagic	Status: Seasonal patterns, higher when upwelling was weaker Trend: No strong trends	Figure S.WQ.6.2
Net primary productivity - seasonal	CeNCOOS/CeNCOOS	Pelagic	Status: Seasonal patterns, higher in cold years, patterns consistent across larger area Trend: No long term trends	Figure S.WQ.6.3
Net primary productivity - monthly and annual	CeNCOOS/CeNCOOS	Pelagic	Status: Seasonal patterns, higher in cold years, patterns consistent across larger area Trend: No long term trends	Figure App.EX.6.5
Phytoplankton species (diatom/dinoflagellates)	ACCESS/Point Blue	Pelagic	Status: Higher ratios of diatoms than dinoflagellates Trend: No strong trends	Figure S.WQ.6.4
Phytoplankton species (diatom/dinoflagellates)	ACCESS/Point Blue	Pelagic	Status: Higher ratios of diatoms than dinoflagellates Trend: No strong trends	Figure App.E.6.6

Nutrients can play a limiting role in primary production and increases in nutrient loads can be a cause of eutrophication. Average nitrate (NO_3+NO_2) concentrations in CBNMS varied over time, with a slightly declining trend (Figure S.WQ.6.1). Nitrate concentrations ranged between 0 and 21.9 µM from 2009 to 2019. There was a relationship between nitrate levels and temperature, with higher nitrates in years when ACCESS cruises measured cooler water temperatures compared to cruises that measured warmers ones (Figure App.EX.6.1, Figure App.EX.6.2 and Figure App.EX.6.3), and this relationship also holds true for the region (Figure App.EX.6.4, García-Reyes et al., 2014). Higher levels of nitrates occurred in 2010 and 2012 (when ACCESS cruises measured average water temperatures) and lower levels of nitrates occurred in 2014 and 2015 (when ACCESS cruises measured warmer water temperatures[1]). Contributions of nutrients from anthropogenic sources would be expected to be minimal given the sanctuary's distance from land. Furthermore, outflow from the bay was unlikely to enter the sanctuary, as water tends to flow southward (Largier, 2020).

Commented [1]: Requested reference from Frances Wilkerson to respond to reviewer comments about how this compares to eutrophic conditions. This may result in one sentence and a reference added here.

Commented [2]: @kathy.broughton@noaa.gov new footnote - renumber

[1] For consistency throughout the report, we used +/-0.5°C as a threshold to delineate temperature anomalies and define warm vs. cold years. Methodology is described in the caption of each figure.

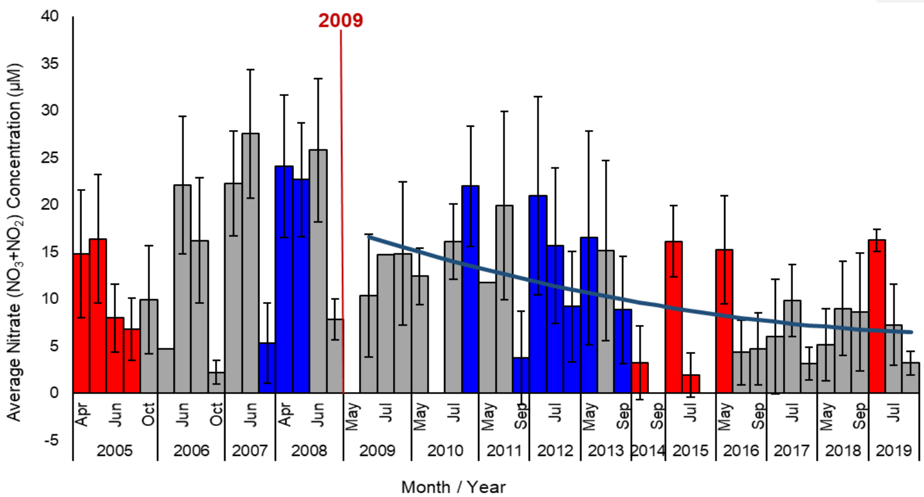


Figure S.WQ.6.1. Mean surface water nutrient levels (mean +/- standard deviation) from ACCESS samples.Cruises occur 3-4 times per year (except in 2005 when 5 occurred). Each bar is the average from a cruise for line 2 (located in CBNMS). There were no data for blank bars in 2009 and 2010; Blanks in 2014 and 2015 indicate nitrates were not detected. Red bars represent warm years (above +0.5°C annual temperature anomaly), blue bars represent cold years (below -0.5°C annual temperature anomaly), and gray bars represent normal years (within +/-0.5°C of long-term average) calculated from CTD data collected on ACCESS. Trendline is a second degree polynomial line and calculated only for 2009 to 2019 data (time period of this condition report). The vertical red line indicates the year of the last condition report (2009). Figure: Point Blue Conservation Science.

Chlorophyll *a* concentrations in the CBNMS region showed strong seasonal patterns (Figure S.WQ.6.2). There was also a correlation between annual water temperature and chlorophyll, as some cold water years (e.g. 2007 and 2012) had lower chlorophyll *a* levels than warmer or average water years. Although upwelling can bring nutrients, cold water, and high productivity, the ocean color data showed blooms were more common during weak upwelling years (e.g., 2004-2006, 2013-2016) in CBNMS, perhaps as a result of relaxation and stratification. The highest chlorophyll *a* concentrations for the study period occurred in 2011 and 2019, with the lowest concentrations in 2015 and 2016. Occasionally, high chlorophyll *a* concentrations resulted in toxic conditions, as was the case in the 2015 HAB event (see Question 7 for further discussion of this event).

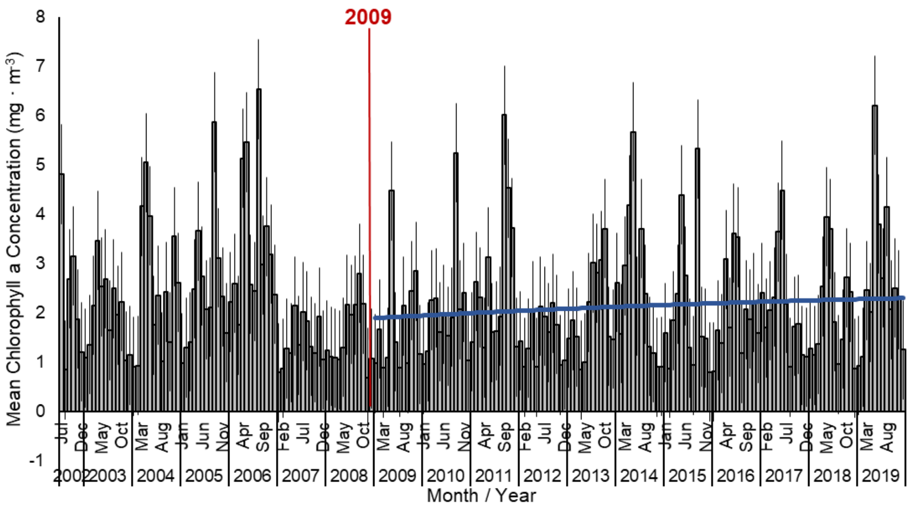


Figure S.WQ.6.2. Mean chlorophyll *a* concentrations and standard deviation, derived from satellite data (Aqua MODIS), at 4km resolution for the CBNMS region from 2002 to 2019. Trendline is a second degree polynomial line and calculated for 2009 to 2019 data (time period of this condition report). The vertical red line indicates the year of the last condition report (2009). Figure: Point Blue Conservation Science.

Net Primary Productivity (NPP), carbon assimilation by phytoplankton, showed consistent seasonal patterns in CBNMS, with the lowest occurring during winter seasons, and increases during relaxation and upwelling seasons (Figure S.WQ.6.3). The highest NPP occurred during the 2014 and 2019 upwelling seasons and during the 2011 and 2019 relaxation periods. There were no strong trends, and patterns in CBNMS were consistent with nearby sanctuaries (GFNMS and MBNMS) (Figure App.E.6.5.).

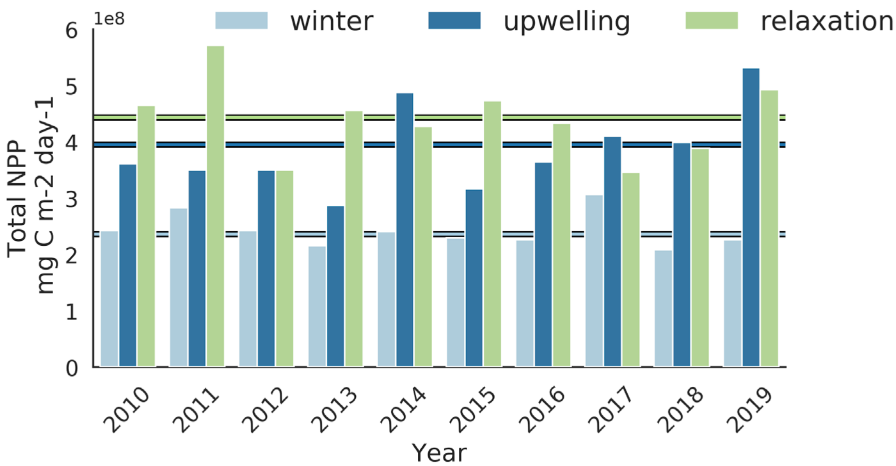
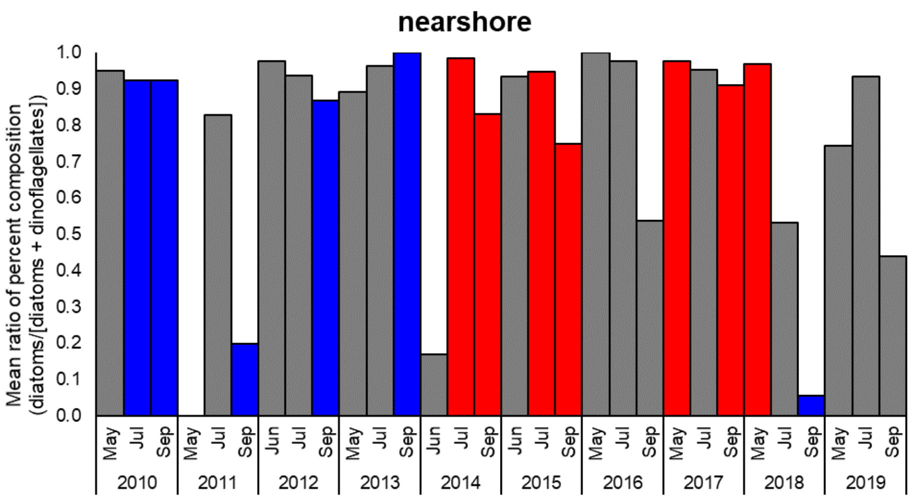


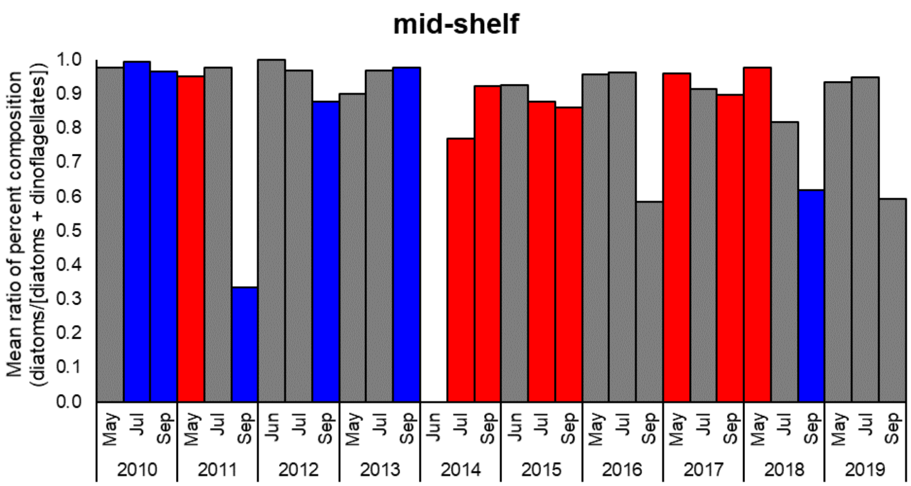
Figure S.WQ.6.3. Cumulative Seasonal NPP in CBNMS estimated by summing monthly averages of the NPP record for the Winter (Nov to Feb), Upwelling (March to June), Relaxation (July to Oct) seasons. The seasonal average for each season for the entire time series (2000-2019) are shown as the horizontal lines. NPP estimates are calculated from the 5-day merged Chla, merged daily PAR (from MODISA, MODIST, VIIRS-SNNP, VIIRS-JPSS1) and daily SST-OI data. Figure: CenCOOS.

Commented [3]: I asked Patrick Daniel if error bars could be added.

Commented [4]: Averages should include error bars that show standard deviation

Diatoms can become dominant in a system following the addition of nutrients (Malone, 1980; Bode et al., 1997) and therefore an increase in diatoms could be an indicator for eutrophication, but in CBNMS could also indicate upwelling conditions and cold, productive conditions. Changes in the relative abundance of each phytoplankton group can affect the food web, beginning with the grazers that consume them (Wasmund et al., 2017), and, under the right conditions, both can produce toxins (e.g., when *Alexandrium* spp. dinoflagellates were present or during blooms of *Pseudo-nitzschia* spp. diatoms; Question 7 provides additional information). Additionally, diatoms tend to sink more rapidly, which could reduce the secondary effects of eutrophication, while enhancing rates and magnitudes of carbon delivery to deep ecosystems (Wasmund et al., 2017). The ratio of diatoms to dinoflagellates (based on the percent composition of the number of individuals found in phytoplankton samples) in CBNMS was calculated for offshore, mid-shelf, and nearshore sampling locations (Figure S.WQ.6.4). Overall ratios tended to be relatively high (i.e., more diatoms than dinoflagellates) across years and sampling locations. Lower ratios tended to occur in the sanctuary in years that ACCESS cruises measured cooler and average water temperatures compared to warmer water temperatures. Ratios also tended to be slightly lower in CBNMS nearshore sampling locations than mid-shelf and offshore locations. Percent compositions of diatoms were greatest for all CBNMS locations combined from March to July 2014 (Figure App.E.6.6).


nearshore
Mean ratio of percent composition (diatoms/[diatoms + dinoflagellates])
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
May Jul Sep May Jul Sep Jun Jul Sep May Jul Sep Jun Jul Sep Jun Jul Sep May Jul Sep May Jul Sep May Jul Sep May Jul Sep
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019


mid-shelf
Mean ratio of percent composition (diatoms/[diatoms + dinoflagellates])
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
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May Jul Sep May Jul Sep Jun Jul Sep May Jul Sep Jun Jul Sep Jun Jul Sep May Jul Sep May Jul Sep May Jul Sep May Jul Sep
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

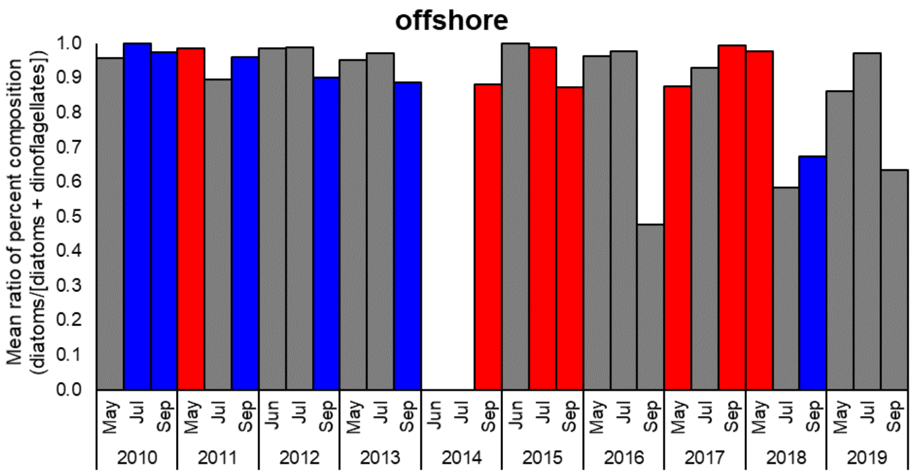

Figure S.WQ.6.4.[2] Mean ratio of percent composition of diatoms to dinoflagellates in nearshore, mid-shelf, and offshore areas in CBNMS. Phytoplankton samples collected during ACCESS cruises and analyzed by California Department of Public Health Biotoxin Monitoring Program. Note: data from stations N4-WN and N2-WN (nearshore), 4-E and 2-E (mid-shelf), and 4-W and 2-W (offshore) were used in these figures. No samples were collected nearshore in May 2011 or mid-shelf and offshore in June 2014. The July 2014 offshore sample contained dinoflagellates but no diatoms. Red bars represent warm years (above +0.5°C annual temperature anomaly), blue bars represent cold years (below -0.5°C annual temperature anomaly), and gray bars represent normal years (within +/-0.5°C of long-term average) calculated from CTD data collected on ACCESS.

Commented [5]: Footnote #10

Commented [6]: We think adding error bars is not appropriate for this figure based on the calculations made, but will need to clarify after Meredith returns from vacation 11/12. We may want to add one sentence to the caption to clarify this after discussing with her.

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Conclusion

In this condition report, the status of eutrophic conditions in CBNMS was rated good with a trend of not changing, both with a medium confidence. Although data are limited and only provide proxy information, there is no clear evidence of eutrophication resulting from anthropogenic sources. To better understand eutrophication and conditions that could lead to eutrophication, CBNMS requires data with an increased temporal and spatial resolution, particularly because eutrophication events can be episodic. Additionally, data on ammonium and DO would further inform this topic.

[2] These data sets and figures were not presented to experts during the status and trends workshop.

Figures for APPENDIX (to be moved when report is compiled)

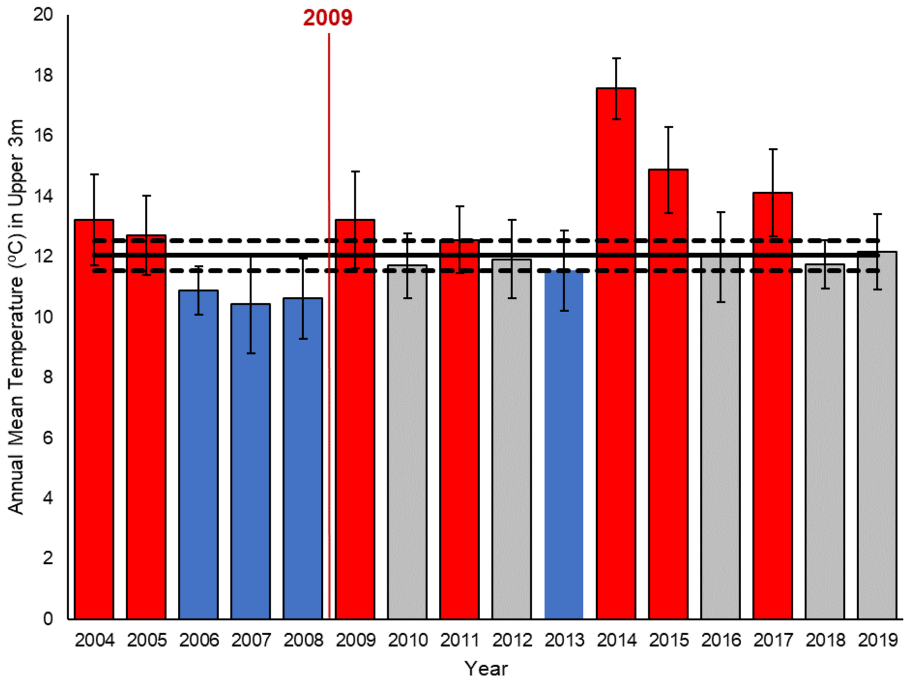

Figure App.E.6.1. Annual mean temperature in surface waters (mean +/- standard deviation) measured at CBNMS during ACCESS stations. Temperature was measured by a conductivity-temperature-depth (CTD) recorder. Solid line represents the long-term average (2004-2019), and dotted lines represent the +0.5°C and -0.5°C around long-term average. Red bars represent warm years (above +0.5°C line), blue bars represent cold years (below -0.5°C line), and gray bars represent normal years (within +/-0.5°C of long-term average) calculated from CTD data collected on ACCESS. The vertical red line indicates the year of the last condition report (2009).

Commented [8]: Need to update all Appendix figures E (for all resource figures)

Commented [9]: How the red, blue, gray categories were determined throughout this section is a little difficult to follow because I think they were calculated from Figure S.WQ.8.1 on page 28 - Figure S.WQ.8.1. Persistent sea surface temperature anomalies, NOAA Bodega Bay buoy (46013), 1981-2019. Bars represent the three-month means subtracted by the monthly long-term mean. Red bars represent warm periods (i.e., +0.5ºC for 5 months in a row), and blue bars represent cold periods (i.e., -0.5ºC for 5 months in a row). Data source: NOAA. Data Visualization: Point Blue Conservation Science. However in another figure Figure S.WQ.6.4 . its mentioned that "Periods determined to be cold (in blue) and warm (in red) based on CTD measurements of the water temperatures during ACCESS cruises. See Figure App. X.6.1 for ACCESS water temperature classifications."

Where did the 0.5 to -0.5 come from again? Providing more clarity up front and at the beginning of Chapter 6 would be helpful.

Commented [10]: How the red, blue, gray categories were determined throughout this section is a little difficult to follow because I think they were calculated from Figure S.WQ.8.1 on page 28 - Figure S.WQ.8.1. Persistent sea surface temperature anomalies, NOAA Bodega Bay buoy (46013), 1981-2019. Bars represent the three-month means subtracted by the monthly long-term mean. Red bars represent warm periods (i.e., +0.5ºC for 5 months in a row), and blue bars represent cold periods (i.e., -0.5ºC for 5 months in a row). Data source: NOAA. Data Visualization: Point Blue Conservation Science. However in another figure Figure S.WQ.6.4 . its mentioned that "Periods determined to be cold (in blue) and warm (in red) based on CTD measurements of the water temperatures during ACCESS cruises. See Figure App. X.6.1 for ACCESS water temperature classifications."

Where did the 0.5 to -0.5 come from again? Providing more clarity up front and at the beginning of Chapter 6 would be helpful.

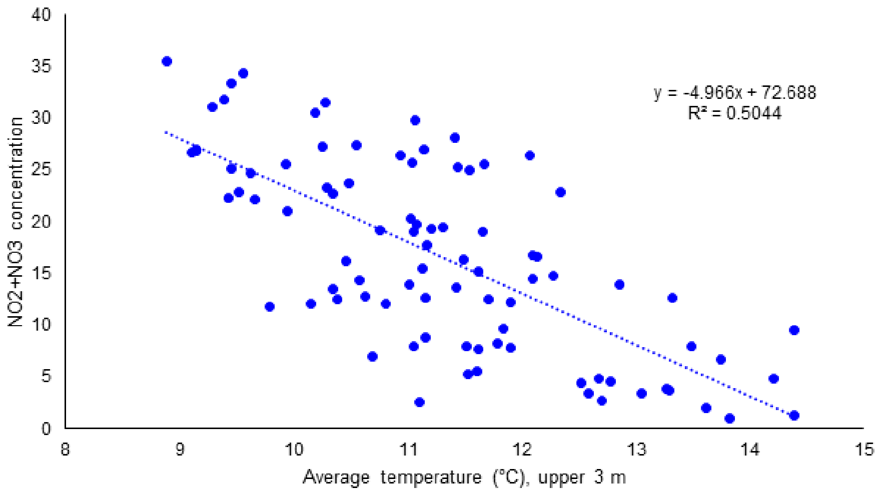

Figure App.E.6.2. The relationship between temperature and nitrates during cold periods in the upper 3 m at CBNMS ACCESS stations (i.e., CTD data with average temperature 0.5°C below the long-term mean).

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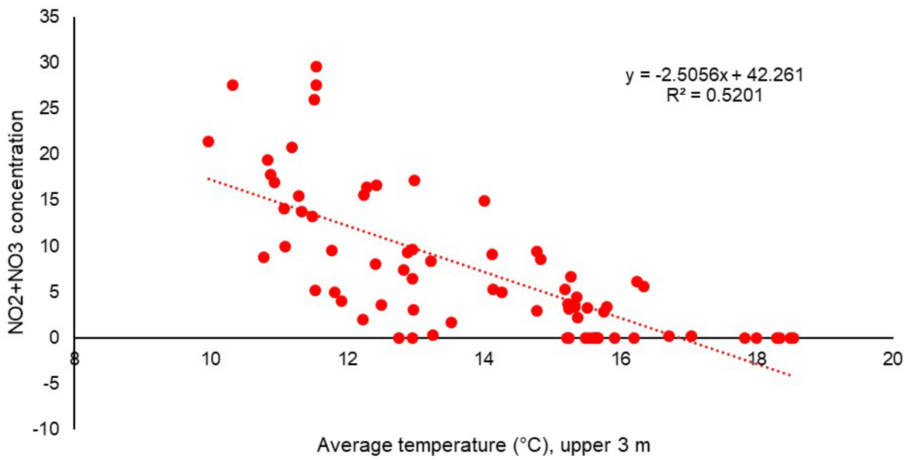

Commented [12]: These figures are showing the relationship between temperature and nitrates but we are not showing statistical significance. P value was not calculated. No change to these figures based on Ginny's comment.

Figure App.E.6.3. The relationship between temperature and nitrates during warm periods in the upper 3 m at CBNMS ACCESS stations (i.e., CTD data with average temperature 0.5°C above the long-term mean).

Commented [13]: some stats/p value would be useful here

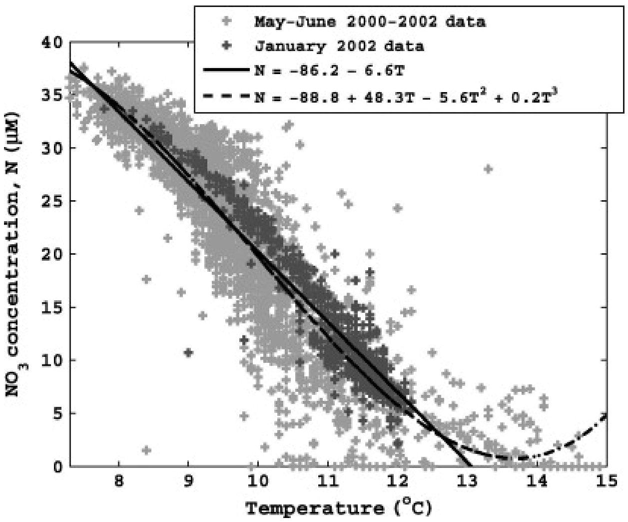

Figure App.E.6.4. Temperature vs. NO_3 concentration for water samples of the WEST program (Largier et al., 2006). Lines show a linear and a cubic polynomial fitting of the data.180M. Figure: García-Reyes et al., 2014.

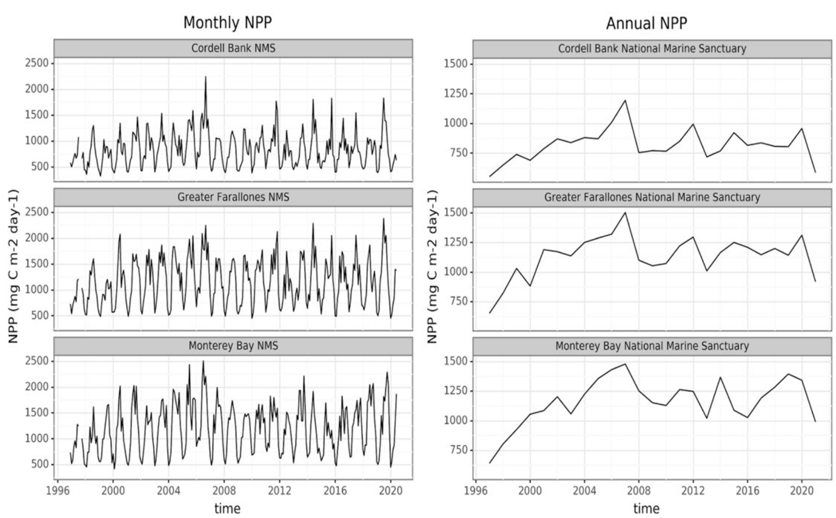

Figure App.E.6.5. Monthly and annual NPP for Cordell Bank, Greater Farallones and Monterey Bay national marine sanctuaries. NPP estimates are calculated from the 5-day merged Chla, merged daily PAR (from MODISA, MODIST, VIIRS-SNNP, VIIRS-JPSS1) and daily SST-OI data. Figure: CenCOOS.

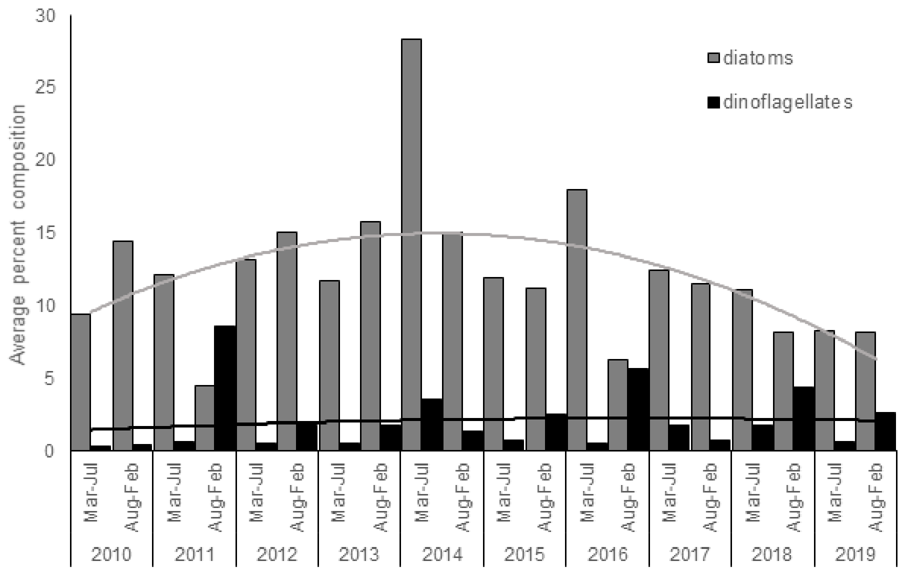

Figure App.E.6.6. Mean ratio of the percent composition of the number of individuals of dinoflagellates and diatoms found in phytoplankton samples in CBNMS. Phytoplankton samples collected during ACCESS cruises and analyzed by California Department of Public Health Biotoxin Monitoring Program. Note: data from stations N4-WN and N2-WN (nearshore), 4-E and 2-E (mid-shelf), and 4-W and 2-W (offshore) were used in these figures. No samples were collected nearshore in May 2011 or mid-shelf and offshore in June 2014. Figure: Point Blue Conservation Science.

Commented [14]: We think adding error bars is not appropriate for this figure based on the calculations made, but will need to clarify after Meredith returns from vacation 11/12. We may want to add one sentence to the caption to clarify this after discussing with her.

Commented [15]: Similar comment from other figures about error bars, reason for trend line, quantitative description.

Question 6 Literature Cited

Bode, A., Botas, J.A., & Fernandez, E. (1997). Nitrate storage by phytoplankton in a coastal upwelling environment. *Marine Biology*, *129*, 399-406. https://doi.org/10.1007/s002270050180

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Question 7: Do sanctuary waters pose risks to human health and how are they changing?

Status: Good/Fair (high confidence)
Trend: Worsening (low confidence)
Status Description: One or more water quality indicators suggest the potential for human health impacts but human health impacts have not been reported.
Rationale: Phytoplankton species that produce harmful algal blooms (HAB) and biotoxins were present in CBNMS during the 2010 to 2019 time period. A HAB event occurred in 2015 that was unprecedented in scope and impact. California sea lions and coastal bivalves, which were used as proxies for environmental biotoxins, indicated toxins were present throughout the region and appear to be worsening over time. Biotoxins were monitored in Dungeness and Rock crabs by CDPH, and levels often triggered fishery closures, which likely prevented human health impacts. The low confidence in the trend was due to the limited data available in HAB levels throughout the time period.

Findings from the 2009 Condition Report
In 2009, this question was rated good with a not changing trend (see Table S.WQ.6.1). Samples of phytoplankton species that were known to produce biotoxins were monitored in the sanctuary and showed no signs of elevated levels. Additionally, there were no known cases of shellfish poisoning reported to the California Department of Public Health (CDPH). Consequently, the good rating was based on the lack of any indications that CBNMS waters posed a risk to human health.

New Information in the 20__ Condition Report
The new rating for this question is good/fair with a worsening trend. The basis for this rating was that phytoplankton species that produce biotoxins, as well as the biotoxins themselves, were documented in the sanctuary during the study period (Table S.WQ.7.1). Additionally, harmful algal blooms occurred during the study period, including an event in 2015 that was

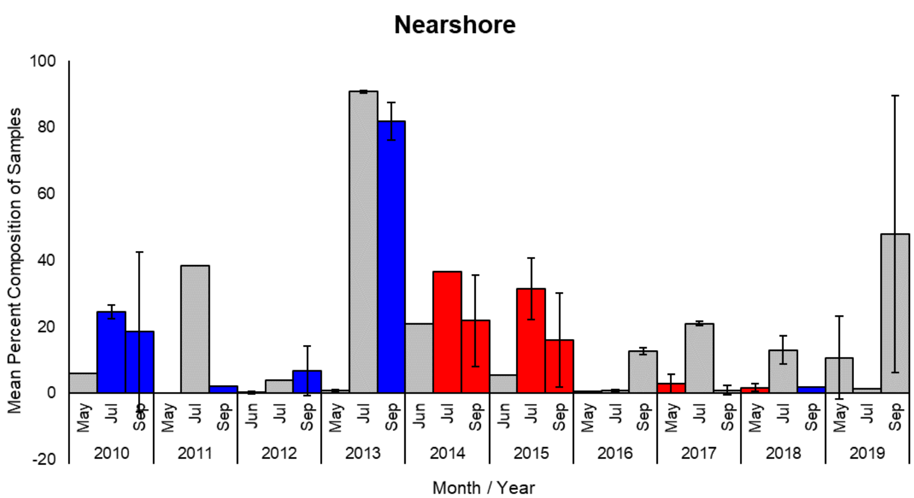
unprecedented in scope and impact. Domoic acid (DA) in crabs and bivalves also indicated biotoxins were present in the environment and DA toxicosis in California sea lions appear to be worsening over time. These data indicate that there is the potential for human health to be negatively affected by the water quality of the sanctuary. However, CDPH and Central and Northern California Ocean Observing System (CeNCOOS) closely monitor these biotoxins and blooms, and fisheries closures likely prevented people from ingesting toxic seafood. As a result, there were no known cases of shellfish poisoning in humans during this time.

Table S.WQ.7.1. Status and trends for individual indicators discussed at the March 24, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
HAB producing phytoplankton	ACCESS/Point Blue	Pelagic	Status: HAB producing species are present, higher in warmer years Trend: no strong trend	Figure S.WQ.7.1, Table App.E.7.1
DA and *Pseudo-nitzschia*	McCabe et al., 2016	Pelagic	Status: Elevated levels of DA and *Pseudo-nitzschia* during marine heatwave Trend: no trend	Figure S.WQ.7.2
Crabs - DA	CDPH/CBNMS	Benthic	Status: At least 1 positive DA sample in crabs each year of sampling Trend: Higher levels in 2015-2016	Figure S.WQ.7.3
Crab fishery closures	McCabe et al., 2016/McCabe et al., 2016 and CDFW, CDPH, and Pacific States Marine Fisheries Council/Chris Free	Benthic	Status: DA caused delays and closures during reporting period Trend: 2016-2017, 2019 DA delays	Figure S.WQ.7.4, Figure S.WQ.7.5
Sea lions - DA	The Marine Mammal Center/The Marine Mammal Center and McCabe et al., 2016/McCabe et al., 2016	Pelagic	Status: Sea lions with DA recorded in region since 1998 and high levels during the marine heatwave Trend: Higher levels now than previous reporting period	Table App.E.7.2, Figure S.WQ.7.4
Bivalve - DA	CDPH/CBNMS	Coastal	Status: variable, peak during heatwave Trend: no trend	Figure App.E.7.1
Bivalve - Paralytic Shellfish Poisoning	CDPH/CBNMS	Coastal	Status: variable Trend: no trend	Figure App.E.7.2

HAB phytoplankton species and biotoxins

Phytoplankton species that can cause HABs (see Table App.E.7.1 for a full list of species) were measured in the CBNMS water column during ACCESS cruises from 2010 to 2019 (Figure S.WQ.7.1). Note not all of the HAB species identified produce biotoxins but some species could be harmful in other ways (e.g., mechanical clogging of gills). While these are not direct measurements of biotoxins in the water column, changes in the presence, abundances and/or distributions of certain species could indicate a potential risk of certain biotoxins being present in the sanctuary (e.g., two of the main HAB species and biotoxins found locally: *Pseudo-nitzschia* spp. and domoic acid or *Alexandrium* sp. and paralytic shellfish poisoning toxins). Some of these species have been prevalent in CBNMS and the surrounding region throughout the 2010 to 2019 time period, although there is no clear long term trend. The average percent composition of HAB species in samples ranged from 0 to 65%, with the highest occurring in 2013 and 2019. Note some HAB species (e.g., *Pseudo-nitzschia* spp.) produce high biotoxin levels only when found in high abundances, while others (e.g., *Alexandrium* sp.) can still produce high biotoxin levels when found in relatively low abundances. Concentrations of *Pseudo-nitzschia australis* and water column particulate (pDA) were also measured along the west coast, including the sanctuary, during a NOAA cruise from June to September of 2015 (Figure S.WQ.7.2). Both *P. australis* and pDA had elevated concentrations (Figure S.WQ.7.2), although measurements at stations located in the sanctuary were relatively low compared to other areas (In CBNMS *P. australis* abundances ranged between 0 and 107000 cells/L and pDA ranged between 73 and 76.3 ng/L). The 2015 HAB event was the largest domoic acid event off the west coast of North America (McCabe et al., 2016), and a marked change from the previous condition report time period. This event was likely caused by warm and nutrient-poor waters associated with the marine heat wave (Bond et al., 2015).



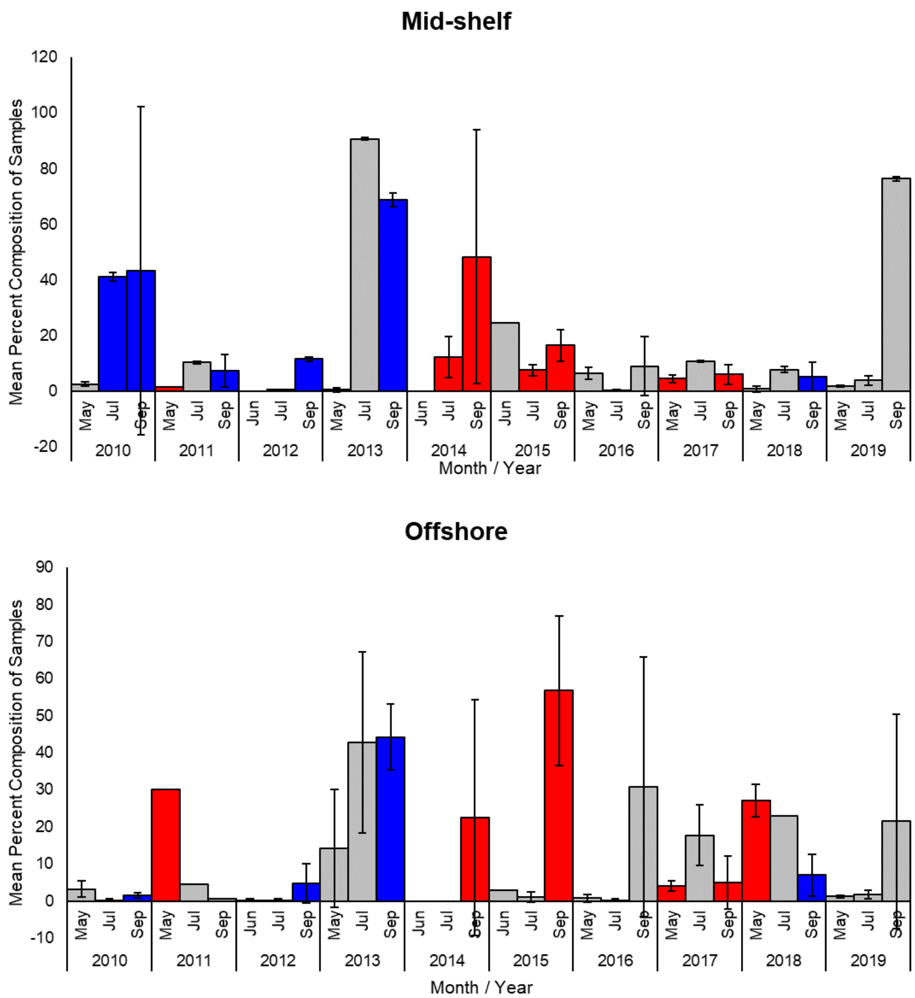


Figure S.WQ.7.1. Average percent composition of plankton species (mean +/- standard deviation) that can produce HABs (see Table App.E.7.1 for a species list) in phytoplankton samples taken during ACCESS cruises from 2010 to 2019 from stations in CBNMS. Red bars represent warm years (above +0.5°C annual temperature anomaly), blue bars represent cold years (below -0.5°C annual temperature anomaly), and gray bars represent normal years (within +/-0.5°C of long-term average) calculated from CTD data collected on ACCESS. Figure: Point Blue Conservation Science.

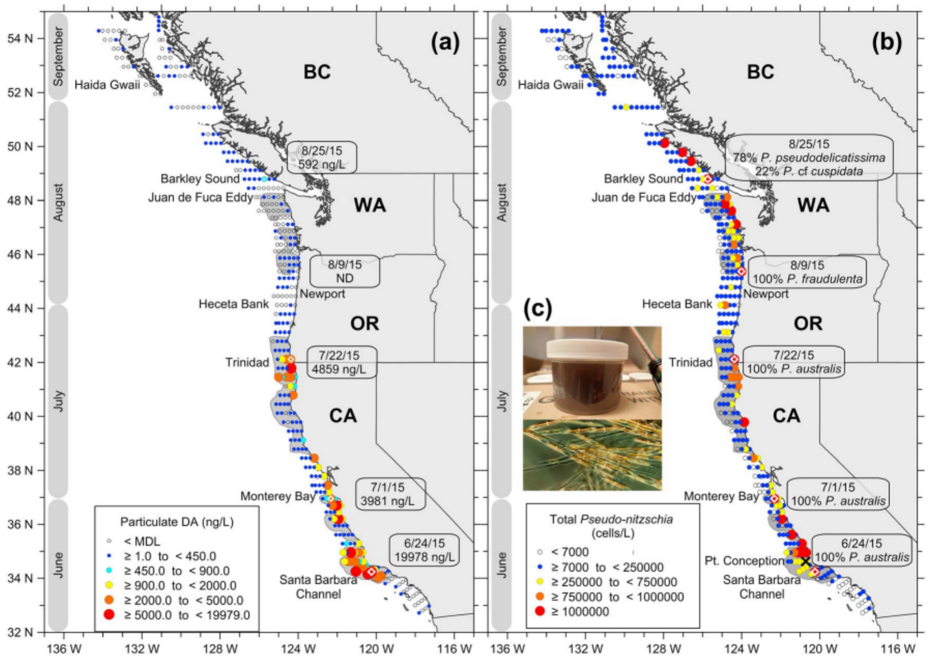


Figure S.WQ.7.2. (a) Particulate DA and (b) *Pseudo-nitzschia* abundance in surface (3m) seawater samples collected aboard the NOAA Ship *Bell M. Shimada* from June through September (months shown in shaded boxes, left side of both panels). Red "targets" in (b) are locations where representative pDA and *Pseudo-nitzschia* abundances are shown on select dates in adjacent boxes. Gray shading along the coast indicates regions where *Pseudo-nitzschia* was the dominant phytoplankton. (c) A Bongo net tow sample off Point Conception on 24 June (concentrated sample, top panel; microscopic image of ~100X diluted sample at 200X magnification, bottom panel). ND = not detected. Figure: McCabe et al., 2016.

<u>Biotoxins and fisheries</u>

For CBNMS, human health would most likely be affected through the consumption of contaminated crabs. Dungeness and rock crabs are recreationally and commercially fished from the sanctuary and the surrounding region, and the CDPH Food and Drug Branch closely monitors DA levels (Figure S.WQ.7.3). Since 2015, crabs have been collected offshore between San Francisco and Point Arena, CA (exact locations are unknown, but at least some samples were likely from CBNMS) and tested annually prior to the opening of the fisheries. DA levels in crabs have exceeded the action limit of 30 ppm at least once every year, with the highest levels occurring in 2015 and 2016. Consequently, human consumption of contaminated seafood could have posed a serious risk to human health, however management action prevented such impacts. Based on data compiled from CDFW, CDPH, and Pacific States Marine Fisheries Council (PSMFC), public health advisories were issued in 2015, and fishery openings were delayed or closed in multiple locations along the west coast (Figure S.WQ.7.4) including the CBNMS region (Figure S.WQ.7.5) These management actions greatly reduced risks of shellfish poisoning in humans.

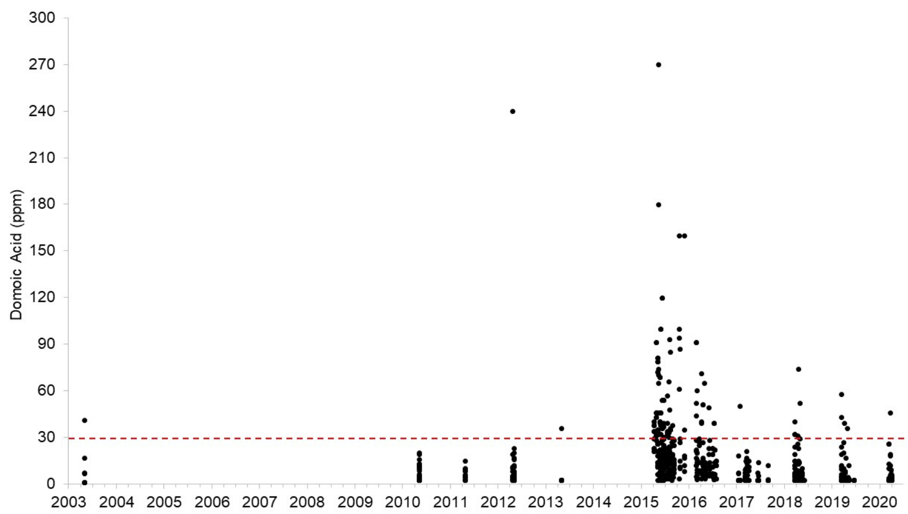
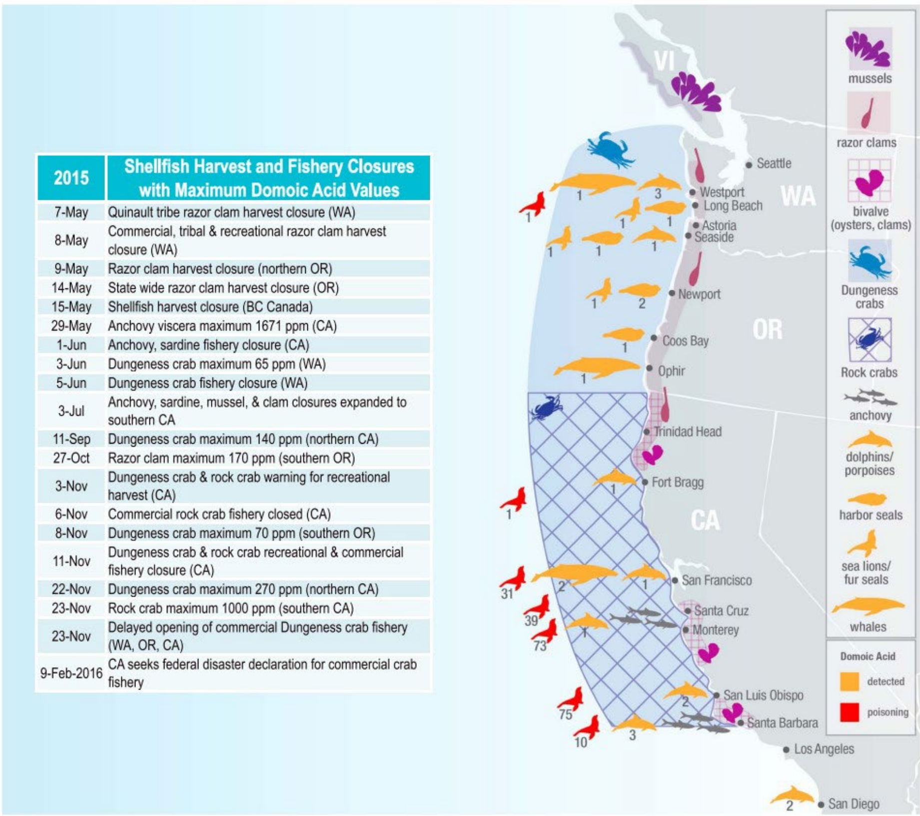


Figure S.WQ.7.3. Domoic acid in Dungeness and Rock crabs from Point Arena to San Francisco, CA. Regular sampling began in 2015 with some sampling occurring prior to that. Dotted red line indicates action limit for crab viscera (30ppm). Data: California Department of Public Health



2015	Shellfish Harvest and Fishery Closures with Maximum Domoic Acid Values
7-May	Quinault tribe razor clam harvest closure (WA)
8-May	Commercial, tribal & recreational razor clam harvest closure (WA)
9-May	Razor clam harvest closure (northern OR)
14-May	State wide razor clam harvest closure (OR)
15-May	Shellfish harvest closure (BC Canada)
29-May	Anchovy viscera maximum 1671 ppm (CA)
1-Jun	Anchovy, sardine fishery closure (CA)
3-Jun	Dungeness crab maximum 65 ppm (WA)
5-Jun	Dungeness crab fishery closure (WA)
3-Jul	Anchovy, sardine, mussel, & clam closures expanded to southern CA
11-Sep	Dungeness crab maximum 140 ppm (northern CA)
27-Oct	Razor clam maximum 170 ppm (southern OR)
3-Nov	Dungeness crab & rock crab warning for recreational harvest (CA)
6-Nov	Commercial rock crab fishery closed (CA)
8-Nov	Dungeness crab maximum 70 ppm (southern OR)
11-Nov	Dungeness crab & rock crab recreational & commercial fishery closure (CA)
22-Nov	Dungeness crab maximum 270 ppm (northern CA)
23-Nov	Rock crab maximum 1000 ppm (southern CA)
23-Nov	Delayed opening of commercial Dungeness crab fishery (WA, OR, CA)
9-Feb-2016	CA seeks federal disaster declaration for commercial crab fishery

Figure S.WQ.7.4. Impacts of domoic acid (DA) on fisheries and marine mammals in 2015. Shaded areas with shellfish symbols on land denote shellfish closures. Fish symbols indicate northern anchovy closures at designated landing sites. Shaded or hatched areas offshore (Dungeness crab and rock crab) correspond to the closures listed on the left. Stranded marine mammals with detectable DA (orange) and California sea lions diagnosed with DA poisoning (red) are pictured with the number of individuals indicated. DA poisoning is defined as the presentation of at least two of the following: neurologic signs (seizures, head weaving, ataxia), detectable DA, histopathologic lesions, and/or blood chemistry changes. Figure: McCabe et al., 2016.

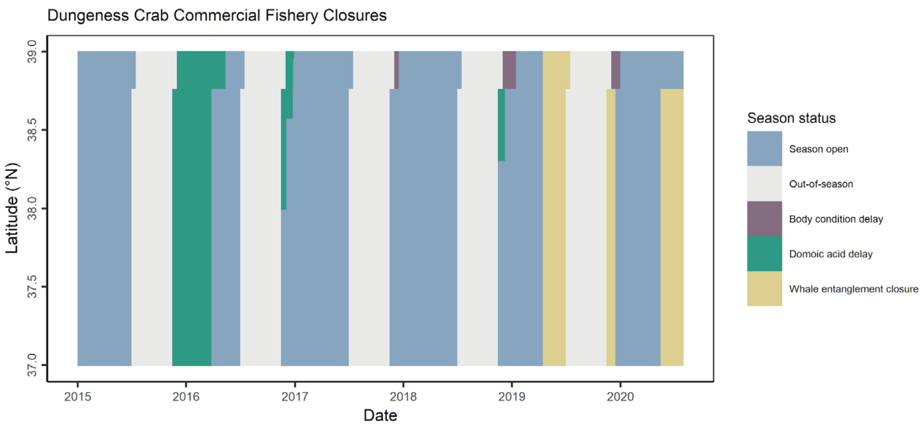


Figure S.WQ.7.5. Fishery delays in the Dungeness crab commercial fishery closures by reason. Data sources: CDFW, CDPH, and Pacific States Marine Fisheries Council (PSMFC). Figure: Chris Free, University of California, Santa Barbara.

Regional biotoxins measured by environmental proxies

Some marine organisms, such as California sea lions and bivalves, can serve as proxies for measurements of environmental biotoxins, as these animals can be impacted by directly or indirectly consuming biotoxins. California sea lions become poisoned with DA after ingesting contaminated prey items, such as anchovies, and are good indicators of the severity of blooms (McCabe et al., 2016; Bejarano et al., 2008). Since 1998, California sea lions have shown signs of DA intoxication and/or tested positive for DA at nearshore sites adjacent to the sanctuary (between San Mateo to Mendocino counties, including San Francisco Bay; see Table App.E.7.2). While no tested animals can be directly linked to CBNMS, their health may reflect DA toxicity in the greater sanctuary region. The highest number of stranded animals occurred in 2009 (41 sea lions) and the lowest number was in 1998 (2 sea lions). The 2015 DA event resulted in high numbers of California sea lions, as well as other marine mammal species, with detectable DA levels and/or DA poisoning throughout the west coast (Figure S.WQ.7.5, McCabe et al., 2016). Overall, there were higher numbers of stranded sea lions from 2009 to 2020 (mean of 15.5 ± 12.0 (SD)) than 1998 to 2008 (mean of 9.7 ± 6.1 (SD)), suggesting that this trend could be worsening.

Consuming contaminated bivalves can cause shellfish poisoning in humans. However, because bivalves from CBNMS are not sampled, those from other locations serve as proxies for environmental biotoxins in the general sanctuary region. The CDPH Environmental Management Branch closely monitors coastal bivalves for DA and a suite of neurotoxins responsible for Paralytic Shellfish Poisoning (PSP). Biotoxin levels exceeding the action limit (set by the Food and Drug Administration) can result in the issuance of health advisories, or a delayed or closed fishery (See Figures App.E.7.1–2). All DA measurements taken since the program began in 1991 were below the action limit (20 ppm), and the maximum measured DA levels coincided with the marine heat wave of 2015. DA was therefore unlikely to have posed a risk to human health in the CBNMS region. By comparison, PSP levels in bivalves have often exceeded the action limit (80 ug/100g), with levels varying between 25 and 10,000 ug/100g. The presence and pervasiveness of PSP biotoxins in the region surrounding CBNMS throughout the time period could have posed a risk to human health if consumed.

Conclusion

HAB producing phytoplankton species and biotoxins were detected in sanctuary and regional waters, crabs, and proxy species from 2010 to 2019. Biotoxin levels in crabs frequently exceeded the action level and this could have been harmful to human health if not for protective mitigating measures. As a result, this question is rated good/fair and worsening and it is critical this issue continues to be monitored in the sanctuary, particularly as HABs are predicted to worsen under future climate change scenarios (Gobler, 2020). Additionally, further research is needed to document how biotoxins are transferred throughout the marine food web and to higher trophic levels.

Commented [16]: So this indicator is kind of tricky to me because it seems like it could be possible for the conditions to be deplorable but yet human health remain OK because of the closures and other mitigating measures. So the assessment could still be good, but that would seem a bit artificial since it's only good because of mitigation.

Commented [17]: We reviewed and determined this had been adequately addressed in the text. There is no change to the text in response to Kristy's comment.

FIGURES FOR APPENDIX (TO BE MOVED ONCE REPORT IS COMPILED)

Table App.E.7.1. Phytoplankton species from ACCESS cruise that can produce harmful algal blooms.

Alexandrium catenella
Alexandrium spp.
Cochlodinium spp.
Dinophysis acuminata
Dinophysis caudata
Dinophysis fortii
Dinophysis mitra
Dinophysis odiosa
Dinophysis rotundata
Dinophysis spp.

Dinophysis tripos
Gonyaulax spinifera
Gonyaulax spp.
Gonyaulax triacantha
Lingulodinium polyedrum
Prorocentrum gracile
Prorocentrum micans
Prorocentrum spp.
Protoperidinium bipes
Protoperidinium conicum
Protoperidinium divergens
Protoperidinium ovatulum
Protoperidinium ovum
Protoperidinium spp.
Pseudo-nitzschia spp.
Pseudo-nitzschia: delicatissima complex
Pseudo-nitzschia: seriata complex

Table App.E.7.2. Number of California Sea Lions admitted to The Marine Mammal Center with signs of and/or positive tests for Domoic Acid poisoning. The locations of these strandings ranged between San Mateo to Mendocino counties (including inside San Francisco Bay). Shaded boxes indicate years considered for this condition report.

Year	Sea lion
1998	2
1999	1
2000	12
2001	7
2002	7
2003	12
2004	5
2005	10
2006	22
2007	16
2008	13
2009	41
2010	6
2011	9
2012	4
2013	7
2014	12
2015	27
2016	12
2017	6
2018	10
2019	33
2020	20
Total	**294**

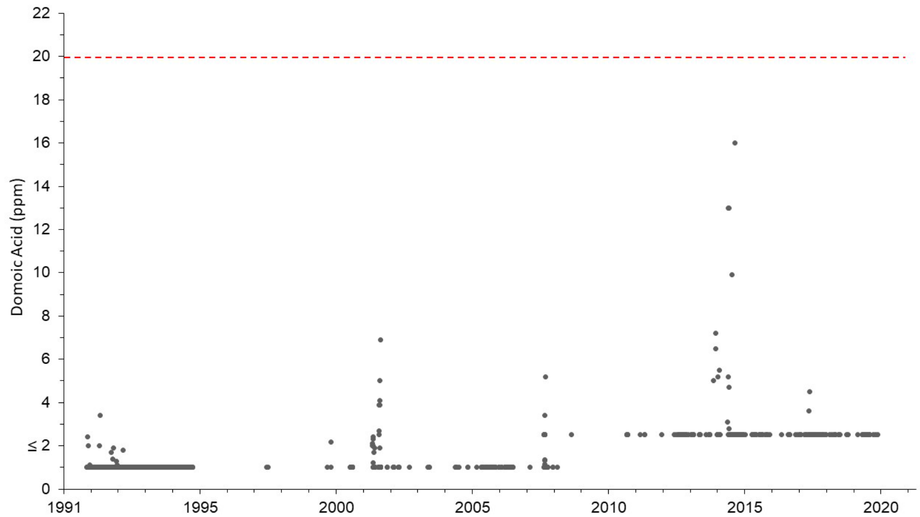


Figure App.E.7.1. Domoic acid in 1,694 bivalves (mussels, clams, oysters) taken coastally in Marin and Sonoma counties (including inside San Francisco Bay). Dashed red line indicates the action limit. Data provided by the California Department of Public Health, Environmental Management Branch. Note that there was a change in analytical techniques in 2008 that changed the lower reporting limit. No samples came from CBNMS.

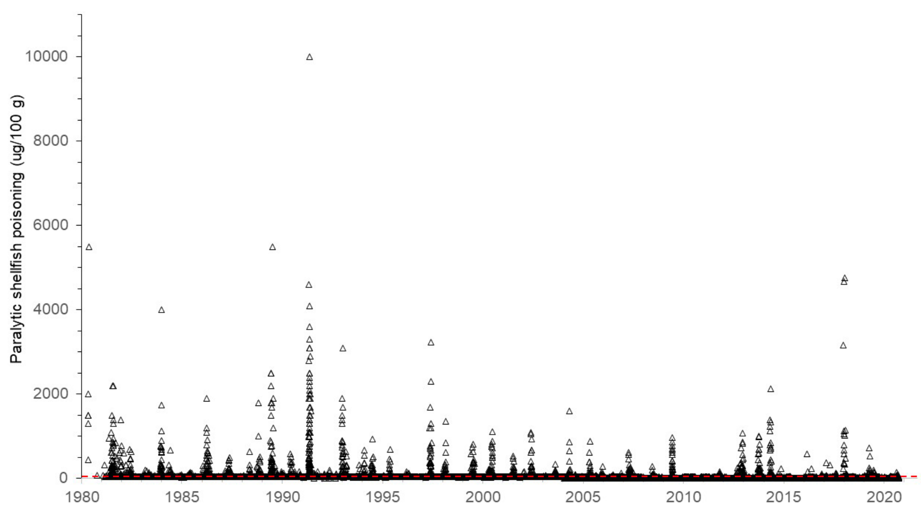


Figure App.E.7.2. Paralytic shellfish poisoning in 13,859 bivalves (mussels, clams, oysters) taken coastally in Marin and Sonoma counties (including inside San Francisco Bay). Dashed red line indicates the action limit. Data from California Department of Public Health, Environmental Management Branch. No samples came from CBNMS.

Question 7 Literature Cited

Bejarano, A., Gulland, F., Goldstein, T., St. Leger, J., Hunter, M., Schwacke, L., VanDolah, F., & Rowles, T. (2008). Demographics and spatio-temporal signature of the biotoxin domoic acid in California Sea Lion (*Zalophus californianus*) stranding records. *Marine Mammal Science, 24*(4), 899–912. https://doi.org/10.1111/j.1748-7692.2008.00224.x

Bond, N.A., Cronin, M.F., Freeland, H., & Mantua, N. (2015). Causes and impacts of the 2014 warm anomaly in the NE Pacific. *Geophysical Research Letters*, *42*(9), 3414–3420. https://doi.org/10.1002/2015GL063306

Gobler, C.J. (2020). Climate change and harmful algal blooms: Insights and perspective. *Harmful algae*, *91*, 101731. https://doi.org/10.1016/j.hal.2019.101731

McCabe, R.M., Hickey, B.M., Kudela, R. M., Lefebvre, K.A., Adams, N.G., Bill, B.D., Gulland, F.M.D., Thomson, R.E., Cochlan, W.P., & Trainer, V.L. (2016). An unprecedented coastwide toxic algal bloom linked to anomalous ocean conditions. *Geophysical Research Letters*, *43*(19), 10366–10376. https://doi.org/10.1002/2016GL070023

Question 8 (Water/Climate Change): Have recent, accelerated changes in climate altered water conditions and how are they changing?

Status: Fair (high confidence)
Trend: Worsening (low confidence)
Status Description: Climate-related changes have caused measurable but not severe degradation in some attributes of ecological integrity.
Rationale: Climate-related changes in some water quality indicators have been observed. Notably, a marine heatwave in 2014–2016, during the time period for this assessment, resulted in the highest sea surface temperature (SST) on record for the area. This marine heatwave was present for an extended duration, with modeling showing the heat extending into the water column to at least 100 meters. In addition, during the assessment period both the warmest and coolest conditions were recorded, indicating high variability in the system. Periods of anomalous conditions, both warm and cool, appear to be more extreme and longer in duration than in the past. Increased variability is one potential outcome of climate change and can be indicative of a worsening condition. Localized upwelling appears to buffer CBNMS at times from anomalous heating events observed in the surrounding region. Periodic occurrences of low pH water and low dissolved oxygen levels extend onto the bank and shelf at times during the year, but trend data are not available. These climate-related changes are notable because they have been linked to changes in some ecosystem components, including abundance and distribution of

pelagic prey and predator species, condition of krill, and the presence and intensity of harmful algal blooms and domoic acid. The low confidence in the trend was due to low agreement among the experts in how to interpret the high variability in the data and the lack of evidence of a clear trend during the time period that was evaluated.

Findings from the 2009 Condition Report

A direct comparison between this assessment and the 2009 condition report is not possible because this specific question was not included in the 2009 report. In 2009, a question was included for water quality that asked, "Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality and how are they changing?" The narrative to this question stated, "Stressors on water quality from changing oceanographic and atmospheric conditions are currently not producing long-term negative effects." Other factors that were considered for this question in 2009 included El Niño events, flooding, and debris flow. The rating for this question was good and the trend was undetermined due to a paucity of data (see Table S.WQ.6.1).

New Information in the 20__ Condition Report

Cordell Bank National Marine Sanctuary is within the California Current Ecosystem, a dynamic system driven by upwelling. Upwelling brings cold, nutrient rich waters to the surface, resulting in high productivity, and high variability in the system occurs as conditions transition between upwelling and relaxation states. The prominent coastline feature of Point Reyes, influence of strong upwelling from the Point Arena region, together with the features of Cordell Bank and Bodega Canyon, cause the sanctuary to experience a range of currents and oceanographic conditions. Changes in the magnitude, periodicity, and synchronicity of these processes could make resident and transient sanctuary resources, which are highly adapted to this dynamic system, particularly vulnerable to climate altered conditions. For this question, ocean indices, timing of upwelling, ocean temperature, dissolved oxygen, ocean acidification, and marine heatwaves were considered (Table S.WQ.8.1).

Table S.WQ.8.1. Status and trends for individual indicators discussed at the March 26, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Oceanic Nino Index	University Corporation for Atmospheric Research/Point Blue	pelagic	Status: Cold and warm phases during reporting period Trend: Recent trend to warmer conditions	Figure App.X.8.1
Pacific Decadal oscillation	Joint Institute for the Study of Atmosphere and Oceans/Point Blue	pelagic	Status: Warm and cold phases during reporting period Trend: Recent trend to warmer conditions	Figure App.X.8.2

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North Pacific Gyre Oscillation	Di Lorenzo et al et a., 2016/Point Blue	pelagic	Status: High and low productivity phases during reporting period Trend: Recent trend to warmer conditions	Figure App.X.8.3
Upwelling index - CUTI	NOAA/Point Blue	pelagic	Status: Upwelling dominated area Trend: No trend	Figure App.X.8.4; App.X.8.5
Upwelling index - BEUTI	NOAA/Point Blue	pelagic	Status: Strong nutrient upwelling Trend: Slight decline, no long term trend	Figure App.X.8.6; App.X.8.7
Timing of upwelling	Point Blue/Point Blue	pelagic	Status: Variability in timing of upwelling Trend: No trend	Figure App.X.8.8; App.X.8.9
SST - satellite-regional	NOAA/CeNCOOS	pelagic	Status: Patterns similar across CB, GF, MB Trend: Recent warm years	Figure S.WQ.8.2
SST - satellite - CBNMS	NOAA/Point Blue	pelagic	Status: Typical seasonal variability with peaks in 2014-2015 Trend: Increasingly warm years	Figure App.X.8.10
SST - buoy	NOAA/Point Blue	pelagic	Status: Warm and cold anomalies since 2009 Trend: Recent warm years	Figure S.WQ.8.1
Temperature at depth	BML,CBNMS/BML	pelagic	Status: Seasonal pattern, warmer in winter Trend: No long term trend	Figure App.X.8.11
Heat Content	UCSC ROMS/CeNCOOS	pelagic	Status: Water column warming is evident Trend: Unknown	Figure S.WQ.3
Marine heatwaves	NOAA/NOAA	pelagic	Status: Strong recent heatwaves Trend: Unknown	Figure S.WQ.4
OA - regional	Feely et al., 2016	pelagic	Status: Low aragonite conditions are more severe here than in some other places along the coast Trend: Undetermined	Figure App.X.8.13
OA - local	ACCESS/Point Blue	pelagic	Status: Low aragonite conditions are present at times Trend: No trend	Figure S.WQ.5

OA impacts	ACCESS/Point Blue	pelagic	Status: Fewer juv krill and pteropods in low aragonite conditions Trend: No data	Figure App.X.8.14; App.X.8.15
DO - mooring	BML, CBNMS/BML	benthic	Status: Low DO conditions at times Trend: No trend	Figure App.X.8.16
DO - CTD casts	ACCESS/Point Blue	pelagic	Status: Low DO conditions at times Trend: No trend	Figure App.X.8.17
DO - deep habitat	CBNMS/CBNMS	benthic	Status: Oxygen is low in this habitat Trend: No data	Figure App.X.8.18

The sanctuary waters are influenced by both large-scale and local conditions. The basin level indicators considered for this assessment included Oceanic Nino Index (ONI) (Figure App.E.8.1), Pacific Decadal Oscillation (PDO) (Figure App.E.8.2), and North Pacific Gyre Oscillation (NPGO) (Figure App.E.8.3).The ONI and the PDO indices, although different, are associated with warm and cold water conditions off California, which result in low and high productivity respectively. Over the study period there were both warm and cold, and high and low productivity phases in all indices, indicating variability in the system. Examining the time period back several decades beyond the study period, a long-term trend in more frequent or more extreme phases was not evident. The oceanographic system off the U.S. west coast is highly driven by upwelling. In recent decades, increases in alongshore winds have resulted in a rise in upwelling duration and intensity (Garcia-Reyes & Largier, 2010). During the study period, the west coast-wide or regional indices for upwelling show that there is clear seasonality and high variability in strength and timing of upwelling, but a long-term trend in the indices values or timing of upwelling is not evident (Figures App.E.8.4 - App.E.8.9).

Sea surface temperature data from multiple sources and scales, including NOAA satellite and buoy data, indicate that there have been both cold and warm conditions since 2009, with a trend towards warmer temperatures in the second half of the assessment period. The satellite data allow for a comparison across a region while the NOAA buoy 46013, which is located within CBNMS, provides a local measurement. Both satellite (AVHRR) and buoy data (NOAA Buoy 46013) located in CBNMS, show peaks during the coastwide marine heatwave from 2014-2016 (NOAA 2021b; Elliott et al., 2020) (Figure S.WQ.81, Figure S.WQ.8.2, Figure App.E.8.10). Using the buoy measurements, an analysis of anomalies show that during the first half of the assessment period, cold water anomalies dominated, but there was a clear change in 2014-2015 when the marine heatwave was present (Elliott et al., 2020). Since 2016, warm anomalies have dominated (Elliott et al., 2020). The satellite data can be used to compare CBNMS to a larger region, including GFNMS and MBNMS, which have patterns similar to CBNMS, indicating large scale drivers in SST (NOAA 2021b).

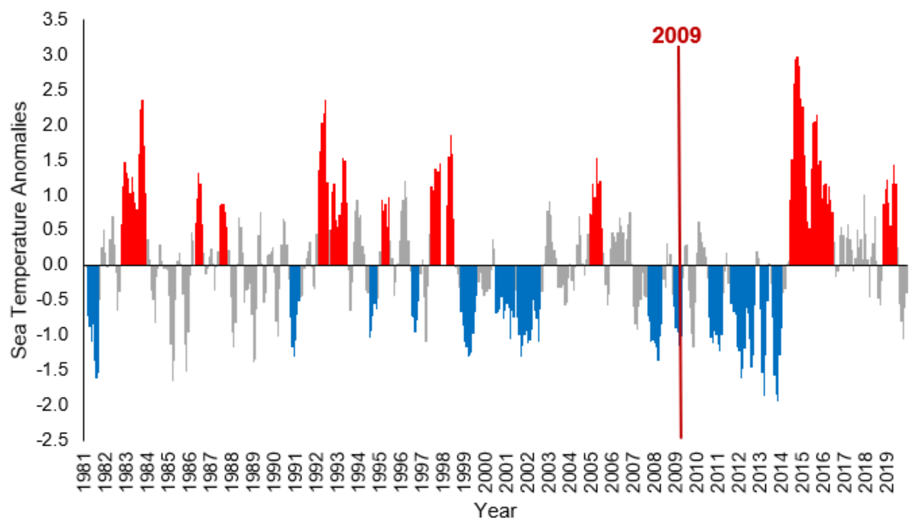

Figure S.WQ.8.1. Persistent sea surface temperature anomalies, NOAA Bodega Bay buoy (46013), 1981-2019. Bars represent the three-month means subtracted by the monthly long-term mean. Red bars represent warm periods (i.e., +0.5ºC for 5 months in a row), and blue bars represent cold periods (i.e., -0.5ºC for 5 months in a row). Data source: NOAA. Data Visualization: Point Blue Conservation Science.

Figure S.WQ.8.2. Monthly SST measured from the AVHRR remote sensing, displayed for CBNMS, GFNMS, and MBNMS. Source: Advanced Very High Resolution Radiometer data are collected by the NOAA Polar-orbiting Operational Environmental Spacecraft and analyzed by Central and Northern California Coastal Observing System

In addition to assessing SST, temperature at depth measured on a mooring at 80 meters depth on Cordell Bank shows a seasonal pattern with warmest temperatures in the winter (UC Davis Bodega Marine Laboratory and CBNMS unpublished data, 2021) (Figure App.E.8.11). At the time of this report, a summary was available for only two years of data, so a trend analysis is not informative. Modeled data for heat content of the top 100 meters for the sanctuary area from the University of California Santa Cruz Regional Ocean Modeling System, analyzed by Central and Northern California Coastal Ocean Observing System, indicates seasonal fluctuations and warming through the water column, but no long-term trend (Moore et al., 2013) (Figure S.WQ.8.3). There are peaks in 2015-2016 from the marine heatwave, and a smaller peak in 2019.

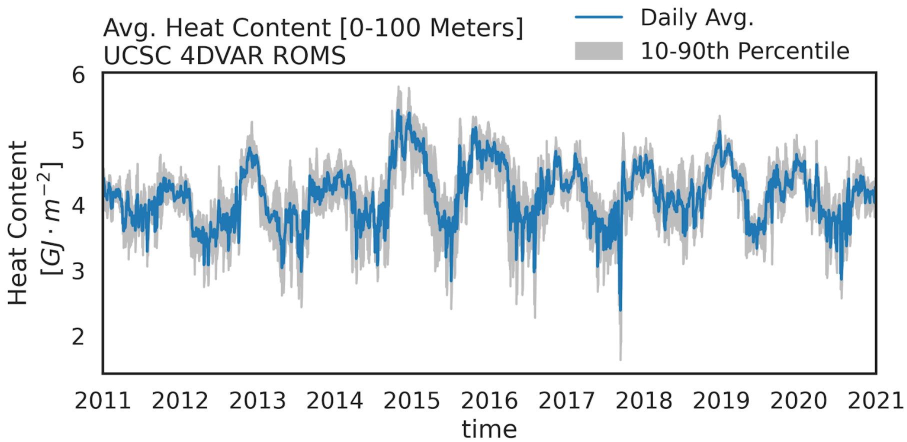

Figure S.WQ.8.3. Daily average (spatial mean) heat content up to 100 meters depth in CBNMS with 10th to 90th percentile range shown in the gray shading. Source: Central and Northern California Coastal Observing System.

In 2014 a marine heatwave that formed in the Gulf of Alaska extended to the entire west coast and was present into 2016 (Bond, et al., 2015; Di Lorenzo & Mantua, 2016; Gentemann et al., 2017). The heatwave had numerous impacts to biological species and distributions (Cavole et al, 2016, Lonhart et al., 2019, Sanford et al., 2019, Santora et al., 2020). Analysis of coast-wide conditions show that temperatures were above normal for extended periods (NOAA, 2021c). These conditions were detected in the sanctuary on moored instruments and in at-sea monitoring data (Elliott et al., 2020, UC Davis, BML & CBNMS 2021). Analysis of satellite imagery shows that at times, during the 2014 – 2015 period, the entire sanctuary was in a marine heatwave status, that the heatwave was intense, and that this was a part of a large heatwave feature and not a localized event (NOAA, 2021d) (Figure S.WQ.8.4). Looking back several decades to 1982, other warming events were present but they were El Niño driven and the mechanism and timing of these events differ from the 2014-2015 marine heatwave (NOAA, 2021c). Analysis of the spatial resolution of the heatwave indicates that CBNMS may benefit from local upwelling in mediating some impacts of major marine heatwaves (NOAA, 2021d). During some periods when there was a large and intense heatwave feature in the region, CBNMS experienced some cooler temperatures (NOAA, 2021d) (Figure App.E.8.12). This may be a result of the strong upwelling in the region in combination with the coastal geography of Point Reyes which can funnel water offshore.

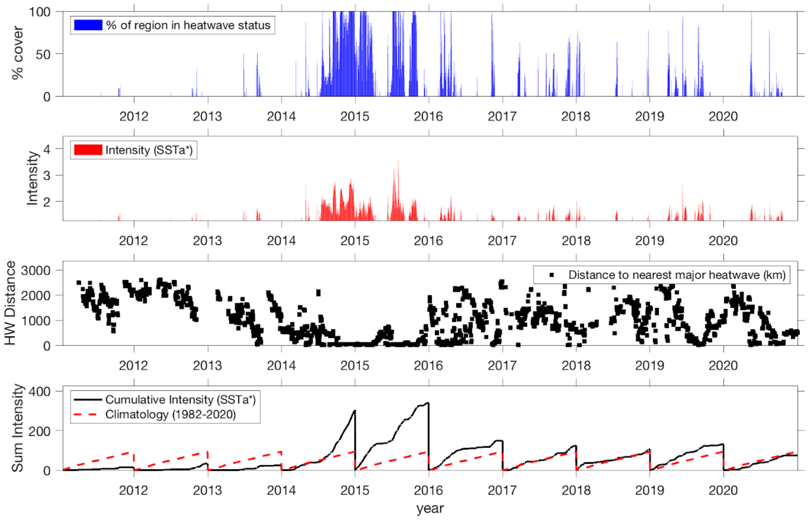

Figure S.WQ.8.4. Top panel – Percent of the area in heatwave status, 2nd panel – Average SST anomaly standardized for all pixels in the area, 3rd panel – Distance from the center of the area to the nearest major heatwave feature, bottom panel – the cumulative intensity summed over time at each pixel for a year (NOAA, 2021c)

The west coast is highly vulnerable to ocean acidification because the variability created by seasonal upwelling conditions in combination with anthropogenic CO2 accumulation exacerbates OA conditions (Feely et al., 2008; Feely et al., 2016; Gruber et al., 2012;, Osborne et al., 2020). Aragonite saturation has been calculated from measured pH and total alkalinity data regularly in the sanctuary since 2010 during Applied California Current Ecosystem Studies (ACCESS) at-sea surveys that occur three to four times a year at repeated sampling stations throughout CBNMS. ACCESS data indicate that there are low aragonite conditions in the sanctuary, particularly at stations beyond the shelf break in deeper water. In the spring, mixing prevents shoaling of the aragonite saturation horizon to shallower waters, but later in the year stratification is more prevalent (Elliott et al., 2020) (Figure S.WQ.8.5). Ocean acidification can affect the calcification, growth, behavior, and survival of marine organisms (Cooper et al., 2017, Fabry et al., 2008, Miller et al., 2016). Analysis of plankton samples co-located with these ACCESS oceanographic data show that there are lower counts of juvenile krill and Limacina pteropods when lower aragonite saturation conditions are present, although the causality cannot be determined (App.E.8.14, App.E.8.15).

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There are less frequent, but broader scale surveys conducted by NOAA for ocean acidification that include sampling in CBNMS at depths similar to the sampling of the local surveys, which allow for comparison to the larger region. These surveys show that the area around Point Reyes, including CBNMS, can be an area of low aragonite saturation, along with the Pacific Northwest, compared to other areas along the coast (Feely et al., 2016). As such, calcifying organisms in the sanctuary are experiencing stressful conditions compared to other areas, which may worsen in the future.

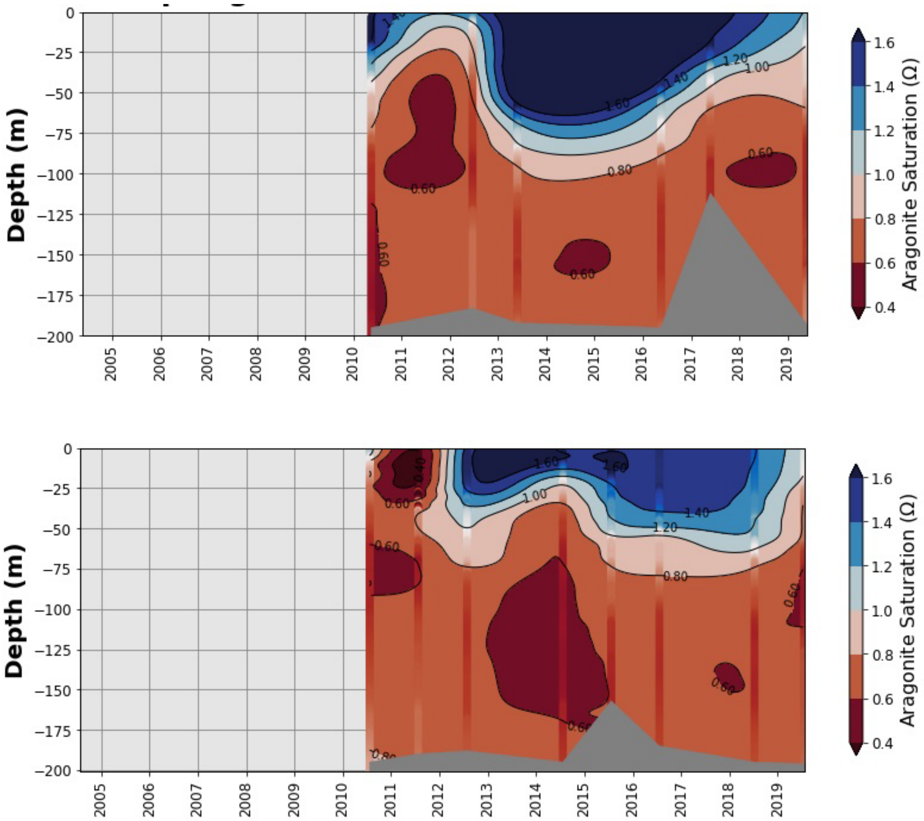


Figure S.WQ.8.5. Aragonite saturation values with depth, stations 2-W (west of Cordell Bank), spring (top) and summer cruises (bottom), years 2010-2019. Data Source: ACCESS, Data Visualization: Point Blue Conservation Science.

Along the California coast, low oxygen levels have been observed and the low oxygen zone has increased (Chan et al., 2017, Keller et al, 2015). Locally, dissolved oxygen is measured at a buoy on Cordell Bank and during ACCESS at-sea sampling. The mooring measures dissolved oxygen, salinity, and temperature and has been deployed since 2014. Data from the mooring indicate that Cordell Bank occasionally experiences low dissolved oxygen levels(5 mg/L or below) for short periods. There is no evidence to date of severe hypoxia (Bodega Marine Lab/CBNMS unpublished data, 2021). At-sea monitoring from the ACCESS project indicates that levels of low oxygen are present in CBNMS, particularly in the deep offshore waters beyond the shelf break. Low oxygen can be seen in surface waters at times, but these conditions occur typically below 75 meters at the westernmost station sampled, located past the shelf break (Elliott et al., 2020). This has the potential to impact large areas of sanctuary habitat. Deep habitats in the sanctuary are naturally lower in oxygen (Table AppX.WQ.8.1, Figure AppX.WQ.17)

Conclusion
In 2021, the status of climate-altered water conditions was fair with a worsening trend. The evidence of climate-altered water conditions is much more evident in 2021 than in 2009, when the first CBNMS condition report was published. The availability of large-scale data, both modeled and observed, as well as local monitoring data provide a fairly robust assessment of the conditions and allow for high confidence in the status. However, the confidence in the worsening trend was low, largely due to the high variability in the system as well as the absence of long-term data or the inability to detect trends for most indicators. Increased variability is one potential outcome of climate change and can be indicative of a worsening condition.The 2014-2016 marine heatwave was an unprecedented event but heatwaves are occurring with greater frequency (Tanaka & Van Houtan, 2022). Continuing to monitor these oceanographic conditions in the coming years will be key to assessing the status and trend of the sanctuary.

Figures for appendix

Table AppX.WQ.8.1 Dissolved O2 average, min and max for ROV Hercules while surveying the seafloor.

Year	Dive	Site	Avg O2 (mg/L)	Min O2 (mg/L)	Max O2 (mg/L)	Min Depth (m)	Max Depth (m)
2017	H1625	BC I	2.14	1.57	2.71	1660	2207
2017	H1626	BC II	1	0.43	1.43	1205	1599
2017	H1627	Box	2.86	2.14	3.43	1976	2737
2017	H1628	SW CB I	0.43	0.29	0.57	1005	1126
2017	H1629	SW CB II	0.29	0.29	0.29	866	988
2017	H1630	BC III	0.43	0.14	0.71	744	1291

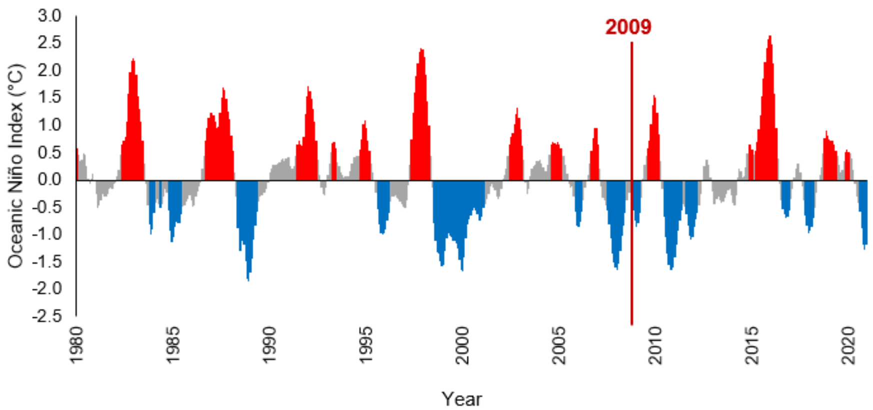


Figure App.E.8.1. Oceanic Niño Index (ONI), 1980-2020. ONI is a 3 month running mean of ERSST.v5 SST anomalies in the Niño 3.4 region (5°N-5°S, 120°-170°W. Red bars represent warm years (above +0.5°C annual temperature anomaly), blue bars represent cold years (below -0.5°C annual temperature anomaly), and gray bars represent normal years (within +/-0.5°C of long-term average). The vertical red line indicates the year of the last condition report (2009). Data source: NOAA, processed by Point Blue Conservation Science.

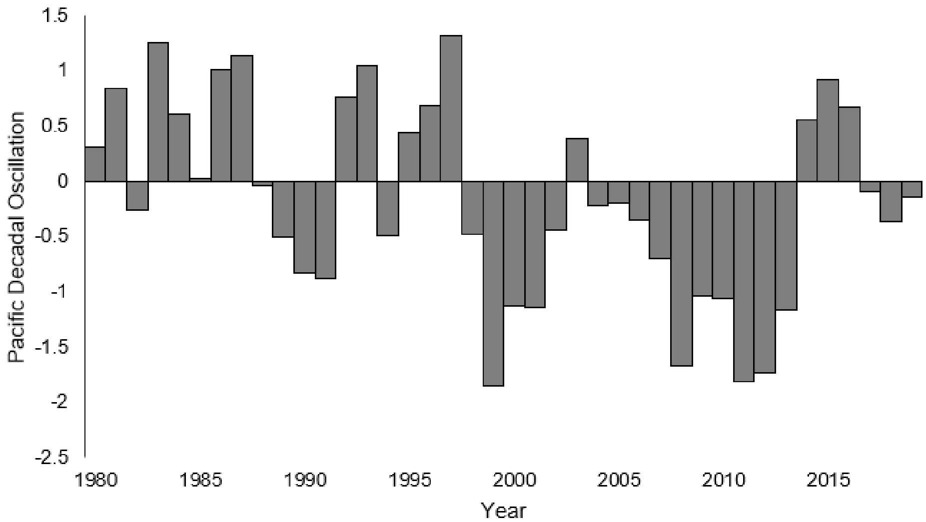


Figure App.E.8.2. Annual averages of the Pacific Decadal Oscillation (PDO), years 1980-2019. Line shows polynomial trend for 2009-2019. Data source NOAA, data visualization by Point Blue Conservation Science.

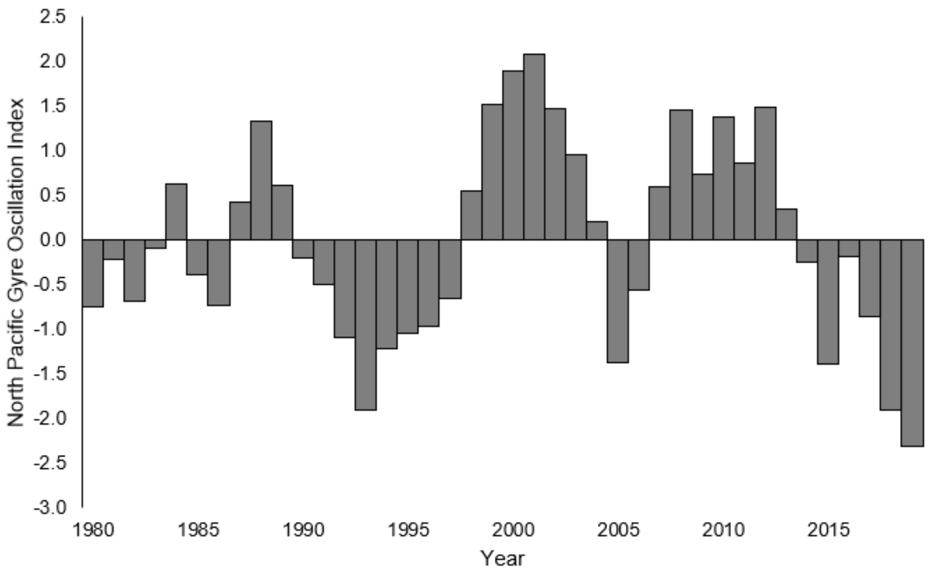


Figure App.E.8.3. Annual averages of the North Pacific Gyre Oscillation (NPGO), years 1980-2019. Line shows polynomial trend for 2009-2019. Data source Di Lorenzo et al., 2008, data visualization by Point Blue Conservation Science.

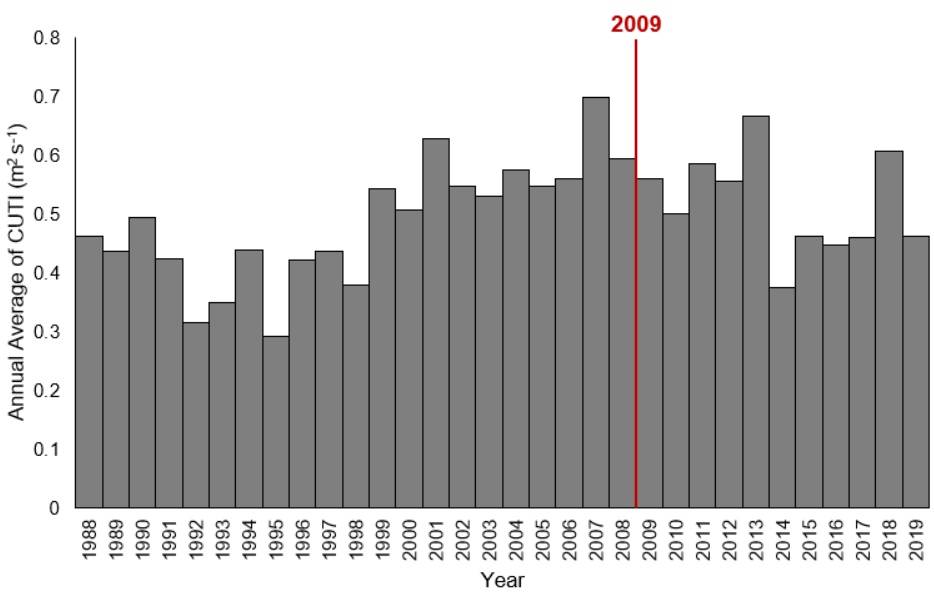


Figure App.E.8.4. Annual averages of the Coastal Upwelling Transport Index (CUTI), years 1988-2019. The vertical red line indicates the year of the last condition report (2009). Data source Jacox et al., 2018, data visualization by Point Blue Conservation Science.

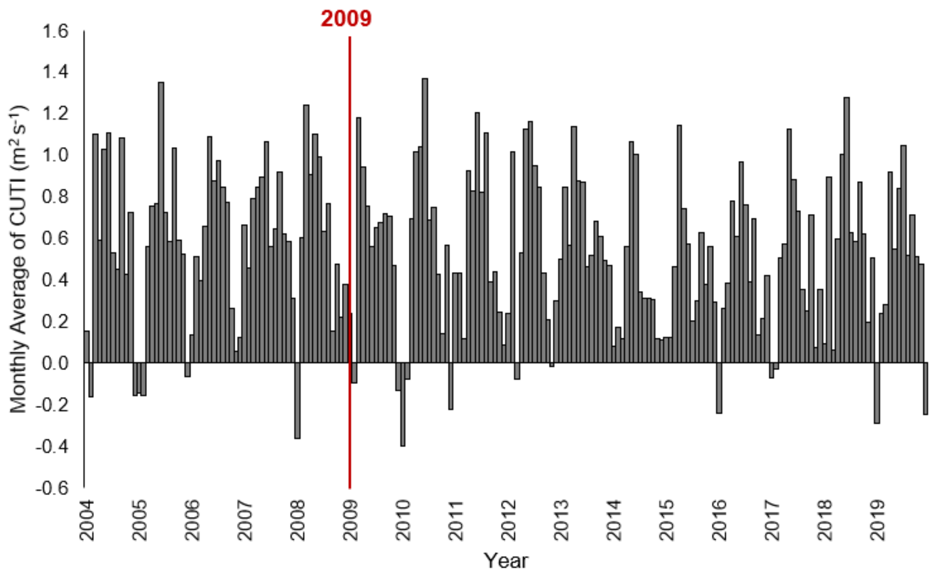


Figure App.E.8.5. Monthly values of the Coastal Upwelling Transport Index (CUTI), years 2004-2019. The vertical red line indicates the year of the last condition report (2009). Data source Jacox et al., 2018, data visualization by Point Blue Conservation Science.

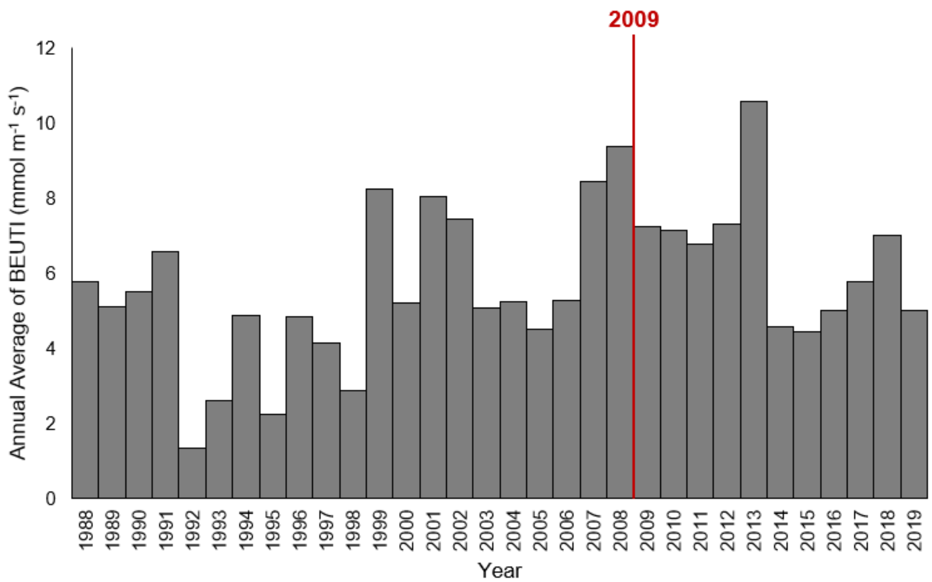


Figure App.E.8.6. Annual averages of the Biologically Effective Upwelling Transport Index (BEUTI), years 1988-2019. The vertical red line indicates the year of the last condition report (2009). Data source Jacox et al., 2018, data visualization by Point Blue Conservation Science.

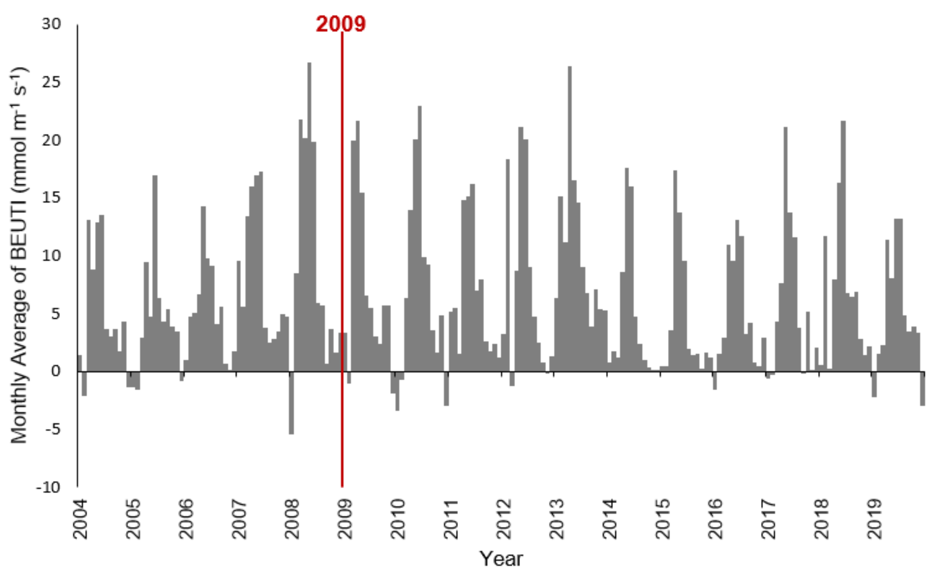


Figure App.E.8.7. Monthly values of the Biologically Effective Transport Index (BEUTI), years 2004-2019. The vertical red line indicates the year of the last condition report (2009). Data source Jacox et al., 2018, data visualization by Point Blue Conservation Science.

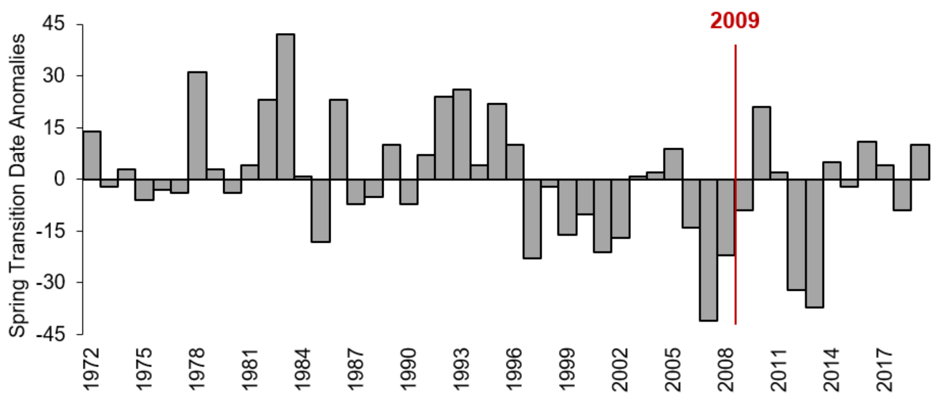


Figure App.E.8.8. Spring transition date anomalies determined from daily Bakun upwelling indices (averaged values from 36°N and 39°N), years 1972-2019. The vertical red line indicates the year of the last condition report (2009). Data source NOAA, processed by Point Blue Conservation Science.

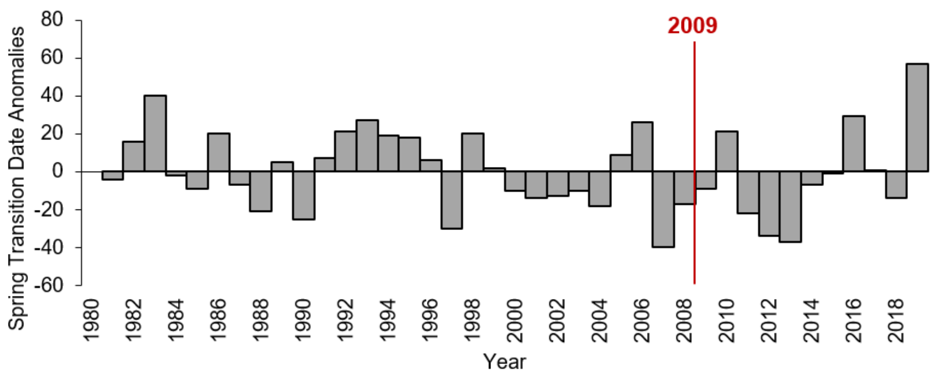


Figure App.E.8.9. Spring transition date anomalies determined from NOAA buoy data (46013), years 1972-2019. The vertical red line indicates the year of the last condition report (2009). Data source NOAA, processed by Point Blue Conservation Science.

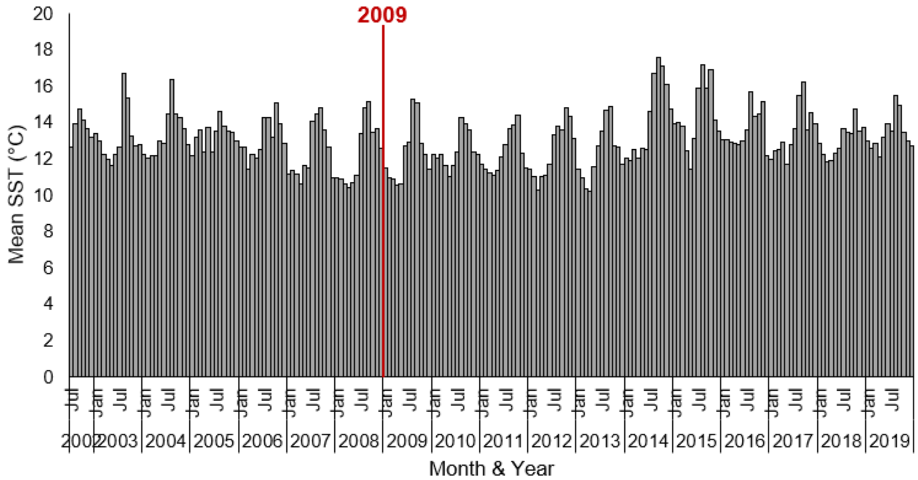


Figure App.E.8.10. Mean monthly sea surface temperature from Aqua MODIS 4km satellite data for CBNMS region, 2002-2019. Line shows polynomial trend for 2009-2019. The vertical red line indicates the year of the last condition report (2009). Data source NASA, data visualization by Point Blue Conservation Science.

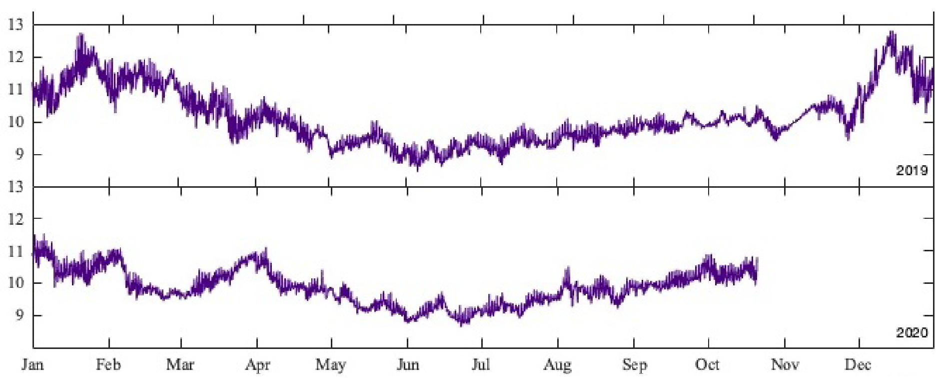


Figure App.E.8.11. Temperature at 80 meters depth on Cordell Bank mooring. Data source: CBNMS/BML; Data Visualization: BML.

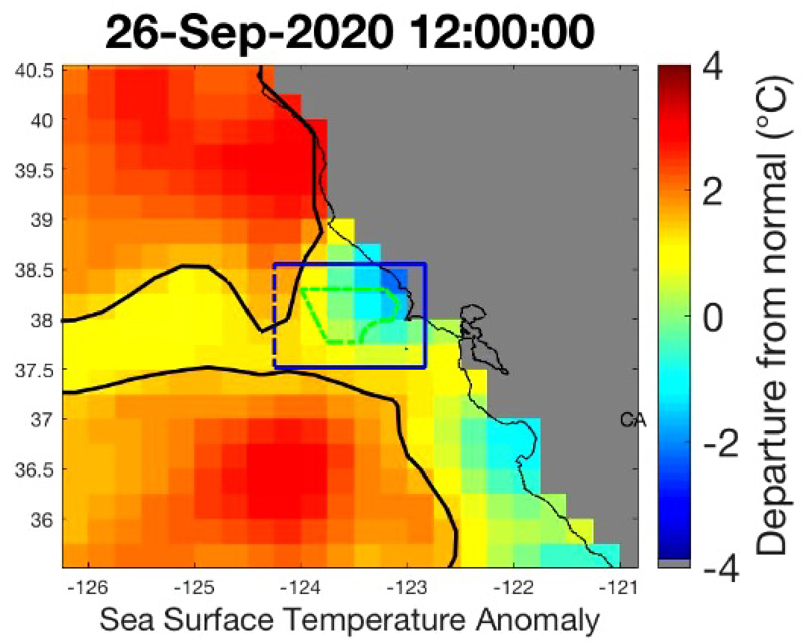


Figure App.E.8.12. Temperature anomalies on September 26, 2020. Data source NOAA OISTT dataset, processed and displayed by Andrew Leising (NOAA).

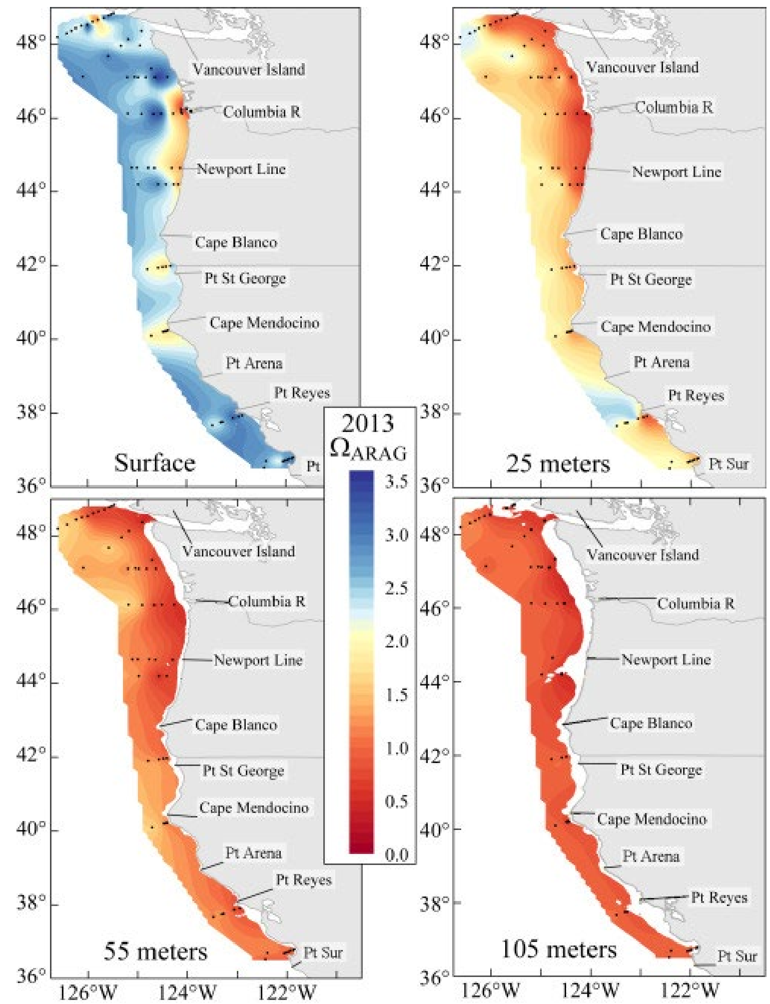


Figure App.E.8.13. Aragonite saturation state at the surface, 25 m, 55 m, and 105 m depth during the 2013 West Coast survey, from Feely et al., 2016

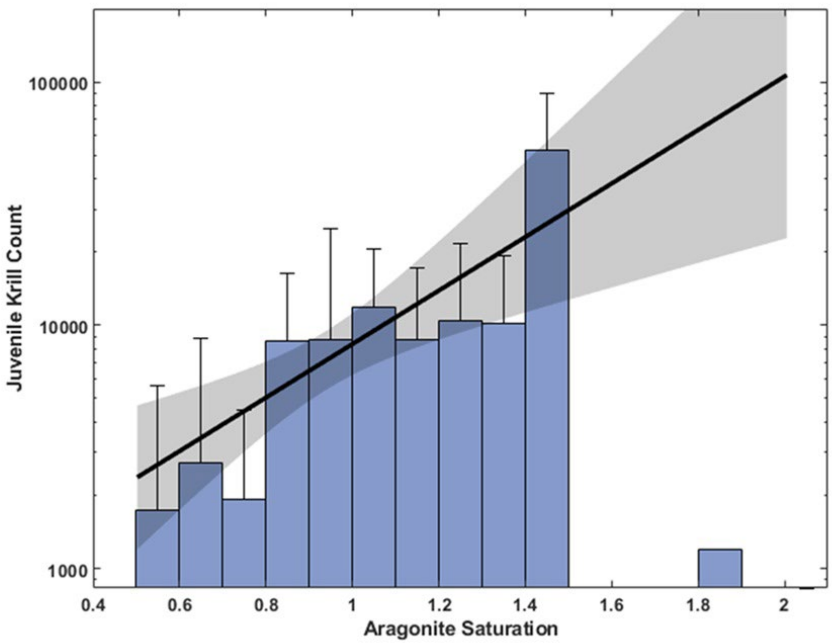


Figure App.E.8.14. Juvenile krill counts (in the upper 50m) in relation to aragonite saturation values at ACCESS stations (lines 2, 4, 6) for years 2010-2014. Data source ACCESS, Figure by Ryan Anderson.

Commented [20]: probably not OK to extrapolate this regression past 1.5

Commented [21]: We need to follow up with Meredith on these figures, when she is back from vacation

Commented [22]: Explain what the gray shaded area is, what the error bars represent, the equation line/stats to support the statements made in the text for 8.14 and 8.15

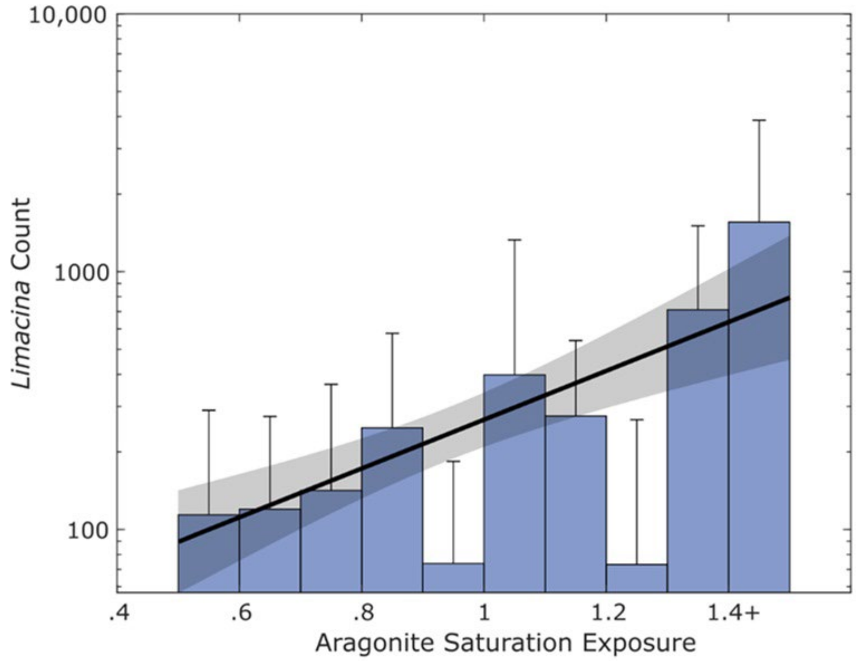
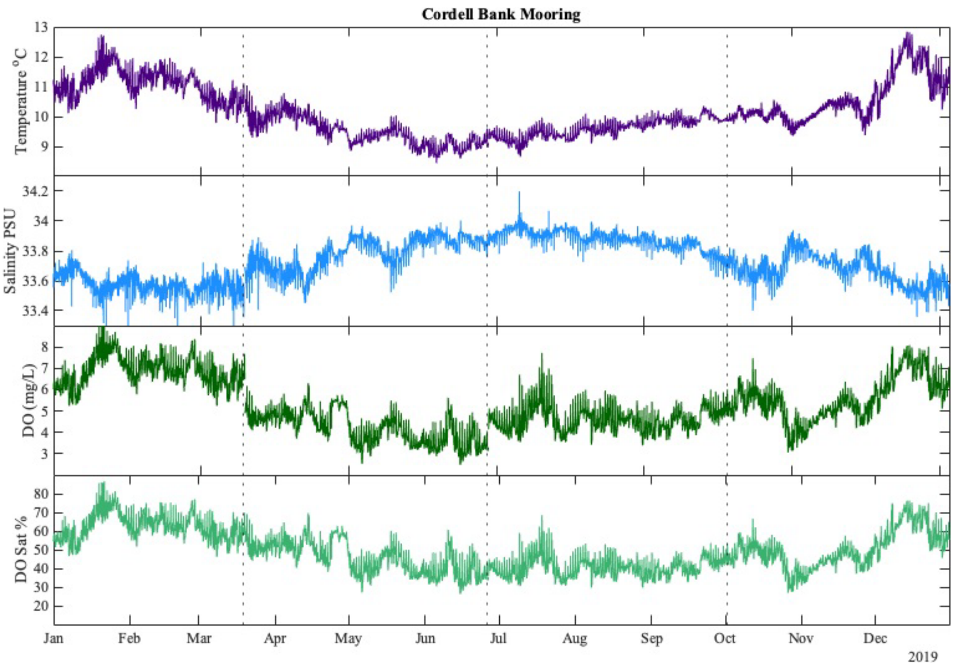


Figure App.E.8.15. Limacina helicina counts (in the upper 50m) in relation to aragonite saturation values at ACCESS stations (lines 2, 4, 6) for years 2011-2014. Data source ACCESS, Figure by Ryan Anderson.



Cordell Bank Mooring
Temperature °C
Salinity PSU
DO (mg/L)
DO Sat %
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2019

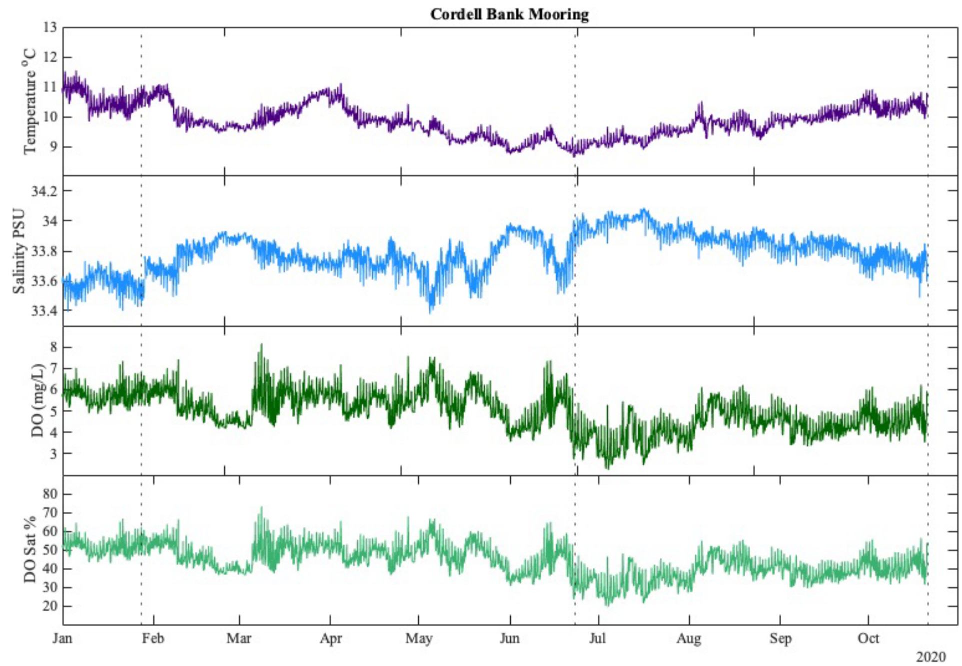
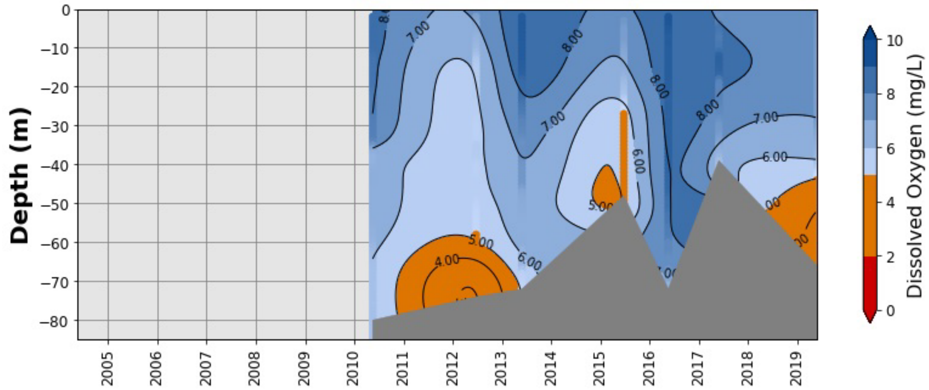
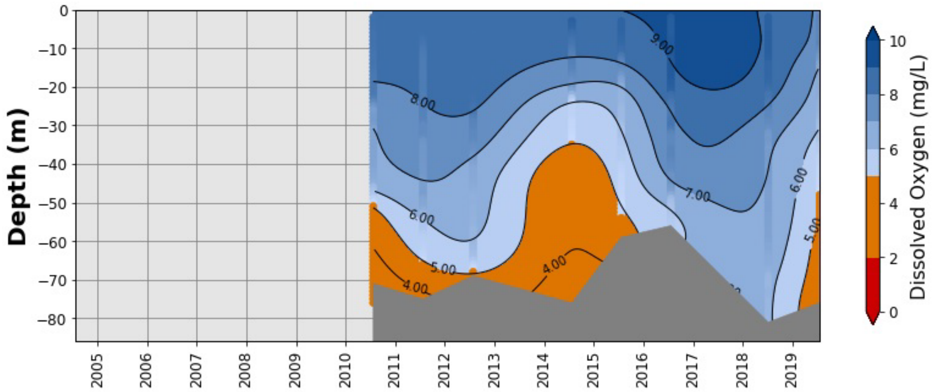


Figure App.E.8.16. Temperature, salinity, dissolved oxygen (mg/L) and dissolved oxygen (% saturation) at 80 meters depth on Cordell Bank mooring in 2019 (top) and 2020 (bottom). Data source: CBNMS/BML; Data Visualization: BML.


Depth (m)
Dissolved Oxygen (mg/L)
0
−10
−20
−30
−40
−50
−60
−70
−80
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
7.00
8.00
6.00
5.00
4.00
10
8
6
4
2
0


Depth (m)
Dissolved Oxygen (mg/L)
0
−10
−20
−30
−40
−50
−60
−70
−80
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
9.00
8.00
7.00
6.00
5.00
4.00
10
8
6
4
2
0

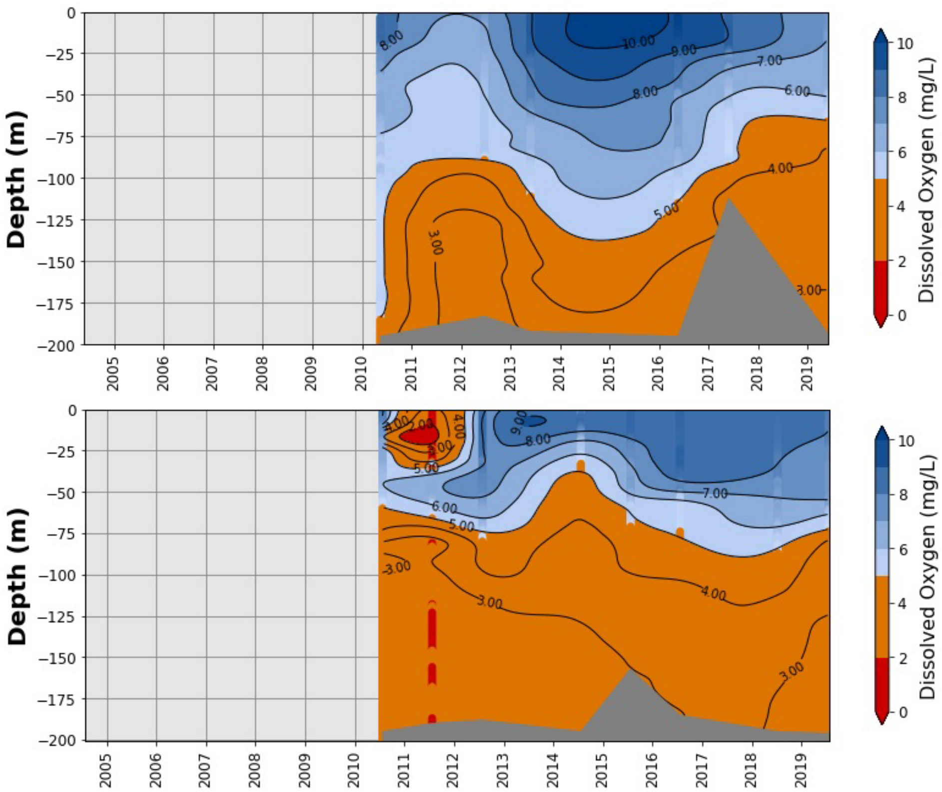


Figure App.E.8.17. Dissolved oxygen values with depth, stations 2-M, spring and summer (top 2 figures) and 2-W, spring and summer cruises, (bottom 2 figures) years 2010-2019. Data Source ACCESS, displayed by Point Blue Conservation Science.

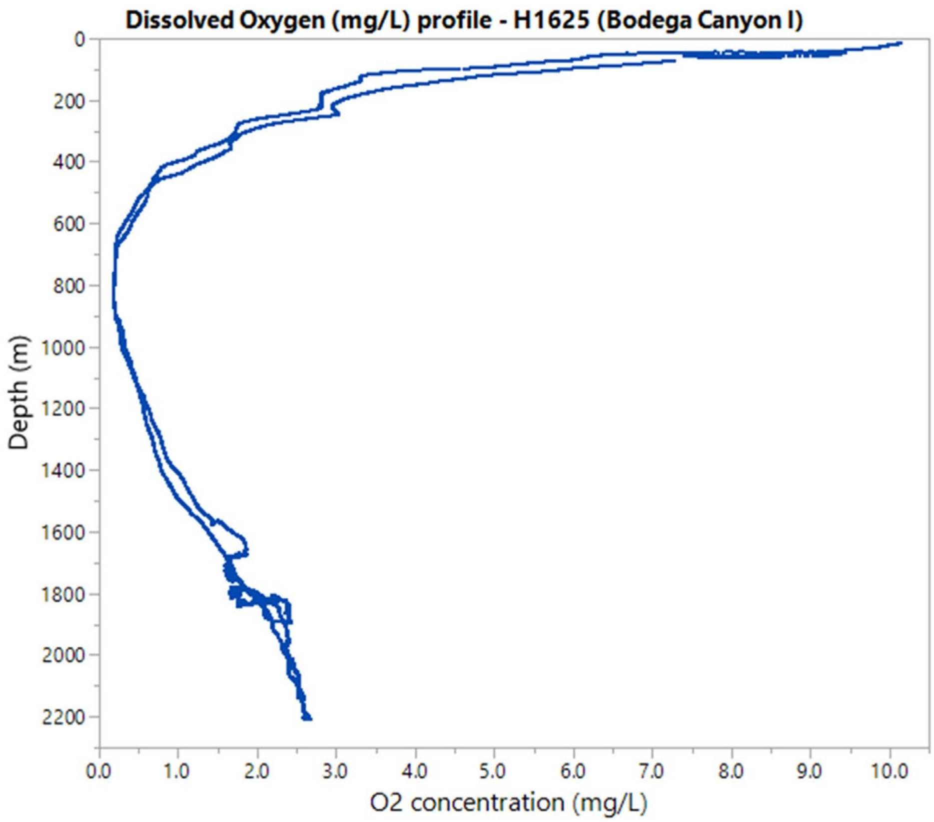


Figure App.E.8.18. Dissolved oxygen profile from Hercules ROV on dive to Bodega Canyon, August 7, 2017. Data source: CBNMS/Ocean Exploration Trust. The Coastal Upwelling Transport Index (CUTI) on this day was -1.038, indicating downwelling, at 38 degrees latitude near the location of the ROV dive (NOAA ERDDAP, 2022).

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Paul McElhany Exposure to low pH reduces survival and delays development
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Question 9: Are other stressors, individually or in combination, affecting water quality, and how are they changing?

Status: Good/Fair (medium confidence)
Trend: Undetermined (medium confidence)
Status Description: Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Rationale: Microplastics are present in the sanctuary but within the range of other open ocean marine settings and much lower than San Francisco Bay. There were no reported oil spill incidents inside CBNMS, but incidents that occurred nearby had the potential to affect the

sanctuary. Vessel discharges were recorded in the sanctuary and are likely underreported. Changes to ocean temperature and chemistry caused by global greenhouse gasses (GHG) are also affecting CBNMS. The undetermined trend was based on the limited time-series data available on most of these indicators.

Comparison to the 2009 Condition Report

In the 2009 condition report, “other stressors” were part of a question that combined climate and non-climate stressors: “Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality and how are they changing?” In 2009, that question received a good rating and an undetermined trend; impacts to this offshore location were not suspected, but data were lacking (Table S.WQ.6.1). In addition, there was no indication of reduced productivity or degraded water quality resulting from inputs from San Francisco Bay or the Russian River. The current report considers climatic drivers of water quality and other stressors separately, in Questions 8 and 9, respectively; hypoxia and ocean acidification are addressed in Question 8.

New Information in the 2022 Condition Report

Microplastics, oil spills, and vessel discharge are the non-climate stressors most likely to affect the sanctuary (Table S.WQ.9.1). Unfortunately, there are no long-term monitoring studies in the sanctuary for these indicators and as such, there are limited data available. Nevertheless, experts considered data that are available, and recognized the limited potential for land-based pollution and runoff due to the sanctuary's offshore location and the low numbers of reports related to these problems.

Table S.WQ.9.1. Status and trends for individual indicators discussed at the March 26, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figures
Microplastics	San Francisco Estuary Institute, Sutton et al., 2019/CBNMS	pelagic	Status: Fewer microplastics in the sanctuary than SF Bay, similar to levels found in the open ocean Trend: no trend data	S.WQ.9.1, Figure App.E.9.1
Oil spills	NOAA Office of Response and Restoration and U.S. Coast Guard/NCCOS	pelagic	Status: No incidents in the sanctuary, some nearby Trend: unknown/no trend	S.WQ.9.2
Vessel discharges	USCG	pelagic	Status: Generally low incidents in CBNMS, recent cruise ship incidents Trend: No trend data	None

Greenhouse gas emissions - CA	U.S. EPA/U.S. EPA	pelagic	Status: High levels in CA throughout time period Trend: Some recent improvements, not enough to counteract high levels	S.WQ.9.3, Figure App.E.9.5
Greenhouse gas emissions - states and sectors	U.S. EPA/U.S. EPA	pelagic	Status: High levels in some CA sectors Trend: no trend	Figure App.E.9.4, Figure App.E.9.5
Greenhouse gas emissions - gas type	U.S. EPA/U.S. EPA	pelagic	Status: Overall high levels of greenhouse gasses in CA and U.S. Trend: Consistent over time	S.WQ.9.3, Figure App.E.9.6
Heat content anomalies	NOAA/NOAA	pelagic	Status: Heat content consistently above-average since mid-1990s Trend: Increasing over time	Figure App.E.9.2
Carbon dioxide and pH	NOAA PMEL/NOAA PMEL	pelagic	Status: Higher carbon dioxide and lower pH Trend: Carbon dioxide has been increasing and pH has been decreasing over time	Figure App.E.9.3

Microplastics are an ecological stressor that degrade water quality, with implications for ecosystem and human health when present in seafood. They are found in nearly every environment on Earth (Thompson et al., 2004). Plastic debris, including microplastics, in the marine environment contains organic contaminants, some added during manufacturing, and some absorbed from surrounding seawater (Teuten et al., 2009). San Francisco Estuary Institute studied microplastics from 2017-2018 in three California marine sanctuaries (Cordell Bank National Marine Sanctuary, Greater Farallones National Marine Sanctuary [GFNMS], and Monterey Bay National Marine Sanctuary [MBNMS]) as well as in San Francisco Bay (Sutton et al., 2019; Figure App.E.9.1). Surface water samples were collected using manta trawls during the dry and wet seasons. Their results show microparticles, including plastics, are present in CBNMS, however, abundance levels were much lower than in San Francisco Bay, and were within the range of abundance in other open ocean marine settings (Figure S.WQ.9.1). There were no long-term data for the trend. Other types of marine debris are considered in Question 10 regarding habitat integrity and Question 3 regarding human activities and impacts to water quality.

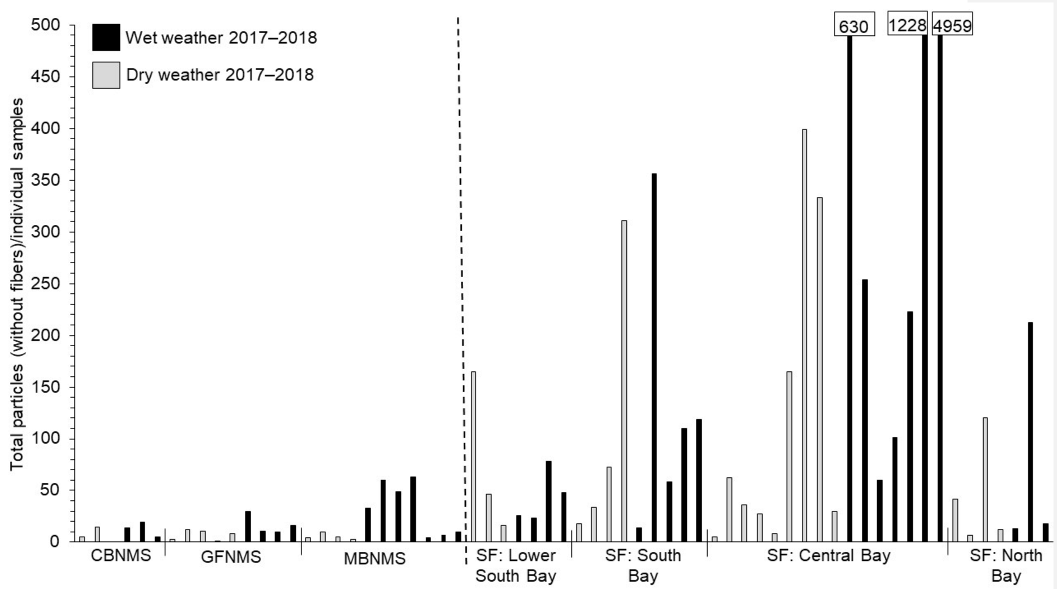

Figure S.WQ.9.1. Total particles (excluding fibers) per individual samples San Francisco Estuary Institute measured in CBNMS, GFNMS, MBNMS, and San Francisco (SF) Bay in the dry and wet seasons 2017–2018. Numbers in boxes indicate values exceeding the axis maximum. Data: Adapted from Sutton et al., 2019 Tables A-4.3a and A-4.3c.

NOAA's Office of Restoration and Response (ORR) and the U.S. Coast Guard (USCG) collect data on reported oil spills. Since 2009 there have been no reported oil spill incidents in CBNMS, however, oil spill incidents have been recorded near the CBNMS boundary. In 2013 a fishing boat spilled 70 gallons of diesel, and another fishing boat sunk in 2019 with 17,000 gallons of diesel on board. These incidents could affect the water quality of the sanctuary (Figure S.WQ.9.2).

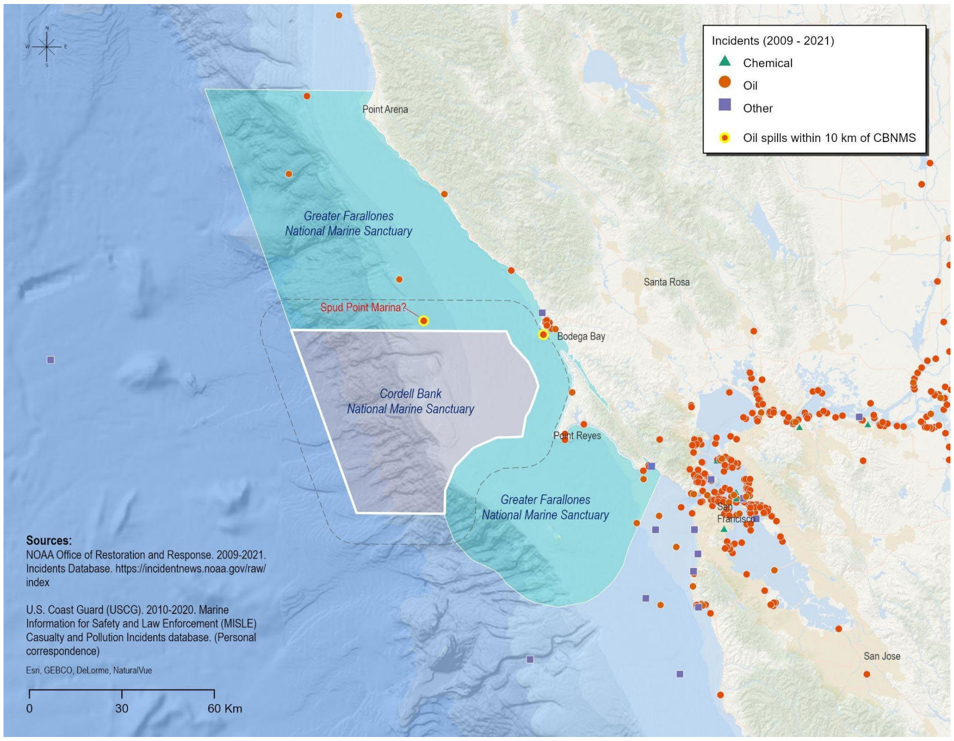

Figure S.WQ.9.2. Locations of oil spills incidents near CBNMS (Sources: NOAA Office of Response and Restoration (ORR) 2009-2021, U.S. Coast Guard (USCG) 2010-2020). Note that the point labeled "Spud Point Marina?" is likely a latitudinal data entry error for an incident directly east in Bodega Bay.

Most vessel discharges are prohibited in CBNMS, except for those from lawful fishing and certain types of treated sewage. Although it is a legal requirement to report vessel discharges, small and large vessel discharge data are limited and likely underreported. However, there were reported incidents from enforcement authorities about extensive cruise ship discharges (190 prohibited discharges) in CBNMS and GFNMS from June 2015-2017. The discharges in these sanctuaries included 8.4 million gallons of untreated and treated black and gray water, besides water treatment sludge, exhaust gas cleaning system, and food wastes. Additionally, in 2019, a large ship that drifted into CBNMS self-reported that it had discharged black water for 18 minutes.

Greenhouse gas (GHG) emissions are stressors causing impacts to global ocean temperatures and ocean chemistry, including CBNMS. Global ocean heat content anomalies (Figure App.E.9.2) have been increasing over time, as a result of GHG emission-caused warming and increasing GHG gas levels (Figure App.E.9.3). Although there have been some recent reductions, there are still high levels of GHG generated by many sectors in the state of

California (Figure S.WQ.9.3, Figure App.E.9.4, Figure App.E.9.5; U.S. EPA 2021) and the United States (Figure App.E.9.4, Figure App.E.9.6). More information on these emissions and impacts are considered in Question 8.

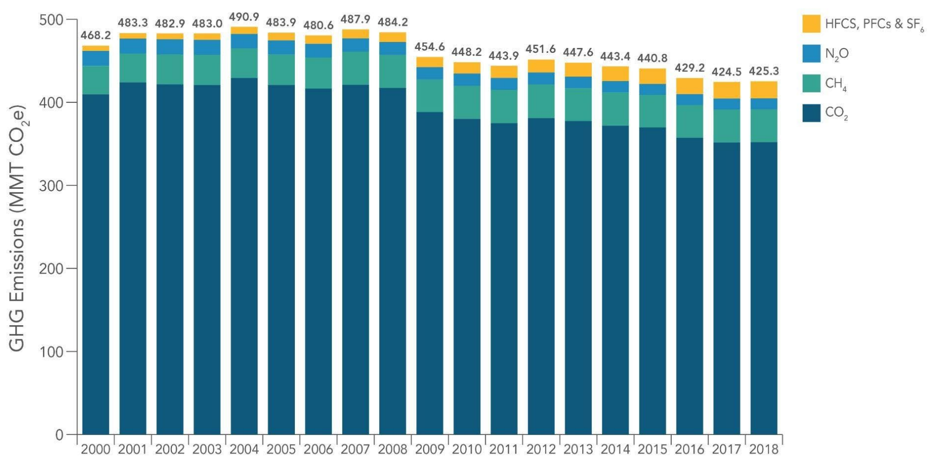

Figure S.WQ.9.3. Greenhouse gas (GHG) emissions in million metric tons for California from 2000 to 2018. Source: U.S. EPA 2021.

Conclusion

The distance of the sanctuary from outflows of land-based sources of pollution provide some protection against common sources of water quality stressors. Experts agreed that although some extreme storms can result in debris and runoff reaching CBNMS, these occurrences are rare enough to limit the level of concern. Still, it was evident that some stressors are or have affected water quality of the sanctuary, namely plastics, vessel discharges, and oil spills. Data are beginning to become available for these stressors, leading to increased awareness of their potential to threaten marine resources.

The lack of long-term monitoring for these indicators led experts to recommend an undetermined trend and identify a data gap. Continued sampling for microplastics, monitoring of vessel discharges, and increased outreach about regulations and reporting requirements could improve our knowledge about these stressors. Increasing our understanding of greenhouse gas emissions and trends and the contributions they make as stressors to CBNMS water quality will also be helpful. Other indicators like ship exhaust deposition, ship scrubber wash, and wildfires were considered by experts but were not included due to a lack of data. Should data become available, it should be evaluated for relevance to the condition of the sanctuary.

Figures for Appendix

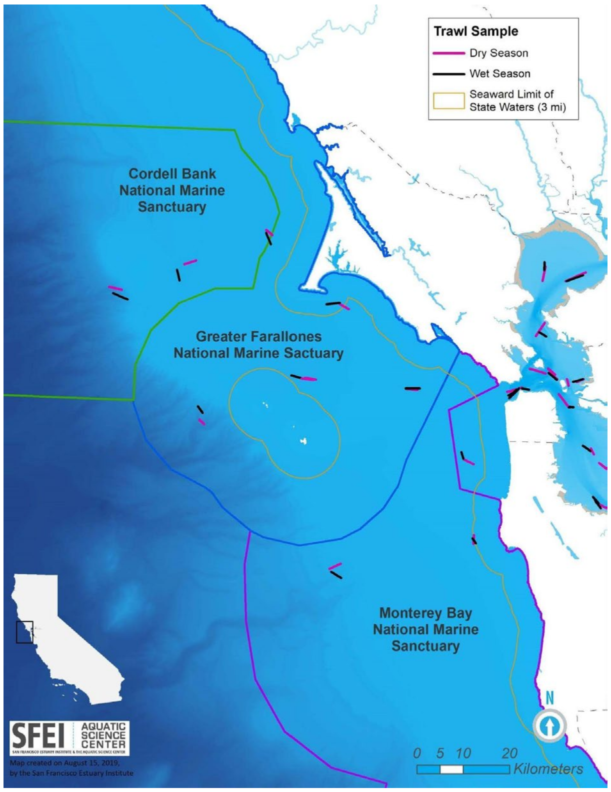

Figure App.E.9.1. Map of the San Francisco Estuary Institute microplastic study areas from 2017–2018. Surface water samples were collected using manta trawls during the dry and wet seasons. Figure: Sutton et al., 2019.

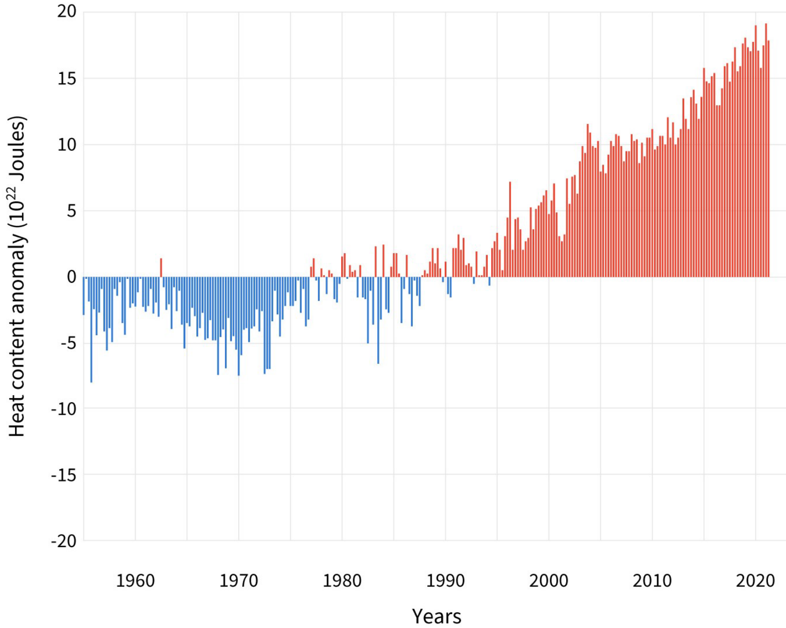

Figure App.E.9.2. Seasonal (3-month) heat energy in the top half-mile of the ocean compared to the 1955-2006 average. Heat content in the global ocean has been consistently above-average (red bars) since the mid-1990s. More than 90 percent of the excess heat trapped in the Earth system due to human-caused global warming has been absorbed by the oceans. NOAA Climate.gov graph, based on data (0-700m) from the NCEI Ocean Heat Content product collection. Source: NOAA

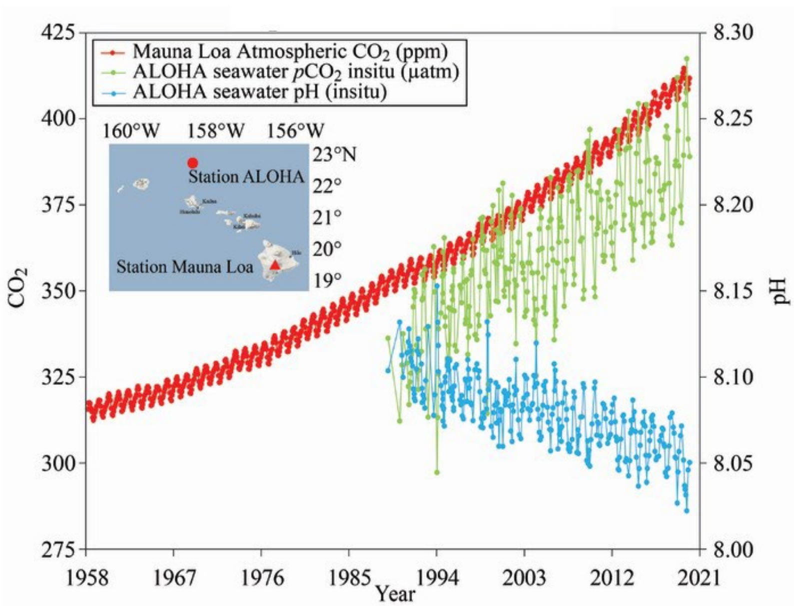

Figure App.E.9.3. Carbon dioxide and pH measurements in the north Pacific Ocean. Data: Mauna Loa (ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt), ALOHA (http://hahana.soest.hawaii.edu/hot/hot-dogs/bextraction.html), ALOHA pH & *p*CO2 are calculated at in-situ temperature from DIC & TA (measured from samples collected on Hawaii Ocean Time-series (HOT) cruises) usings co2sys (Pelletier, v25b06) with constants: Lueker et al., 2000, KS04: Dickson, Total boron: Lee et al., 2010, & KF: seacarb. Source: NOAA PMEL

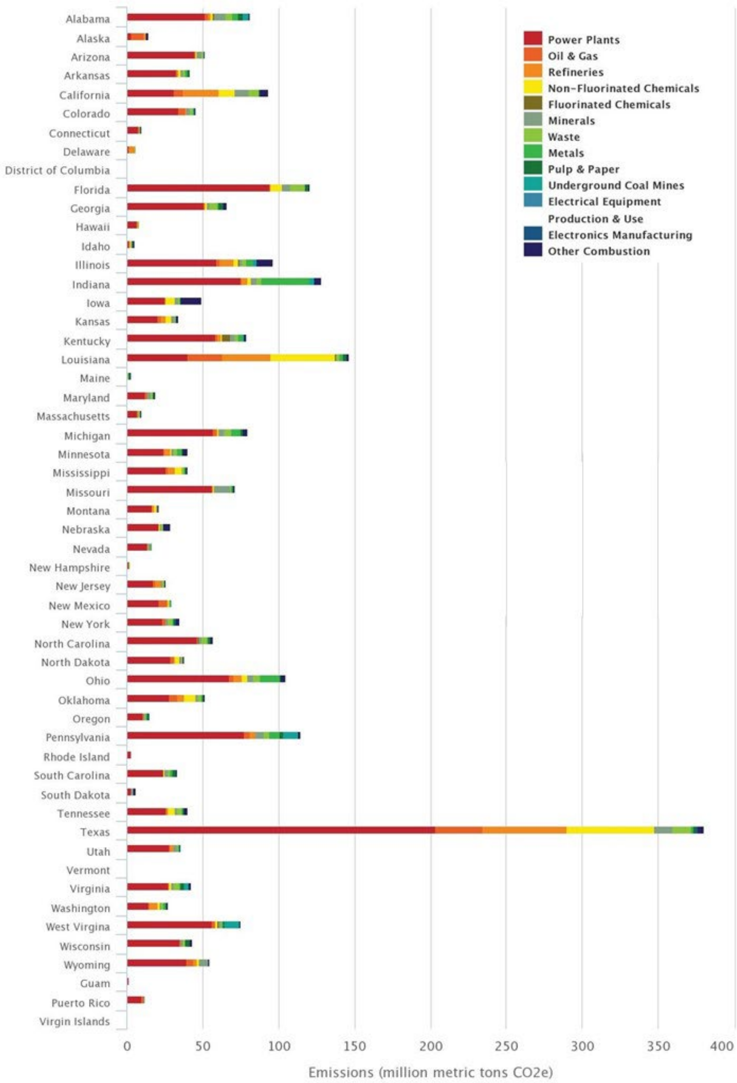

Figure App.E.9.4. Annual reported greenhouse gas emissions in 2020 by industry and state. Totals do not include emissions from the transportation and agriculture sectors, or from the Petroleum and Natural Gas Systems Onshore Production and Gathering and Boosting segments and electric distribution systems. Source: U.S. EPA

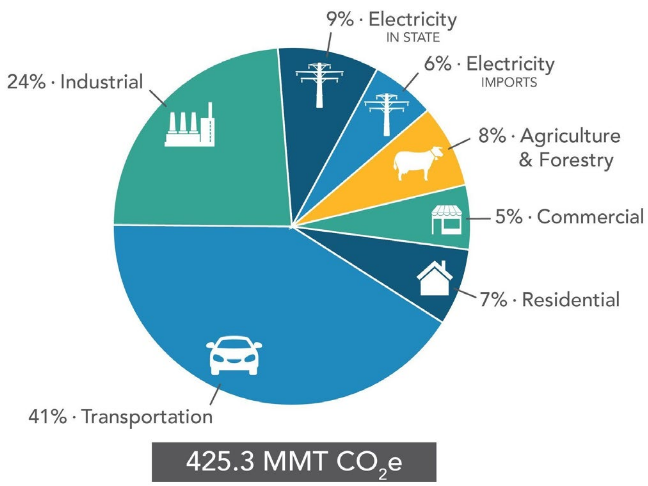

Figure App.E.9.5. Total greenhouse gas emissions in million metric tons in California in 2018. Source: U.S. EPA 2021.

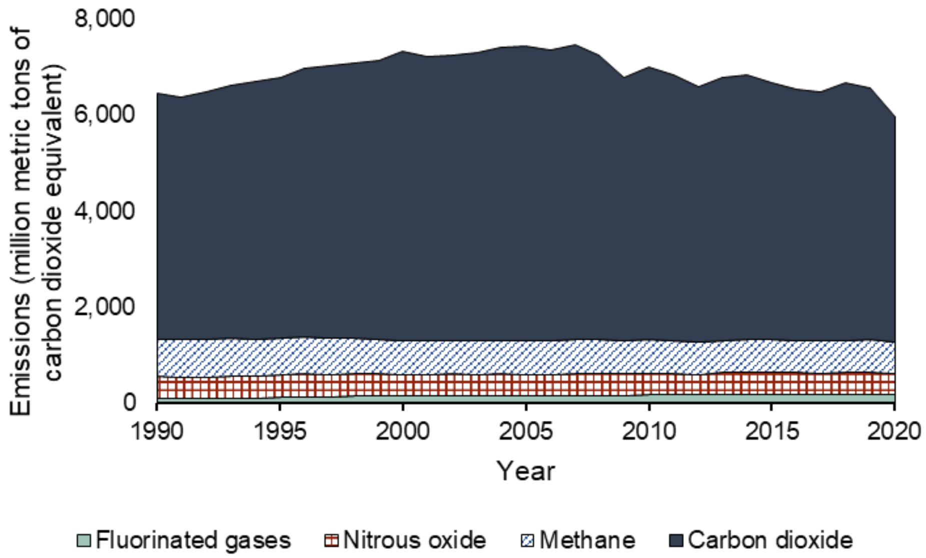

Figure App.E.9.6. Greenhouse gas emissions by gas in the United States from 1990 to 2018. Source: U.S. EPA

Question 9 Literature Cited

Sutton, R., Franz, A., Gilbreath, A., Lin, D., Miller, L., Sedlak, M., Wong, A., Box, C., Holleman, R., Munno, K., Zhu, X., & Rochman, C. (2019). Understanding microplastic levels, pathways, and transport in the San Francisco Bay region. San Francisco Estuary Institute. https://www.sfei.org/sites/default/files/biblio_files/Microplastic%20Levels%20in%20SF%20Bay%20-%20Final%20Report.pdf (Accessed 13 July 2021)

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., Kirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., & Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society B, 364*(1526), 2027–2045. http://doi.org/10.1098/rstb.2008.0284

Thompson, R. C., Olsen, Y., Mitchell, R. P., Davis, A., Rowland, S. J., John, A. W. G., McGonigle, D., & Russell, A. E. (2004). Lost at sea: Where is all the plastic? *Science, 304*(5672), 838-838. http://doi.org/10.1126/science.1094559

U.S. Environmental Protection Agency. (2021, July 13). *Greenhouse Gas Reporting Program (GHGRP) Emissions by Location*. U.S. Environmental Protection Agency. https://www.epa.gov/ghgreporting/ghgrp-emissions-location

This is the post-peer review version of the CBNMS Condition Report. It is now locked and a new copy has been created for copy edits.

Status and Trends of Habitat (Questions 10–11)

Habitats within CBNMS include pelagic and benthic habitat. The following sections provide an assessment of the status and trends of key habitat indicators in CBNMS for the period from 2009–2021.

Question 10 focuses on the integrity of major habitats within the sanctuary, including biologically (biogenic) and abiotically (physical) structured habitats. Physical habitats are abiotic structures, while biogenic habitats are composed of species that form structures used by other living marine resources. Biogenic habitats are layered on top of, and are often associated with, specific physical habitat types. Changes to both biotic and abiotic habitat can significantly alter the diversity of living marine resources and ecosystem services.

Question 11 examines concentrations and variability of contaminants in major sanctuary habitats. Like the other condition report questions, the status and trend ratings represent assessments by subject matter experts given readily available habitat data.

Table S.H.10.1. 2009 Condition Report ratings (left) and 2009–2021 Condition Report ratings (right) status, trend, and confidence ratings for the habitat questions.

<table>
<tr><th colspan="2" rowspan="2">2009 Condition Report Questions</th><th rowspan="2">2009 Rating</th><th colspan="2" rowspan="2">2009–2021 Condition Report Questions</th><th colspan="4">2009–2021 Condition Report Rating</th></tr>
<tr><th>Status</th><th>Confidence (status)</th><th>Trend</th><th>Confidence (Trend)</th></tr>
<tr><td>5</td><td>Habitat abundance/distribution</td><td>?</td><td rowspan="2">10</td><td rowspan="2">Integrity of major habitats</td><td rowspan="2">Fair</td><td rowspan="2">Medium</td><td rowspan="2">▲▼</td><td rowspan="2">Medium</td></tr>
<tr><td>6</td><td>Condition of biologically structured habitat</td><td>?</td></tr>
<tr><td>7</td><td>Contaminants</td><td>?</td><td>11</td><td>Contaminants</td><td>Undetermined</td><td>Medium</td><td>?</td><td>Medium</td></tr>
</table>

Question 10: What is the integrity of major habitat types and how are they changing?[1]

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Status: Fair (medium confidence)
Trend: Mixed (medium confidence)
Status Description: Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.
Rationale: Direct measures of impacts to the sanctuary's benthic habitats are limited, but data show that trawling activities, Dungeness crab fishing, and marine debris are present in the sanctuary, albeit at lower levels than some other areas along the US west coast. Recent shifts in EFHCA closures will need to be monitored to establish trend data in the open and closed areas. Chronic noise from shipping is approaching a threshold level that could cause stress to marine mammals, particularly whales.

Comparison to 2009 Condition Report
In the 2009 condition report, this question was divided into two separate questions, the first examining abundance and distribution of major habitats and a second that assessed condition of biologically structured habitats. These questions both received status ratings of "fair" with an "undetermined" trend. The ratings were based heavily on expert opinion that there were impacts to physical and biological habitats from historic longline and bottom trawling activities and lost fishing gear. Although trawling closures were implemented from 2005—2006, there are no data to determine differences in habitat quality between open and closed areas and recovery rates of benthic habitats that were relieved of fishing pressure. Additionally, the impacts of climate change are unknown for the slow-growing invertebrate communities on the bank and shelf, particularly deep-sea corals (Table S.H.10.1).

New Information in 20__ Condition Report
In this report, all major habitat types are assessed collectively (Table S.H.10.2). The area of the sanctuary more than doubled in size in 2015 from a total area of 529 mi^2 to 1,286 mi^2 to include deep-water habitats off the continental slope, Bodega Canyon, and the surrounding pelagic habitat. Habitat types include mud bottom on the shelf (70—200 m), mud bottom with some rock outcrops, steep rock walls, and deep slope and canyons out to depths greater than 3500 meters. The bank is made up of high relief consolidated rock at the shallowest depths (35 m) and mixed boulder, cobble, and sand habitats at the base (91—122 m) (Appendix.X.10.1).

Table S.H.10.2. Status and trends for individual indicators discussed at the March 29, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Habitat	CBNMS/CBNMS	Benthic	Static measurements for background info	Appendix.X.10.1

[1] Experts assigned a trend rating of undetermined at the workshop. However, following the workshop, a new trend "mixed" was introduced to the condition report rating scheme as a result of discussions with experts. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the combination of trends from available data.

Habitat protections	PFMC/CBNMS	Benthic	Status: Habitat protections for key habitat features Trend: no change - EFHCA maintained	Appendix.X.10.2
Commercial trawling activity	NOAA Northwest Fishery Science Center/California Current Integrated Ecosystem Assessment	Benthic	Status: Trawling on the shelf and slope, less than other areas Trend: Improving (lower amounts of trawling)	Figure S.Hab.1 Figure S.HA.3.3 Appendix.X.10.3 Appendix.X.10.4
Research trawling activity	NOAA Northwest Fishery Science Center/California Current Integrated Ecosystem Assessment	Benthic	Status: Trawling on the shelf and slope at low levels Trend: no change	Figure S.HA.3.1 Appendix.X.10.5 Appendix.X.10.6 Appendix.X.10.7
Crab fishing activity - Rec	CDFW/NA	Benthic	Status: Low levels in CBNMS Trend: variable	NA
Crab fishing - commercial	CDFW/ONMS	Benthic	Status: Low levels in CBNMS Trend: Peaks in 2010, 2011, then decreased	Figure ES.CH.3
Marine debris - surface	ACCESS/Point Blue	Pelagic	Status: Marine debris found in the surface waters of the sanctuary Trend: undetermined	Appendix.X.10.8
Marine debris - bank	CBNMS/CBNMS	Benthic	Status: Marine debris found on the bank Trend: undetermined	Appendix.X.10.9a Appendix.X.10.9b
Marine debris - deep	CBNMS/CBNMS	Benthic	Status: Marine debris found in deep habitat, mostly trash Trend: no trend data	Appendix.X.10.10a Appendix.X.10.10b
Noise	OSU, NOAA/Haver et al., 2020, 2021	Pelagic	Status: Whales and shipping dominate the soundscape, CBNMS is at the threshold of "good ecosystem status" Trend: no long term trend data yet	Figure S.Hab.10.2 Appendix.X.10.11 Appendix.X.10.12 Appendix.X.10.13 Appendix.X.10.14

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Fisheries Management Protections

Multiple habitat and seafloor protections exist in the sanctuary, including Essential Fish Habitat Conservation Areas (EFHCA) and Rockfish Conservation Areas (RCA) which are managed by

NOAA and the Pacific Fisheries Management Council (PFMC). Rockfish Conservation Areas are depth-based closed areas where fishing for groundfish is prohibited depending on what types of fishing gears are being used. Essential Fish Habitat Conservation Areas are closures for habitats that are necessary to the species for spawning, breeding, feeding and growth to maturity.

The Cordell Bank RCA was originally established in 2005 and all of the EFHCA closures were put in place in 2006. Cordell Bank is protected by an EFHCA closure at 50 fathoms within which fishing for groundfish is prohibited and there is no use of bottom contact gear or removal or modification of any benthic animals or substrate (Appendix.X.10.2a) .

In 2014, The Pacific Fisheries Management Council completed a review of EFH and determined that new information from the multi-year public process justified developing modifications to groundfish EFH. The PFMC began developing EFH alternatives and, separately, considered changes to the trawl RCA. These efforts were merged into a single action under Amendment 28 to the groundfish fisheries management plan. The final rule went into effect on January 1, 2020 (C.F.R. 50 part 660) and changed bottom trawl fishing closures to minimize adverse effects of fishing, reopens historically important fishing grounds to groundfish bottom trawling, and prohibited fishing with bottom-contacting gear in deep waters (greater than 3,500 m) off California to protect deep-water ecosystems, including deep-sea corals. In CBNMS, Amendment 28 opened 20 mi^2 of EFHCA in the sanctuary's sand-mud habitat on the continental shelf, while closing 19 mi^2 of EFHCA on the sanctuary's shelf and slope habitats composed of hard and mixed substrate. A total area of 60 mi^2 of trawl RCA in the sanctuary was removed (Appendix.X.10.2b).

Benthic surveys using a remotely operated vehicle (ROV) were conducted in 2018 in the EFHCA and RCA reopen areas in CBNMS (Graiff & Lipski, 2020a). These ROV surveys provided a baseline assessment and characterization of habitat types and densities of fish and invertebrates for a portion of these areas before the final ruling on Amendment 28 went into effect opening these areas to commercial bottom trawling. Monitoring will continue in these areas to assess how habitats are impacted by changes in fishing activities. Continued protections of EFHCA on Cordell Bank and surrounding shelf and slope habitats contribute to the integrity of the associated biological communities.

Fishing Impacts

Bottom contact fishing gear, such as trawls, traps, and pots, can significantly impact benthic habitats and the level of impact is largely based on the magnitude, spatial extent, and frequency of gear use (NRC, 2002; Morgan & Chuenpagdee, 2003). Commercial trawling data from federal groundfish fisheries operating within the boundaries of CBNMS analyzed by NOAA's California Current Integrated Ecosystem Assessment Team (CCIEA) based on analytical approaches used in their report (Harvey et al., 2021) show that seafloor contact by bottom trawl gear decreased from the period of the last condition report (2002-2008) to the current assessment period of this report 2009-2019 (Figure S.Hab.10.1 a, b). Trawling is mainly on the soft shelf and soft upper slope habitats (Appendix.X.10.3). There was a shift in effort, based on distance trawled, from the shelf to the slope between 2009 and 2019 compared to the long term mean (2002-2019). Bottom trawl contact has decreased from 2009-2019 in most areas of

Commented [3]: Figure S.HA.3.2

CBNMS (blue cells) with the exception of a band of grid cells stretching north-south along the eastern boundary (red cells, Fig. S.Hab.10.1 c) Total distance and frequency of trawling scaled to distances trawled across the entire U.S. West Coast shows that CBNMS is at lower levels than other west coast areas (Appendix.X.10.4).

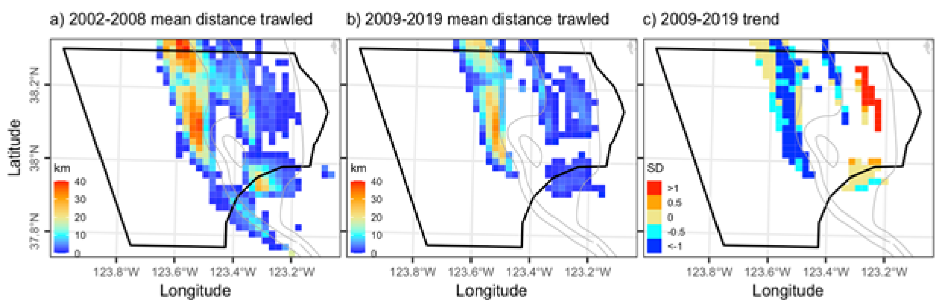

Figure S.Hab.10.1. Spatial representation of seafloor contact by bottom trawl gear from federal groundfish fisheries operating within CBNMS and nearby areas, calculated from annual distances trawled within each 2x2-km grid cell from 2002–19. Left(a): mean distance trawled annually from 2002 to 2008. Middle(b): mean distance trawled annually from 2009 to 2019. Right(c): normalized trend values from 2009 to 2019 - red grid cell values were >1 standard deviation (SD) above and blue grid cells were > 1 SD below the long-term mean (2002-19) of that cell. Gray lines represent 100, 200 and 500-m depth contours. Grid cells with < 3 vessels operating within the time period represented have been removed due to confidentiality. Image: Data from NOAA's Northwest Fisheries Science Center's Fisheries Observation Science Program, analyzed by CCIEA.

Trawling conducted for research purposes is permitted by the sanctuary except for in sensitive habitat like Cordell Bank. Locations of research trawls occur from the sanctuary's eastern boundary to about 1,312 feet depth (Appendix.X.10.5, Appendix.X.10.6). Groundfish time series were provided by the CCIEA program and derived from the Fisheries Resources, Analysis and Monitoring Program West Coast Groundfish Bottom Trawl Survey (WCGBTS, 2019) based on the analytical approaches used in NOAA's California Current Ecosystem Status Report (Harvey et al., 2021). The data show that trawling from the NWFSC's groundfish survey within CBNMS on the shelf and slope is at low levels and seafloor contact (in km) by bottom trawl gear shows no trend in seafloor contact distance from 2009-2019 (Figure S.H.A.3.1, Appendix.X.10.7).

Limited information is available on the fine-scale spatial footprint of recreational Dungeness crab (*Metacarcinus magister*) fishing in CBNMS, but it is mainly concentrated in the eastern portion of the sanctuary (source needed). Crab pots are a type of bottom contact gear with the potential to cause disturbance to the seafloor when they are set or hauled for retrieval. Information is not available about the impacts to the seafloor from crab pots, so we used reported landings of Dungeness crab as a proxy for the frequency of gear use and thus potential impact to the seafloor. Commercial fishing for Dungeness crab during the 2012-2020 period displays relatively high landings in 2013 and 2016. In 2015, landings decreased to a time series low as elevated levels of domoic acid, a neurotoxin produced by a harmful algal bloom (HAB), triggered health advisories and fishery closures for Dungeness crab (California Ocean Science Trust, 2016). Following another peak in 2016, landings decreased to low levels in 2019 and 2020 (Figure ES.CH.3). There are years when Dungeness crab have aggregated offshore in deeper water and populations can differ substantially from year to year (Richard Ogg, personal

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Commented [7]: we need a source. I dont recall seeing one in the presentation

update 10/25: could add the figure Jack linked below or cite as VMS, date.

Commented [8]: @jack.eynon@noaa.gov hi, do you have a source for this statement about crab fishing being concentrated in the eastern portion of the sanctuary? thanks!

Commented [9]: Hi Kaitlin, I know this is based on VMS data from NMFS (slide 15 from https://docs.google.com/presentation/d/11FpRe6O3LIkG2dsEJpY-s4y-Q2Stry8uEfREBD2xmcg/edit#slide=id.ge154188c29_0_6), but I don't have the exact citation. I think @heidi.burkart@noaa.gov may have compiled the data

Commented [10]: That does look like VMS, but @dan.dorfman@noaa.gov pulled it together. He can likely provide you with the details.

Commented [11]: @dan.dorfman@noaa.gov @heidi.burkart@noaa.gov @jack.eynon@noaa.gov @kaitlin.graiff@noaa.gov I've locked this version. Please use this new version for replying: https://docs.google.com/document/d/1qj3quvEC2yWEUc0TQDOtZUv5BX1_-lQegPcz-bVPeTs/edit communication, March 29, 2021). The fishery was subject to delays and closures in 2019, 2020, and 2021 due to elevated risk of whale and sea turtle entanglement in gears used by the fleet (CDFW, 2019; CDFW, 2020a; CDFW, 2021b).

Marine Debris

Marine debris has been found in the sanctuary's surface waters and on all benthic habitats on the bank, shelf, and deep canyons. Surface debris, particularly plastic, is a threat to sea turtles, marine mammals, and seabirds that ingest the debris if they confuse it for prey. The most significant type of marine debris found on seafloor habitats is derelict fishing gear, including longlines, gill nets, crab gear, etc. Derelict fishing gear has been observed entangled on the sanctuary's benthic structures and can damage the associated biological communities. Such gear can also be an entanglement hazard to other pelagic marine life if it extends into the water column.

The collaborative research project, the Applied California Current Ecosystem Studies (ACCESS), conducts annual surveys three times a year covering the different oceanographic seasons of the pelagic ecosystem in CBNMS, GFNMS, and northern MBNMS. As part of the multi-disciplinary cruise objectives, ACCESS documents marine debris on the surface, including plastic bags, bottles, balloons, Styrofoam, wood debris, and out-of-season crab pots. Marine debris has been observed on all cruises in CBNMS and GFNMS from 2008 to 2019, with a peak in marine debris density in 2010 and relatively consistent density for the other years from 2009 to 2019 (Elliott et al., 2020, Appendix.X.10.8).

Marine debris is recorded by type and either count or density when seen on the sanctuary's seafloor during ROV surveys, which vary in sampling year and survey effort. Observations of marine debris are not collected in a standardized effort which limits comparison of marine debris across spatial and temporal scales. On Cordell Bank, marine debris is primarily different types of derelict fishing gear such as gillnets, longlines, monofilament lines, and cables (Appendix.X.10.9). However, because of EFHCA and RCA fisheries management zones established over the bank from 2005—2006, there should not be any recent fishing gear lost on the bank. Similarly, derelict fishing gear has been observed in the deeper slope and canyon habitats as observed on ROV surveys (Appendix.X.10.10). Anthropogenic trash such as plastic bags, bottles, and cans are seen in greater numbers than derelict fishing gear on the deepest surveys (740 – 3,318 m) (Graiff & Lipski, 2020b). The observed trash could have been discarded from ships transiting through the area or from areas outside of the sanctuary and transported by ocean currents.

Soundscape

Anthropogenic noise can affect the sanctuary's pelagic habitat. The main source of anthropogenic noise in the sanctuary is ship traffic. Previously, the noise dynamics in the sanctuary were not well understood, but in October 2015, a stationary, bottom-mounted Noise Reference Station (NRS) hydrophone was deployed in CBNMS to record the underwater ambient soundscape. The NRS is located near the southern border of the sanctuary, approximately 30 kilometers offshore of the northern approach San Francisco Bay Area traffic separation scheme shipping lane (Appendix.X.10.11). Data on sound types, frequency, and levels collected from October 2015 – October 2017 show that vessels transit close to this recording station in the sanctuary year-round with minimal seasonal variation (Haver et al., 2020, Appendix.X.10.12, Appendix.X.10.14).

The European Marine Strategy Framework Directive requires European Union (EU) Member States to develop marine strategies to achieve or maintain good environmental status, and dedicates a qualitative descriptor of this condition to human-induced underwater noise (Dekeling et al., 2014). The Technical Group on Underwater Noise, known as “TG Noise”, is the EU advisory body supporting the EU’s implementation of descriptors for both impulsive and continuous noise. Their early work identified the 63 Hz and 125 Hz 1/3 octave frequency bands for regional EU monitoring of the influence of continuous vessel noise (European Commission, 2017). While there is currently no US equivalent standard, these third octave bands have been increasingly applied in US studies to support international comparisons of the impact of vessel noise (e.g., Haver et al., 2021, Ryan et al., 2021, McKenna et al., in review). Figure S.Hab.10.2 plots 63 Hz and 125 Hz 1/3 octave frequency band sound levels near a hydrophone for multiple US regions, including CBNMS. At the CBNMS location, 2016-2017 median sound levels were 99.5 and 98 dB at 63 Hz and 125 Hz, with higher levels at 63 Hz in fall months due to seasonal peaks in whale calling activity. From this study it is apparent that sound levels at locations in some other US regions (e.g., the Gulf of Mexico and in the Northeast Canyons in the North Atlantic) are considerably higher than levels measured in CBNMS, while levels in other US regions are considerably lower (e.g., Hawaii). Additional monitoring efforts through the Sanctuary Soundscape Monitoring Project (SanctSound) evaluated 63 Hz and 125 Hz third octave levels over three years at vessel-influenced locations north and south of CBNMS including Olympic Coast, Monterey Bay and Channel Islands national marine sanctuaries (Wall et al., 2021). Median sound levels at Monterey Bay and Olympic Coast were broadly comparable to recordings in CBNMS, with median levels at 63 Hz and 125 Hz ranging 98-100 dB. Median levels at traffic-influenced sites in Channel Islands were 88-91 dB in the same bandwidths. By way of comparison, sound levels in nationally-distributed sanctuary habitats with marginal exposure to vessel traffic generally ranged between 70 and 80 dB median values in these frequency bands, while those with moderate exposure saw median values between 80 and 90 dB over multi-year recording effort.

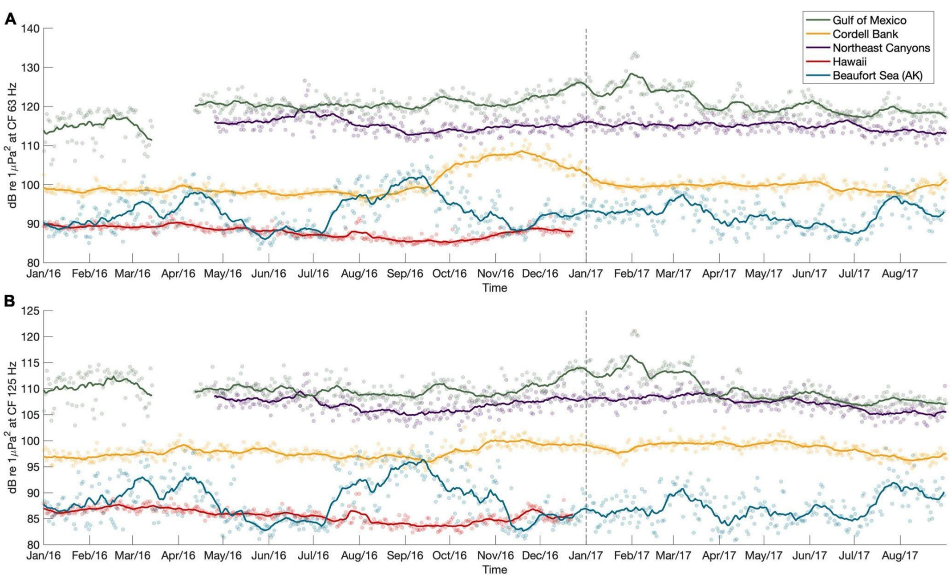


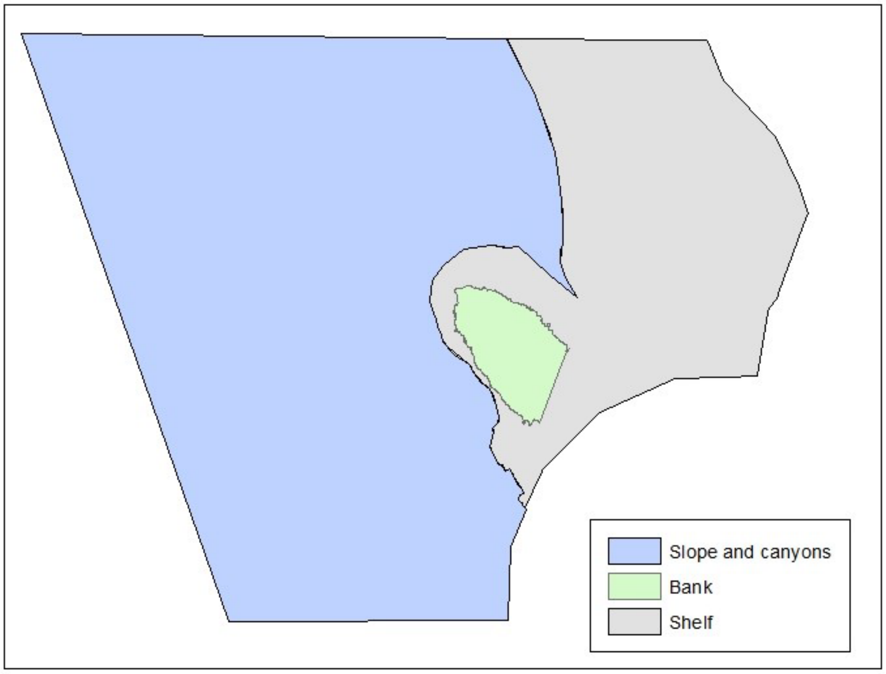
Figure S.Hab.10.2. Daily one-third octave band sound pressure level measurements for 63 Hz **(A)** and 125 Hz **(B)** center frequencies (scatter plot) and overlaid 14-day moving average for five deep-water autonomous underwater hydrophone moorings from January 2016 through August 2017. Each mooring site is color-coded: Gulf of Mexico-green, Cordell Bank National Marine Sanctuary-yellow, Northeast Canyons and Seamounts National Monument-purple, Hawaii-red, Beaufort Sea Alaskan Arctic-blue. Image: Haver et al., 2021

Although useful for coarsely benchmarking the influence of vessel noise on a habitat, the development of EU thresholds for underwater noise conditions in specific habitats has highlighted the importance of representing both the amount of time and the amount of area over which noise levels exceed levels of concern within bandwidths that are important to listening and vocalizing animals. TG Noise recently finalized a framework for setting threshold values beyond which noise has the potential for compromising the health of populations of marine organisms (Sigray et al., 2021). This framework highlights the importance of long term monitoring information as well as spatial modeling in order to establish targets for reducing both the spatial extent (dominance) and time extent (exceedance) for where and when noise levels are greater than a “level of onset of significant effect” (LOSE). This LOSE value is considered to vary regionally and even subregionally based on the vulnerability of acoustically-sensitive taxa to acoustic disturbance, communication masking and lost listening opportunity. Continued monitoring at CBNMS as well as spatial modeling evaluation of priority sanctuary habitats will be necessary to evaluate threshold conditions and trends. The NRS data collected 2015-2017 serve as a baseline for future recordings and analysis (Appendix.X.10.13).

Conclusion

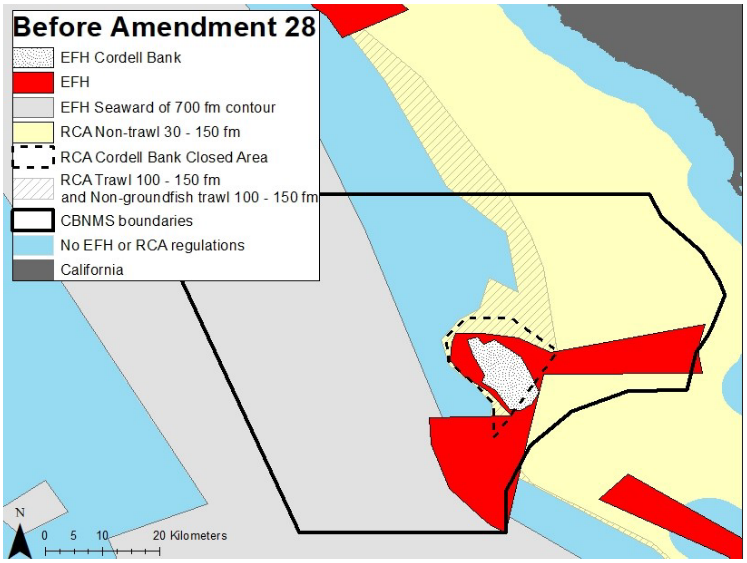
Habitat integrity data indicators demonstrate different levels of impacts. Information is limited on the direct impacts to benthic habitats and living resources by these activities, which limits the assessment of whether impacts are severe. Instead, the assessment relied on interpreting levels of human activities in these habitats. Fishing effort is at relatively low levels of activity, compared to some other areas on the west coast, while marine debris is present across all habitat types and the acoustic environment is being impacted by noise from commercial shipping. Trawling has the potential to impact bottom habitat, but at generally low levels since trawl contact has decreased and in certain types of habitat (e.g., soft sediment) the impacts may not be severe. The sanctuary is an important habitat for marine mammals and high levels of chronic low frequency sound from vessel traffic is a concern for animals that generate and use low frequency sound. Marine debris is known to impact habitat integrity. Therefore, selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity. The trends of each indicator are also variable. Benthic indicator trends based on fishing activity appear to be improving, pelagic indicators appear either not changing (stable) or worsening, leading to an overall trend assessment of mixed.

Appendix Figures

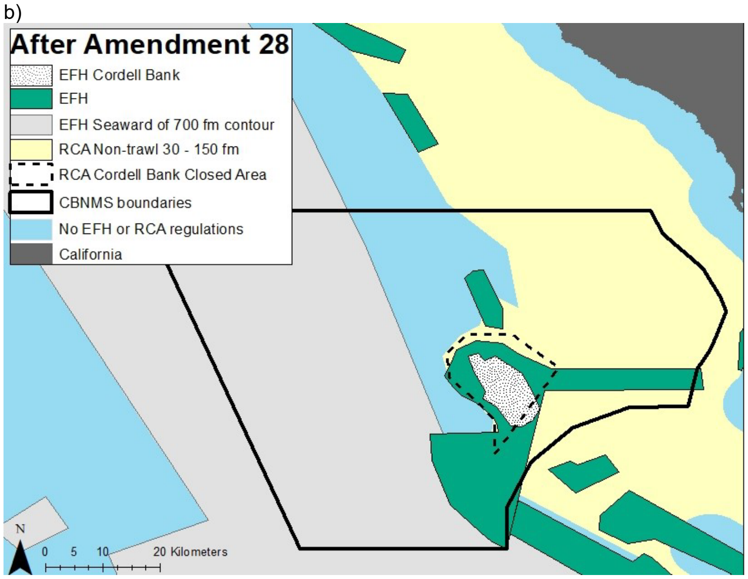


Appendix.X.10.1. The total area of CBNMS is 1,286 mi^2 and includes the continental shelf (356mi^2), Cordell Bank (36 mi^2) and continental slope and canyons (894mi^2). Image: CBNMS.

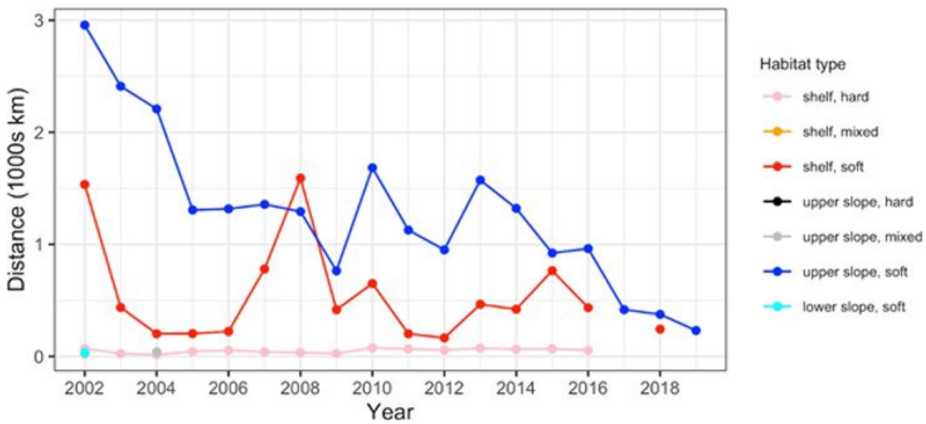
a)



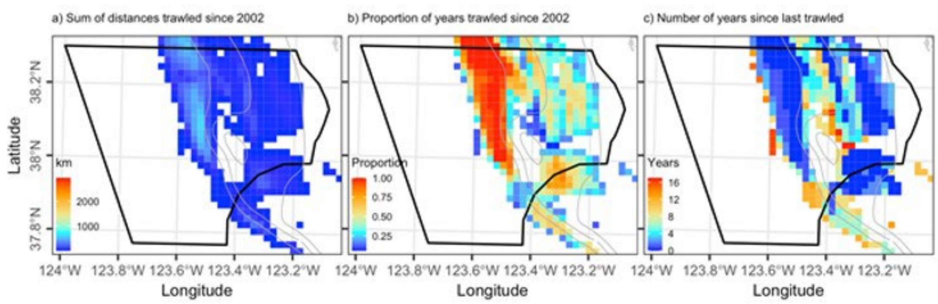
b)



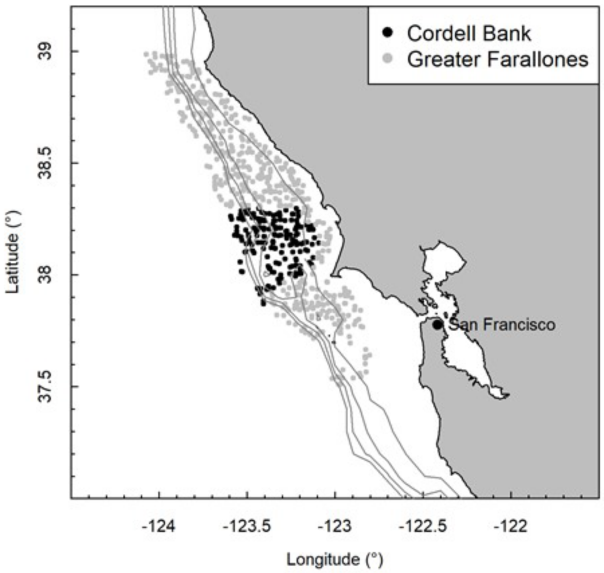
Appendix.X.10.2. Fisheries management areas (EFH and RCA) in CBNMS managed by the Pacific Fisheries Management Council a) first implemented in 2005-2006 and b) modified through Amendment 28 in January 1, 2020. Image: CBNMS.



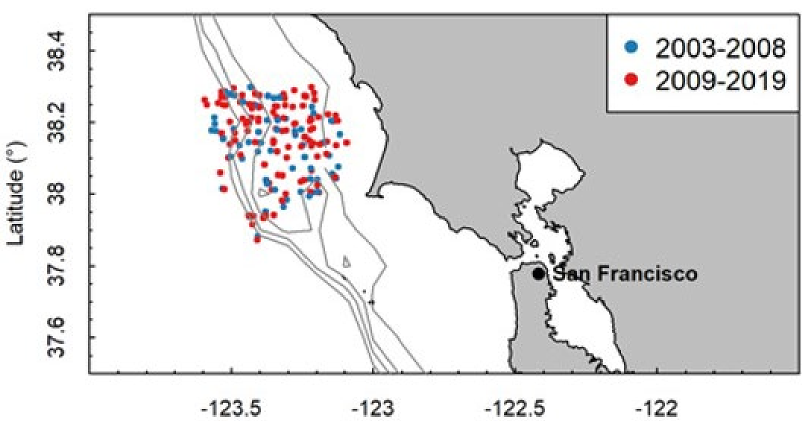
Appendix.X.10.3. Distance of seafloor contact among habitat types by bottom trawl gear from federal groundfish fisheries operating within the boundaries of CBNMS (2002-19). Disconnected lines are due to no trawling in specific years or because < 3 vessels trawled in the spatial domain and are confidential. Image: Data from NOAA's Northwest Fisheries Science Center's Fisheries Observation Science Program, analyzed by CCIEA.



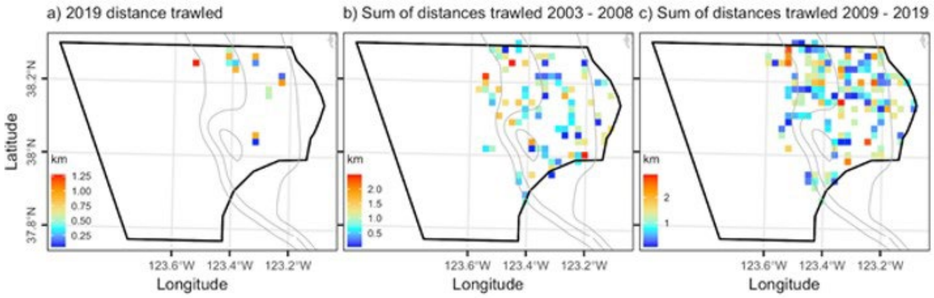
Appendix.X.10.4. Spatial representation of seafloor contact by bottom trawl gear from federal groundfish fisheries operating within CBNMS and nearby areas, calculated from annual distances trawled within each 2x2 km grid cell from 2002–19. Left(a): sum of distance trawled – legend is scaled to distances trawled across the entire US West Coast. Middle(b): proportion of years with > 0 distance trawled. Right(c): number of years since last bottom trawl gear activity. Gray lines represent 100, 200 and 500-m depth contours. Grid cells with < 3 vessels operating within the time period represented have been removed due to confidentiality. Image: Data from NOAA's Northwest Fisheries Science Center's Fisheries Observation Science Program, analyzed by CCIEA.



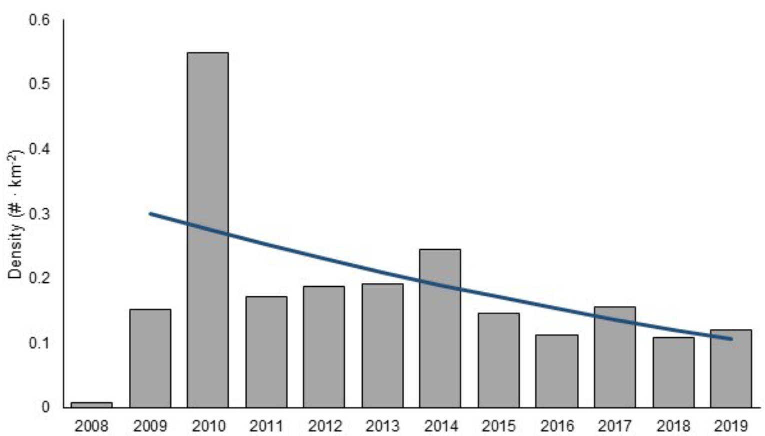
Appendix.X.10.5. Locations of permitted research trawls concluded by NOAA's Northwest Fishery Science Center Groundfish Survey in CBNMS and GFNMS from 2003-2019. Research trawls occur from the sanctuary's eastern boundaries to about 400m depth. Gray lines represent 100, 200, 300 and 400m depth contours. Image: NOAA/NWFSC.



Appendix.X.10.6. Locations of permitted research trawls concluded by NOAA's Northwest Fishery Science Center Groundfish Survey in CBNMS from 2003-2008 (blue dots) and 2009-2019 (red dots). Research trawls occur from the sanctuary's eastern boundaries to about 400m depth. Gray lines represent 100, 200, 300 and 400m depth contours. Image: NOAA/NWFSC.

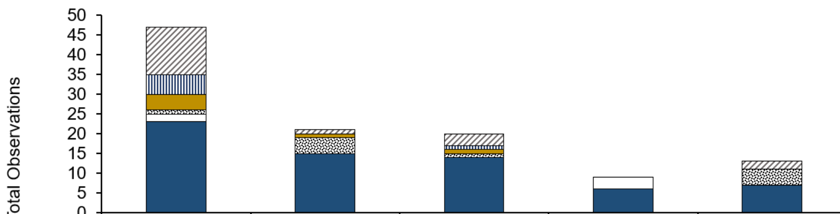


Appendix.X.10.7. Spatial representation of seafloor contact by bottom trawl gear from NOAA's Northwest Fishery Science Center Groundfish Survey within CBNMS, calculated from annual distances trawled within each 2x2 km grid cell from 2003–2019. Left(a): most recent year's distance trawled. Middle(b): total sum of distance trawled from 2003–2008. Right(c): total sum of distance trawled from 2009–2019. Gray lines represent 100, 200 and 500-m depth contours. Image: Data from NOAA's Northwest Fisheries Science Center's Fishery Resources, Analysis and Monitoring Program, analyzed by CCIEA.



Appendix.X.10.8. Abundance of marine debris (#/km^2) observed on ACCESS lines 1-7 in CBNMS and GFNMS from 2008-2019. Marine debris types include out of season crab pots, balloons, styrofoam, wood debris and garbage such as plastic bags, bottles and floats. The vertical red line indicates the year of the last condition report (2009). Image: Point Blue Conservation Science.

a)



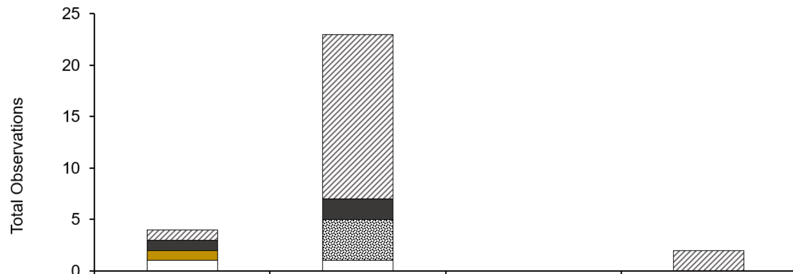
	2002	2003	2004	2005	2017
Trash	12	1	3	0	2
Gillnet	5	0	1	0	0
Cable	4	1	1	0	0
Monofilament line	1	4	1	0	4
Other fishing line	2	0	0	3	0
Longline	23	15	14	6	7

b)

TOTAL	**2002**	**2003**	**2004**	**2005**	**2017**
Marine Debris	47	21	20	9	13
Dives	31	10	12	7	12
Dives with Debris	22 (71%)	8 (80%)	11 (92%)	5 (71%)	5 (42%)

Appendix.X.10.9. a) Abundance (total observations, not standardized for effort) of benthic marine debris by type observed on Cordell Bank from submersible dives from 2002-2005 and ROV dive in 2017. Some marine debris was removed in 2008 during a dedicated marine debris removal ROV cruise. b) Table of marine debris counts and dive effort depicted in histogram. Image: CBNMS

a)

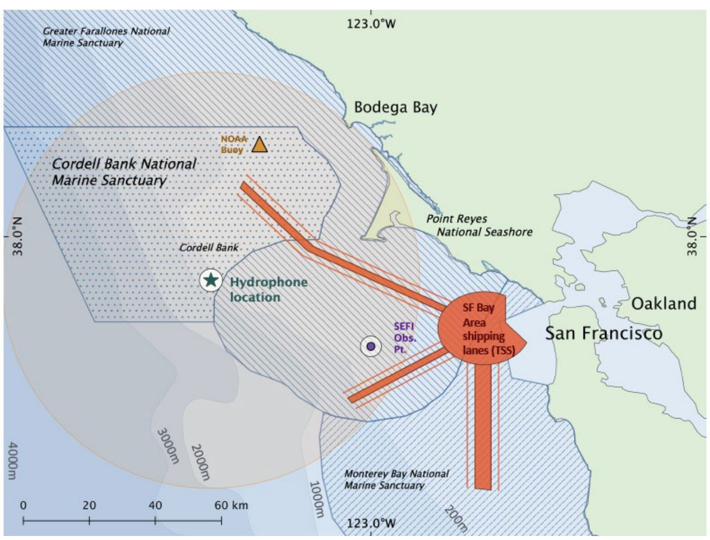


	2014	2017	2018	2019
Trash	1	16	0	2
Trawl net	1	2	0	0
Cable	1	0	0	0
Monofilament line	0	4	0	0
Other fishing line	1	1	0	0

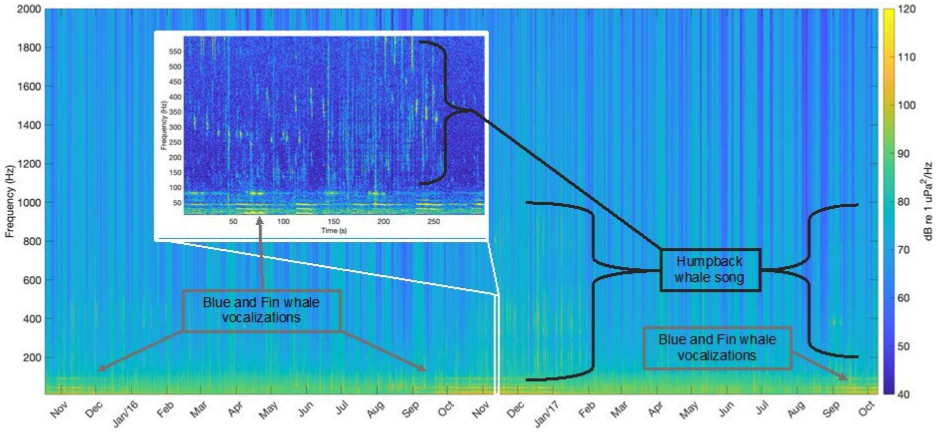
b)

TOTAL	2014	2017	2018	2019
Marine Debris	4	23	0	2
ROV Bottom Time (hr)	4:51	76:29	2	26:25
Depth Range (m)	273-306	740-2700	415-626	1784-3318

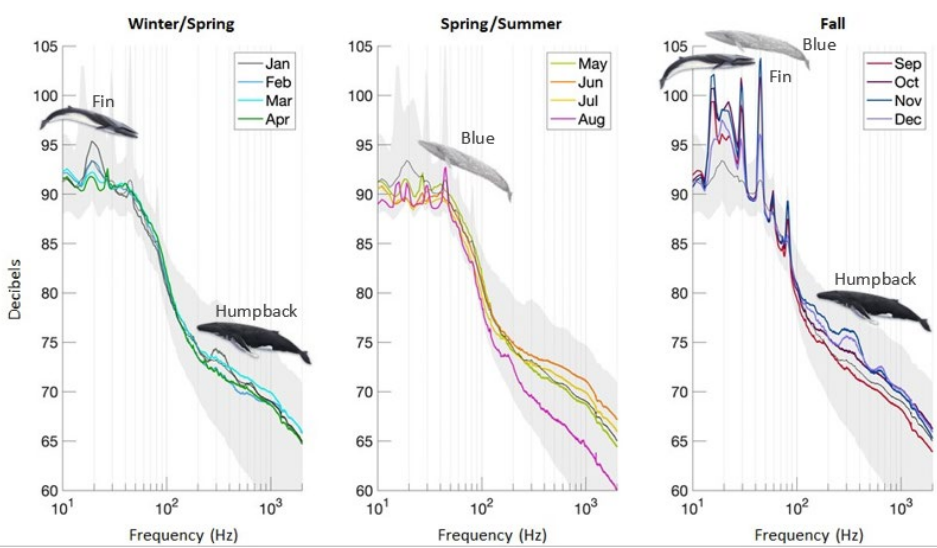
Appendix.X.10.10. a) Abundance (total observations, not standardized for effort) of benthic marine debris by type observed on CBNMS deep slope and canyons from ROV dives in 2014, 2017-2019. b). Table of marine debris counts and dive effort as depicted in histogram. Image: CBNMS



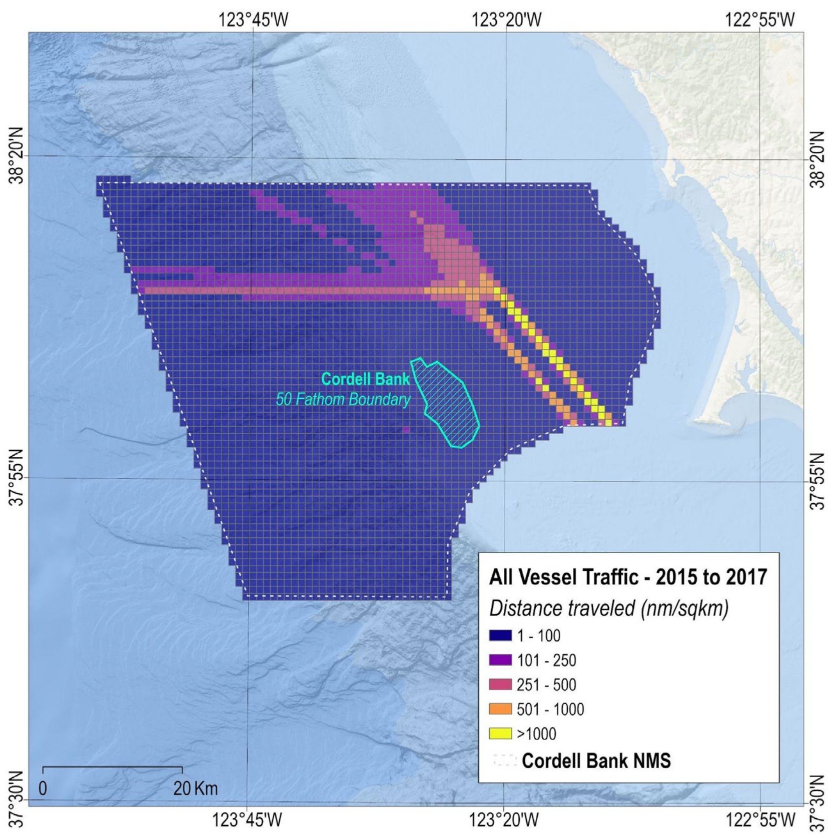
Appendix.X.10.11. Location of a stationary, bottom-mounted Noise Reference Station (NRS) hydrophone deployed in October 2015. The CBNMS NRS is located near the southern border of the sanctuary, approximately 30 kilometers offshore of the northern approach San Francisco Bay Area traffic separation scheme shipping lane. Image: Haver et al., 2020.



Appendix.X.10.12. Plot of CBNMS noise reference station (NRS) data analyzed from Oct 2015 - Oct 2017 across 10 Hz - 2 kHz frequencies in 1 hr/1 Hz bins. Soundscape dominated by ships and whales. Blue and fin whales most audible in Fall >100 Hz and humpback whales detected year-round; most prominent in fall and winter. Vessel detected year-round with minimal seasonal variation. Image: Haver et al., 2020.



Appendix.X.10.13. Seasonal plots (winter/early spring, late spring/summer, and fall) when different whale species contribute to ambient sound levels. Data analyzed from CBNMS noise reference station (NRS) as 10 Hz - 2 kHz acoustic data average in 1 hr/1 Hz bins. Lines are 2-year average median sound level at each frequency in each month of the year. The colored lines represent single months. The gray shading indicates the 10th-90th percentiles of sound levels (i.e., all sound except for the most extreme loud and quiet). Fin and humpback whales are heard in winter/spring, blue whales in spring/summer, and fin, humpback, and blue whales (peak activity) in fall. Image: Haver et al., 2020.



Appendix.X.10.14. Vessel traffic from 2015-2017 in CBNMS as distance traveled (nm/sq km). Data source: USCG. Data visualization: NCCOS.

Question 10 Literature Cited

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Question 11: What are contaminant concentrations in sanctuary habitats and how are they changing?

Status: Undetermined (medium confidence)
Trend: Undetermined (medium confidence)
Status Description: N/A
Rationale: This rating is based on the lack of data for the CBNMS region on contaminants in the water column, sediments and animal tissues. Based on other ocean areas, stressors of concern for CBNMS include persistent contaminants and microplastics in the water column, sediments, and resident species; these are data gaps that should be considered as targets for future research efforts. Very little information is available on trends for any of the indicators.

Comparison to the 2009 Condition Report
In 2009, the status and trend of contaminant concentrations in CBNMS were both rated as undetermined due to a lack of data (see Table S.H.10.1). Sediment samples taken within CBNMS indicated that Dichloro-Diphenyl-Trichlorothane (DDTs), polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) were present in low levels (Hartwell, unpublished data).

New Information in the 202__ Condition Report

In this assessment, the status and trend of contaminants are again rated undetermined, as there continues to be a lack of information in CBNMS regarding contaminant levels in the water column, sediments, and animal tissues. While we are not aware of any direct measurements of contaminants made within CBNMS since 2009, indirect contaminant measurements have been made in the region. Although these data must be interpreted with caution, they provide an indication of contamination that could be present in the sanctuary (Table S.H.10.2).

Table S.H.11.1. Status and trends for individual indicators discussed at the March 29, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Contaminants in harbor seals	Multiple (pub. lit.)/Denise Greig	Pelagic/ Coastal	Status: Levels of concern in seals Trend: undetermined	S.H.11.1
Contaminants in fish	San Francisco Estuary Institute, Surface Water Ambient Monitoring Program, California Environmental Data Exchange Network	Pelagic/ Coastal	Status: Mercury levels of concern in fish Trend: undetermined	Table App.X.11.1
Fukushima radiation	Multiple (pub. lit.)/NCCOS	Pelagic	Status: No levels of concern Trend: Any radiation would diminish over time	None

<u>Contaminants in animal tissue</u>

Due to a lack of direct measurements of contaminants in sanctuary habitats, contaminants in local harbor seals and fish, as well as organisms from the Fukushima earthquake and radiation event were considered as proxies. Harbor seals are known to swim through and feed in CBNMS (Carretta et al., 2021; Elliott et al., 2019). Mercury levels were measured in harbor seal pups from 2002 to 2017 (Figure S.H.11.1; Brookens et al., 2007; Brookens et al., 2008; Van Hoomissen et al., 2015; McHuron et al., 2019). These measurements were taken from stranded animals admitted to The Marine Mammal Center for rehabilitation or captured and released in the wild along the outer coast of Marin, Sonoma, and Mendocino counties, three counties animals coming from sanctuary waters were hypothesized to use (San Francisco County was not included due to a lack of rookeries). Animals were collected on land, therefore no animals were collected from within the sanctuary. Mercury was present in all the harbor seals and there were no discernable patterns in mercury levels during this study period (note: there were no published data in 2005, 2009, 2010 or 2011). Of concern, many of these pups had levels exceeding 30 ug/g dry weight, which is a threshold where neurological effects have been observed in other fish eating wildlife (Basu et al., 2007). These data indicate that mercury exists in the environment located in close proximity to the sanctuary. However, it is important to note that while these animals may have passed through and/or fed in CBNMS, the contaminants cannot be directly linked to sources within the sanctuary, as they bioaccumulate and may have been picked up throughout the region, such as in San Francisco and Tomales bays, which are known to have elevated levels of mercury (Davis et al., 2002, Hornberger et al., 1999, Martin et al., 1984, Ohlendorf et al., 1988) and where harbor seals are known to occur.

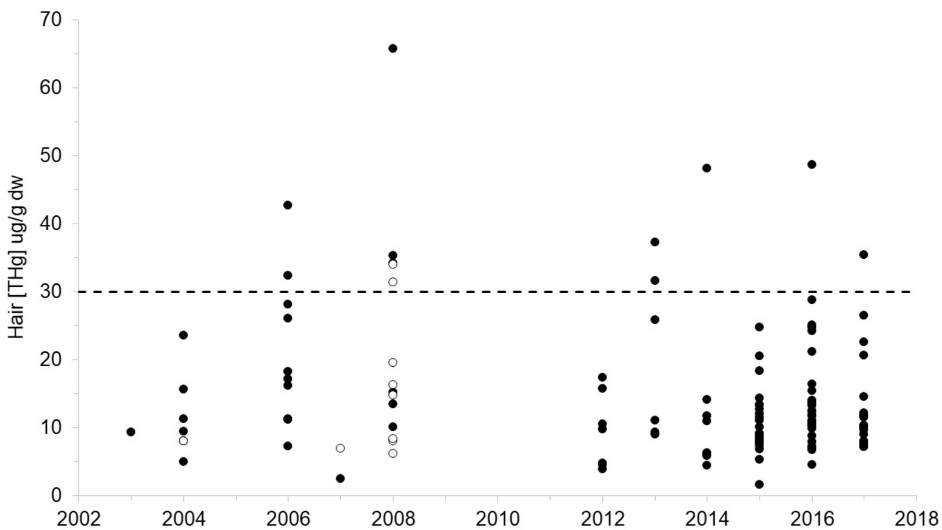

Figure S.H.11.1. Mercury concentrations in the hair of stranded harbor seal pups (n=128) that were admitted for rehabilitation at The Marine Mammal Center (black circles) or that were captured and released in the wild (white circles) along outer coast of Marin, Sonoma and Mendocino counties (counties located closest to CBNMS). The black dashed line indicates the level at which neurological effects have been observed in fish-eating wildlife (Basu et al., 2007). No samples were taken in 2005, 2009, 2010, and 2011. Data compiled from Brookens et al., 2007, Brookens et al., 2008, Van Hoomissen et al., 2015, and McHuron et al., 2019. Figure: Denise Greig.

As part of a state-wide program that monitors fish for human consumption, contaminant levels were measured in fish from coastal sites between Año Nuevo and Jenner, California (including the Farallon Islands, the only offshore site) in 2009 and 2010 (Table App.X.11.1; Davis et al., 2010). No samples were collected in CBNMS. At each location, five species were sampled (species varied between sampling sites); most species selected had been used previously to detect contamination. At least one species from each sampling location contained levels of mercury that exceeded a threshold for concern and should either be limited or excluded from a person's diet (based on assessment of human health risk by the California Office of Environmental Health Hazard Assessment (OEHHA); Klasing & Brodberg, 2008). Only one species from one site exceeded an OEHHA threshold for concern in PCBs (barred surfperch, which has not been observed in CBNMS and is typically found nearshore). No fish from any sampling sites in the region exceeded the thresholds for DDTs, selenium, chlordanes, and dieldrin. These data suggest that fish in the general region, including the sanctuary, could contain concerning levels of mercury, particularly species that are relatively long-lived and prone to bioaccumulation (Davis et al., 2010). However, studies that include samples from CBNMS will be required to test this hypothesis, particularly as many of these fish species demonstrate site fidelity.

Fukushima earthquake

The 2011 Fukushima earthquake and the subsequent nuclear accident at the Fukushima Daiichi Nuclear Power Plant in Japan is a source of concern for contamination. The majority of radiation that leaked from the power plant was in the form of radiocesium (Cs), which dilutes rapidly and has a short half-life (Buesseler et al., 2017). While radiation impacts have been documented for biota in the nearshore environment in the Fukushima region, current levels are below thresholds considered harmful for human consumption (Buesseler et al., 2012) and similar to general background fallout from nuclear weapons testing (Buesseler et al., 2017). On the west coast of North America, detectable Fukushima radionuclides were not above pre-incident levels in several predatory migratory species caught from 2012 to 2015 (Madigan et al., 2017) or in fish caught from 2008 to 2012 (Neville et al., 2014), and most migration-aged fish did not exhibit any Cs accumulation, suggesting they had not recently migrated near Japan (Neville et al., 2014). However, the presence of Cs in fish (tuna) caught in the Eastern Pacific Ocean indicates additional studies are warranted for migratory fish and marine mammals (Madigan et al., 2012).

Conclusion

Currently, information on contaminants in CBNMS and the surrounding region is sparse, preventing the assessment of status and trend. The sanctuary's regulation prohibiting certain types of material discharging into the sanctuary is intended to reduce pollution and contamination; however many contaminants are widespread throughout the ocean. Additionally, the offshore location and relative inaccessibility of CBNMS may mitigate some of the harmful effects of coastal pollutants and direct human impacts. However, given the sanctuary's proximity to San Francisco Bay, increasing our understanding of contaminants in CBNMS is particularly important. While outflow from San Francisco Bay typically moves southward, strong freshwater runoff or weak winds can cause water to move northwards, in the direction of the sanctuary (Largier, 2020). Storm events that are strong enough to bring land based pollution from San Francisco Bay or the Russian River are uncommon. What little evidence we have of regional contaminants indicates that legacy contaminants are present in the environment. More work is needed to understand contaminant concentrations, transport pathways and changes in contaminant concentrations over time, particularly considering that sanctuary stressors could be exacerbated when combined (e.g., climate change and contamination).

Figures for APPENDIX (to be moved when report is compiled)

Table App.X.11.1[2]

Contaminant levels measured in fish, in parts per billion wet weight. Sample locations range from South Sonoma Coast/North Sonoma Coast to San Mateo Coast. Sample types are either composites (C) or

Commented [12]: Move and number footnote in Appendix

[2] These data sets and figures were not presented to experts during the status and trends workshop.

averages of individuals (A). Asterisks next to contaminant measurements indicate advisories have been issued based on assessment of human health risk by OEHHA (Klasing & Brodberg, 2008): * indicates 2 servings/week, ** indicates 1 serving/week, *** indicates no consumption. Data: San Francisco Estuary Institute, Surface Water Ambient Monitoring Program, and the California Environmental Data Exchange Network.

Location	Species	Year sampled	Sample type	Mercury	DDTs	PCBs	Selenium	Chlor-danes	Dieldrin
South Sonoma Coast/North Sonoma Coast	Blue Rockfish	2010	C	ND	ND	1.89	400	ND	ND
South Sonoma Coast/North Sonoma Coast	Blue Rockfish	2010	A	70*	ND	ND	ND	ND	ND
South Sonoma Coast/North Sonoma Coast	Brown Rockfish	2010	C	400**	1.89	1.33	270	ND	ND
South Sonoma Coast/North Sonoma Coast	Copper Rockfish	2010	C	590***	2.46	1.04	300	ND	0.45
South Sonoma Coast/North Sonoma Coast	Olive Rockfish	2010	C	ND	ND	ND	320	ND	ND
South Sonoma Coast/North Sonoma Coast	Olive Rockfish	2010	A	110*	ND	ND	ND	ND	ND
South Sonoma Coast/North Sonoma Coast	Vermilion Rockfish	2010	C	330**	2.52	0.68	340	ND	0.57
Bodega Harbor	Leopard shark	2010	C	ND	1.29	1.17	180	ND	ND
Bodega Harbor	Leopard shark	2010	A	1370***	ND	ND	ND	ND	ND
Bodega Harbor	Rainbow Surfperch	2010	C	ND	0.51	ND	80	ND	ND

Bodega Harbor	Rainbow Surfperch	2010	A	60	ND	ND	ND	ND	ND
Northern Marin Coast	Blue Rockfish	2009	C	ND	0.67	ND	450	ND	ND
Northern Marin Coast	Blue Rockfish	2009	A	60	ND	ND	ND	ND	ND
Northern Marin Coast	Brown Rockfish	2009	C	240**	2.21	1.65	280	ND	ND
Northern Marin Coast	Olive Rockfish	2009	C	ND	0.7	ND	470	ND	ND
Northern Marin Coast	Olive Rockfish	2009	A	40	ND	ND	ND	ND	ND
Southern Marin Coast	Barred Surfperch	2009	C	200**	12.31	18.32	450	1.5	0.49
Southern Marin Coast	Barred Surfperch	2009	A	140*	ND	ND	ND	ND	ND
Southern Marin Coast	White Croaker	2009	C	210**	1.3	1.96	290	ND	ND
Farallon Islands	Blue Rockfish	2009	C	ND	1.71	ND	620	ND	ND
Farallon Islands	Blue Rockfish	2009	A	40	ND	ND	ND	ND	ND
Farallon Islands	Gopher Rockfish	2009	C	290**	2.28	0.29	330	ND	ND
Farallon Islands	Olive Rockfish	2009	C	ND	3.03	0.21	540	ND	ND
Farallon Islands	Olive Rockfish	2009	A	140*	ND	ND	ND	ND	ND
San Francisco	Barred Surfperch	2009	C	110*	21.7	35.77*	210	3.07	0.6

San Francisco	Barred Surfperch	2009	A	140*	ND	ND	ND	ND	ND
San Francisco	White Croaker	2009	C	240**	3.24	4.98	310	ND	ND
Pacifica Coast	Blue Rockfish	2009	C	ND	3.33	1.55	520	ND	ND
Pacifica Coast	Blue Rockfish	2009	A	80*	ND	ND	ND	ND	ND
Pacifica Coast	Gopher Rockfish	2009	C	340**	1.66	0.56	320	ND	ND
Pacifica Coast	Lingcod	2009	C	420**	9.98	8.11	250	0.35	ND
Half Moon Bay Coast	Barred Surfperch	2009	C	ND	2.71	0.57	370	ND	ND
Half Moon Bay Coast	Barred Surfperch	2009	A	200**	ND	ND	ND	ND	ND
Half Moon Bay Coast	Blue Rockfish	2009	C	ND	0.98	ND	410	ND	ND
Half Moon Bay Coast	Blue Rockfish	2009	A	70*	ND	ND	ND	ND	ND
Half Moon Bay Coast	Blue Rockfish	2010	A	70*	ND	ND	ND	ND	ND
Half Moon Bay Coast	Brown Rockfish	2009	C	260**	1.97	3.22	290	ND	ND
Half Moon Bay Coast	Gopher Rockfish	2009	C	260**	1.39	0.52	360	ND	ND
Half Moon Bay Coast	Lingcod	2009	C	270**	12.11	4.95	300	0.35	ND
Pillar Point Harbor	Black Perch	2009	C	ND	1.69	0.63	180	0.3	ND

Pillar Point Harbor	Black Perch	2009	A	60	ND	ND	ND	ND	ND	
Pillar Point Harbor	Shiner Surfperch	2009	C	60	12.99	12.72	230	2.56	ND	
Pillar Point Harbor	Shiner Surfperch	2009	A	60	ND	ND	ND	ND	ND	
Pillar Point Harbor	Topsmelt	2009	C	90*	15.81	11.54	230	1.75		0.51
Pillar Point Harbor	White Croaker	2009	C	100*	3.38	3.27	270	0.28	ND	
Pillar Point Harbor	White Surfperch	2009	C	60	6.86	5.26	190	1.74	ND	
Pillar Point Harbor	White Surfperch	2009	A	70*	ND	ND	ND	ND	ND	
San Mateo Coast	Black Rockfish	2009	C	ND	2.65	0.29	380	ND	ND	
San Mateo Coast	Black Rockfish	2009	A	50	ND	ND	ND	ND	ND	
San Mateo Coast	Blue Rockfish	2009	C	ND	1.57	ND	360	ND	ND	
San Mateo Coast	Blue Rockfish	2009	A	50	ND	ND	ND	ND	ND	
San Mateo Coast	Gopher Rockfish	2009	C	430**	3.34	0.24	360	0.23	ND	
San Mateo Coast	Olive Rockfish	2009	C	ND	4.63	3.01	330	0.23	ND	
San Mateo Coast	Olive Rockfish	2009	A	150*	ND	ND	ND	ND	ND	

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This is the post-peer review version of the CBNMS Condition Report. It is now locked and a new copy has been created for copy edits.

Status and Trends of Living Marine Resources (Questions 12–15)

The following information describes the status and trends of living marine resources inside CBNMS from 2009–2021. The term “living marine resources” encompasses a range of organisms in CBNMS, including keystone, foundation, focal, and non-indigenous species. The status for a species describes changes to their abundance compared to their historical abundance. The historical time period used for comparison depends on data availability and differs across indicators. The trend for a species describes changes to their abundances from 2009–2021. Each of the living marine resource questions focus on specific groups of species in CBNMS.

Question 12 evaluates changes to foundation species (e.g., benthic macroinvertebrates, calanoid copepods, and krill), which are critical to maintaining CBNMS’s ecosystem structure, function, and stability over time.

Question 13 is centered around focal species (e.g., whales, seabirds, leatherback turtles, rockfish, benthic fish on Cordell Bank, and benthic fish and invertebrates on shelf habitat), which may not be abundant or be key to CBNMS’s ecosystem function, but their presence and health is important for the provision of economic, cultural, spiritual, recreational, ecological, or conservation-related values and services. Some focal species discussed here (e.g., whales and turtles) are also threatened or endangered and protected under state and/or federal laws.

Question 14 focuses on the impacts of non-indigenous species (e.g., green crabs and other invertebrates), which are not native to the region. Also called alien, exotic, non-native, or introduced species, these are animals or plants living outside their endemic geographical range. Often having arrived in the sanctuary as a result of human activity, either deliberately or accidentally, their abundance in sanctuary habitats along with any known ecological impacts will be discussed. These species are of concern because they have the potential to impact CBNMS’s ecosystem structure and function, at which point they are considered invasive species.

Lastly, Question 15 addresses the status of biodiversity, which is defined as variation of life at all levels of biological organization and commonly encompasses diversity within species (genetic diversity), among species (species diversity), and comparative diversity among ecosystems (ecosystem diversity). Biodiversity can be measured in many ways. The simplest measure is to count the number of species found in a certain habitat or ecosystem, termed species richness. Other indices of biodiversity couple species richness with relative abundance to provide a measure of evenness and heterogeneity. When discussing “biodiversity” in response to Question 15, the report primarily refers to diversity indices and the abundance of species that influence the integrity of food webs and other aspects of ecosystem function.

Table S.LR.12.1. 2009 Condition Report ratings (left) and 2009–2021 Condition Report ratings (right) status, trend, and confidence ratings for the living resources questions.

2009 Condition Report Questions		2009 Rating	2009–2021 Condition Report Questions		2009–2021 Condition Report Rating			
					Status	Confidence (Status)	Trend	Confidence (Trend)
12	Status of key species	▲	12	Keystone & foundation species	Good/Fair	High	?	High
13	Condition/health of key species	—	13	Other focal species	Fair	High	▲▼	High
11	Non-indigenous species	?	14	Non-indigenous species	Good	Medium	?	Low
9	Biodiversity	▲	15	Biodiversity	Good/Fair	High	—	High

Question 12: What is the status of keystone and foundation species and how is it changing?

Status: Good/Fair (high confidence)
Trend: Undetermined (high confidence)
Status Description: The status of keystone or foundation species may preclude full community development and function, but has not yet led to measurable degradation
Rationale: Foundation species at CBNMS include benthic macroinvertebrates (deep-sea corals and sponges), krill, and calanoid copepods. The abundance and health of corals and sponges appears to be good, however, long term trends are not known due to a lack of historic baseline data. Krill and copepod abundance and composition fluctuated during the assessment period, particularly in association with marine heatwaves.

Keystone species are organisms on which a large number of other species in the ecosystem depend (Paine, 1969), and their contribution to ecosystem function is disproportionate to their abundance or biomass. We did not identify keystone species as data indicators for CBNMS and focused on foundation species. Foundation species are single species that create locally stable conditions for other species (Dayton, 1972). These are typically the dominant biomass producers (e.g., mussels, hake, anchovy, krill) in an ecosystem, and they can strongly influence the abundance and biomass of many other species. Changes in either keystone or foundation species may transform ecosystem structure through disappearances of, or dramatic increases in, the abundance of dependent species.

Findings from the 2009 Condition Report
A direct comparison between the current rating and the 2009 condition report is not possible because this specific question was not previously addressed (Table S.LR.12.1). However, there were two questions in the 2009 condition report that assessed the status and condition and

health of “key species.” In 2009, the status of key species was rated fair with an improving trend and the condition or health of key species was rated good and not changing. In 2009, several indicator species appeared to have been negatively impacted by the combination of natural and human-induced forces. However, some (e.g., krill, blue whales, and Cassin’s auklet) that feed within the sanctuary exhibited healthy populations that were increasing. Additionally, stock assessments of many overharvested rockfish species that had been declared to be overfished in the early 2000’s, were increasing. The rating in the current report integrates the status and trends for numerous foundation species including benthic macroinvertebrate (particularly deep-sea corals and sponges), krill, and calanoid copepods.

New Information in the 20__ Condition Report

We did not identify keystone species, so this section focuses on foundational functional groups, including benthic macroinvertebrates (including deep-sea corals and sponges), calanoid copepods, and krill (Table S.LR.12.2). For the 2009–2021 study period, the status of these groups was good/fair (with high confidence) and the trend was undetermined (with high confidence).

Table S.LR.12.2. Status and trends for individual indicators discussed at the March 31, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Macroinvertebrates - Bank	CBNMS/CBNMS	benthic	Status: Densities appear to be good during the reporting time period Trend: no trend data	Figure App.EX.12.1 Figure App.E.12.2 Figure App.E.12.3
Coral health	CBNMS/CBNMS	benthic	Status: Low numbers of gorgonian corals are unhealthy Trend: no trend data	Figure S.LR.12.1 Figure App.E.12.4
Krill abundance	ACCESS/Point Blue	pelagic	Status:Densities are good but variable during the reporting time period Trend: variable among water temperature regimes	Figure S.LR.12.2
Krill size	ACCESS/Point Blue	pelagic	Status: Larger krill in cold water years Trend: variable in cold vs warm water years	Figure S.LR.12.3
Krill biomass	NOAA-NMFS/Farallon Institute	pelagic	Status: Good, decreases in 2015-2016 not as low as other areas Trend: Increase in 2013-14, then decrease	Figure App.E.12.5
Zooplankton - copepods	ACCESS/Point Blue	pelagic	Status: Generally high abundances of copepods, compositional changes with warm water Trend: Increasing	Figure S.LR.12.4

<u>Macroinvertebrate abundance on Cordell Bank</u>

The sanctuary conducted benthic characterization surveys on Cordell Bank in 2002 through 2005 using the human-occupied Delta submersible. As technological advances in underwater survey equipment became available after the publication of the 2009 condition report, sanctuary staff started using remotely operated vehicles (ROV) with high definition video and enhanced LED lights to survey the sanctuary's benthic habitats. Sanctuary research staff also held a workshop in 2016 with local experts to develop a long-term benthic monitoring plan for CBNMS (Lipski and Graiff, 2017). The plan identified stratified random locations on the bank from 70-120 meters and fixed locations (hereafter referred to as "fixed sites") on the bank's shallowest reef tops. The fixed sites were established to be repeatedly surveyed in order to track long term changes in benthic community assemblages.

Two of these shallow reef top fixed sites are North Point (<70 m depth) and Northwest Ridge (<76 m depth). Densities (per m^2) of foundation species of corals including California hydrocoral *(Stylaster californicus),* gorgonians (*Chromoplexaura* spp.), and sponges classified by morphology (foliose and mound) were compared at each fixed site using 2003 submersible data and 2017 and 2018 ROV data. The results showed there were significantly more foundation species in the 2017 and 2018 surveys, often more than doubling the densities of foundation species seen in 2003 (CBNMS unpublished data, 2021, Appendix.X.12.1, Appendix.X.12.2).This increase could be due to new individuals as a large majority of the foundation species quantified in 2017 and 2018 were small individuals (5-10 cm) that could have recently established on the Bank. We also need to consider that these smaller individuals were more easily detected and thus quantified due to the advancements in video and lighting technology on the ROV versus the technology used in 2003. As this cannot be determined at this time, quantifying the abundances of benthic invertebrate foundation species will continue to be a part of CBNMS's long-term monitoring surveys at the fixed sites to establish trend data for benthic communities.

A similar analysis was completed for the mid-depth habitats on Cordell Bank (70-120 m) as these habitats have different benthic structure and community assemblages than the shallower upper reefs. The foundation species selected were gorgonians (*Chromoplexaura* spp.) and foliose sponges. Densities (per m^2) were compared for all transects conducted within 70-120 m from 2002 and 2003 submersible data and 2017 ROV data. As on shallow reefs, the mid-depth habitats had higher abundances in the 2017 ROV data compared to the historic 2002 and 2003 submersible data (CBNMS unpublished data, 2021). The average density of *Chromoplexaura* spp. in 2017 was four times greater than the average density in 2002 and 2003 (Appendix.X.12.3). Additionally, the greatest frequency of *Chromoplexaura* spp. documented in 2017 were single stalked and 5 cm tall (18% of total, n=751) (Graiff et al., 2019). It is possible these are newly established individuals on the Bank, while also considering that the small individuals were better detected and quantified due to advancements in technology on the ROV versus submersible. Future surveys using ROVs will be conducted to establish trend data for monitoring long-term change.

<u>Coral condition</u>
To support the sanctuary's effort for long-term monitoring of foundation species, particularly deep-sea corals and sponges, the condition of individuals is classified during video analysis. Corals and sponges are of interest because they are long-lived and provide structure and habitat for other invertebrates and fish. During characterization, the condition of each coral and sponge is rated as either healthy (< 10% of organism is dead), unhealthy (10–50% is dead), or dead (> 50% of organism dead). Associations of other invertebrates (e.g., some could be predators) on the corals and sponges are also documented.

To assess the condition of gorgonian corals (*Chromoplexaura* spp.) on Cordell Bank, the percent of total *Chromoplexaura* spp. in each of the three condition categories was compared from ROV data collected in 2017 (48-119 m) and 2018 (84-55 m) (Graiff et al., 2019; Graiff and Lipski, 2020a, CBNMS unpublished data, 2021a). The results show that 86% and 90%, respectively for 2017 and 2018, of *Chromoplexaura* spp. are healthy. Fewer than 10% were classified as unhealthy and fewer than about 5% were classified as dead (Figure S.LR.12.1). The unhealthy or dead gorgonians were usually covered in amphipod tubes and others had associated zoanthids that colonize on dead or dying parts of the coral's skeleton. An unknown ovulid snail (possibly *Simnia* sp.) was also observed on the gorgonians, in highest abundance on healthy corals and lower abundance on dead or dying corals (Graiff et al., 2019). Ovulid snails are known to be predators on gorgonian corals (Williams, pers. comm., Gerhart, 1990; Goh et al., 1999) and zoantharians are known to be parasites on primnoid corals in the northeast U.S., progressively eliminating gorgonian tissue and then using the coral axis for structure and support, and coral sclerites for protection (Carreiro-Silva et al., 2017).

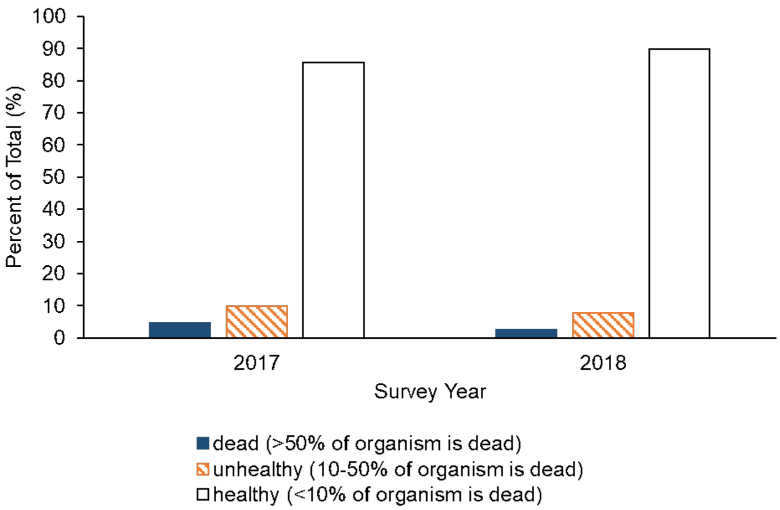


Figure S.LR.12.1. Percent of total *Chromoplexura* spp. gorgonians per condition category, healthy (< 10% of organism is dead), unhealthy (10–50% is dead), or dead (> 50% of organism dead), observed from ROV video collected in 2017 and 2018. Image: CBNMS.

Although the condition of corals with ovulid snails at Cordell Bank was classified as healthy, it is likely that the snails were grazing on the coral tissue, exposing a small area on the axis that could allow other organisms, such as commensal barnacles in the genus Conopea to settle (pers. comm., Gary Williams). After feeding, the snails move on to other healthy corals. This could explain why unhealthy and dying corals were often observed without snails. Conversely, zoanthids and amphipod tubes were always associated on dead or dying corals and likely colonized the structure once the corals' living tissue was eliminated and the axis was exposed. In addition, nudibranchs in the genus Tritonia have also been found on octocorals such as Chromoplexaura, and are presumed to graze on the surface tissues (Gary Williams/CAS, personal communication, March 9, 2022). To date, nudibranchs preying on Chromoplexaura have not been observed on Cordell Bank.

To assess trends in gorgonian condition for this report, videos from submersible surveys at Cordell Bank from 2002-2005 were reviewed because the condition of invertebrates was not classified during the initial analyses. Unfortunately, coral condition or associations could not be determined due to the low resolution and lighting of the submersible's video quality. This is a limiting factor in establishing trend data, but the sanctuary will continue to monitor coral condition on future benthic surveys.

Deep-water habitats on the CBNMS slope and canyons were previously unexplored for the writing of the 2009 condition report. ROV surveys conducted in 2017, 2018, and 2019 have focused on characterizing the seafloor in the sanctuary's deepest areas (415 – 3318 m) and subsequently classifying the condition of all deep-sea corals (Graiff and Lipski 2020a, Graiff and Lipski 2020b, Graiff and Lipski, in review). Although a long term data set has not been established, in general, the majority (>60%) of total *Swifita* spp. gorgonian corals observed in 2018 are healthy (Appendix.X.12.4). The sanctuary will continue to track the condition and associated taxa for these slow-growing and long-lived species.

<u>Krill</u>

Krill serve as the primary food source for many marine mammals, seabirds, and fish in marine food webs (Murphy, 2001). Large changes in krill population abundance and size are related to changing ocean conditions. Krill are monitored in CBNMS and GFNMS by the multidisciplinary pelagic monitoring program Applied California Current Ecosystem Studies (ACCESS). Offshore transect lines in the sanctuaries have been repeatedly sampled by ACCESS since 2004. ACCESS surveys are conducted three times a year, targeting oceanographic seasons. Krill data are collected along transects using acoustic technologies while the research ship is underway and by using collection nets at set sampling stations.

Densities of krill (*Euphausia pacifica* and *Thysanoessa spinifera*) from the ships' acoustic data from 2004-2019 show a variable trend not correlated to cold, average or warm year temperature regimes (Figure App.E.6.1) with overall higher abundances after 2009 in 2010, 2011, 2018), and lower densities in 2012 through 2016 (Figure S.LR.12.2, Elliott et al., 2020).

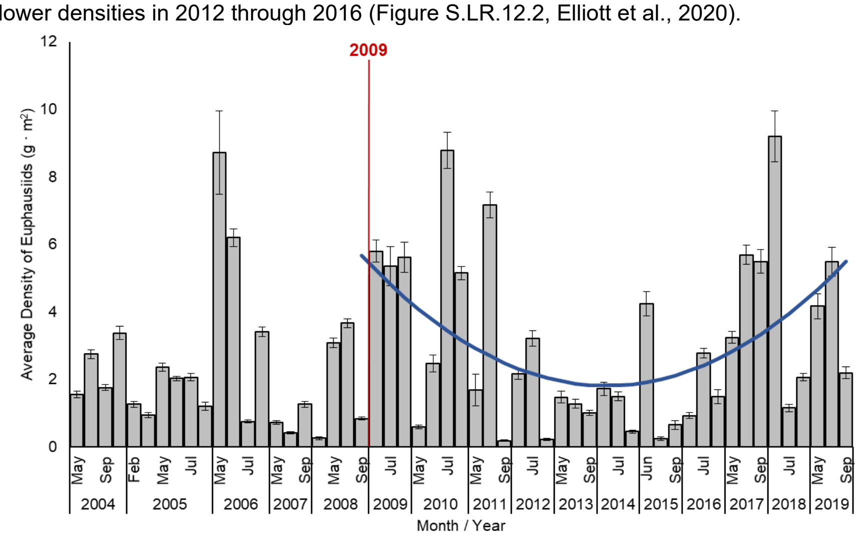


Figure S.LR.12.2. Average densities and standard error (grams standardized per m^2 of ocean surface) of krill (euphausiids) collected from acoustics data during ACCESS sampling on lines 1-7 to 200 m depth in CBNMS and GFNMS. Line shows polynomial trend for the data assessment period of this condition report 2009-2019. The vertical red line indicates the year of the last condition report (2009). Image: Elliott et al., 2020

The lengths of adult krill (*Euphausia pacifica*) are measured from ACCESS net samples. Figure S.LR.12.3 shows the length (mm) of *E. pacifica* collected during spring and summer surveys from 2005-2019. Smaller adult krill were found in warm water periods (e.g., 2005, 2014, and 2015). In addition to smaller krill, there were fewer adult krill captured during and after the marine heatwave years (2013-2017). Changes in krill abundance and size can have impacts on predator species. For example, Cassin's auklets are sensitive to climate-induced changes in prey availability, which can affect timing of breeding and breeding success (Wolf et al., 2009).

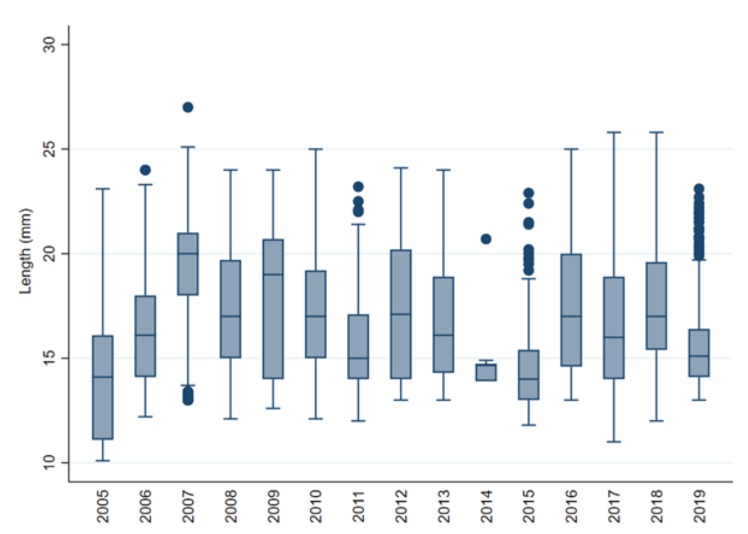


Figure S.LR.12.3. Length of adult krill *Euphausia pacifica* with means and data distribution collected from ACCESS Tucker trawls during spring and summer surveys (May-July) from 2005-2019. Smaller krill were found in warm water periods (2005, 2014 and 2015). Data: ACCESS; Visualization: Point Blue Conservation Science.

Krill biomass from acoustic data from 2012-2018 collected by the NOAA Rockfish Recruitment and Ecosystem Assessment Surveys and analyzed by the Farallon Institute shows some variability in CBNMS, and some differences from the ACCESS data. There was a large increase in krill biomass in 2013 and 2014 and decreased biomass for subsequent years through 2018, which was not seen in the ACCESS data (Appendix.X.12.5). However, looking at this data from the larger sampling region, including CBNMS and areas to the south, 2012-2014 were high to normal krill biomass years, followed by low biomass in 2015-2016 and increasing in 2017 to reach high biomass again in 2018. This highlights the natural variability in krill within the sanctuary and spatial or temporal differences in scale and sampling accuracy of surveys. These changes in krill size and biomass as a result of ocean conditions can have impacts on krill predators including their foraging behavior, condition, and distribution (Croll et al., 2005; Fleming et al., 2016; Jahncke et al., 2008; Santora et al., 2011; Santora et al., 2020) which could be exacerbated with climate change.

Copepods

Calanoid copepods are primary consumers, providing the transfer of carbon from primary producers to zooplankton and fish. Copepod species composition is an indicator of seasonal and intra-seasonal variability in oceanographic conditions. ACCESS surveys conduct hoop net sampling for zooplankton at predetermined stations in CBNMS in the upper 50 meters of the water column. From these samples, copepods are categorized into three main groups based on their common distribution along the west coast of North America. The three main copepod groupings are: cold water boreal species found at higher latitudes (roughly north of 40°N); transition zone species commonly found in temperate latitudes (about 20–40°N), and warm water equatorial species found at lower latitudes (about 10–20°N). Average abundance (number/m^3) of copepods from samples collected from 2004--2015 shows an increasing abundance of multiple species (Figure S.LR.12.4). The highest abundance of copepods were found in samples from 2011, 2014, and 2015. Boreal species were not present in samples from September 2014 through September 2015 (Elliott et al., 2020). These years represent the North Pacific marine heatwave.

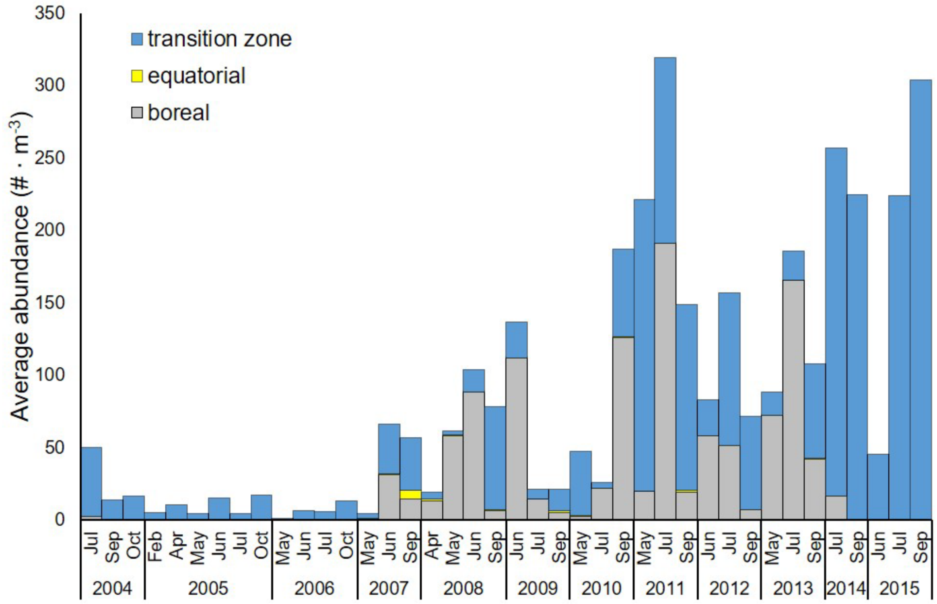
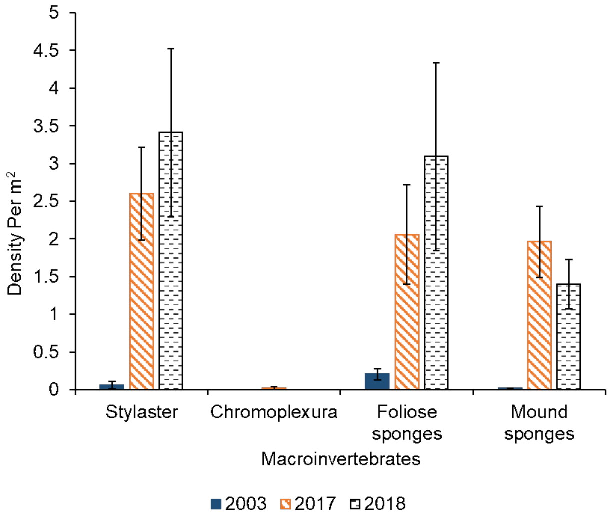


Figure S.LR.12.4. Average abundance (number per m^3) of copepods by distribution group (boreal, equatorial and transition zone) in the upper 50 m of the water columns from CBNMS ACCESS stations from 2004-2015. Image: Elliott et al., 2020

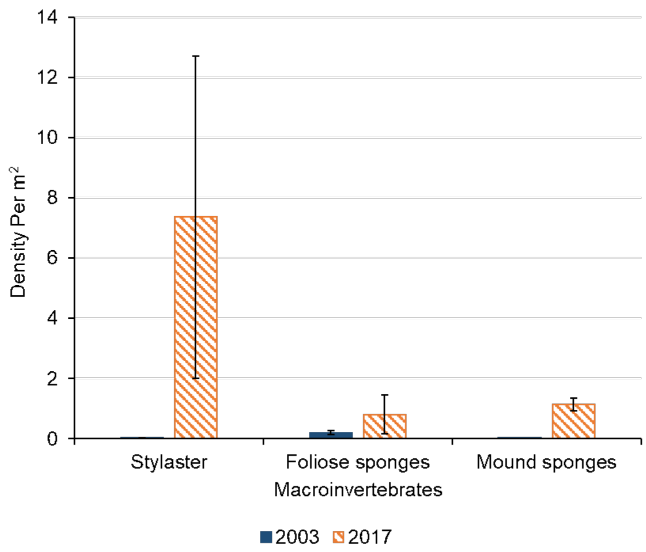
Conclusion

Abundances of corals and sponges on Cordell Bank appear to be generally good. There may be some degradation in coral condition, but the lack of historical data limits confidence in assigning a status rating. High variability was observed in krill and copepod abundance in the sanctuary region during the assessment period which was a time of highly variable environmental conditions (e.g., marine heatwave). There is some concern about the observed increase in variability in the system such as more frequent warm water years and associated smaller krill and less fatty copepods. The limited long-term data provided for krill and copepods in the sanctuary region leads to an assessment of undetermined.

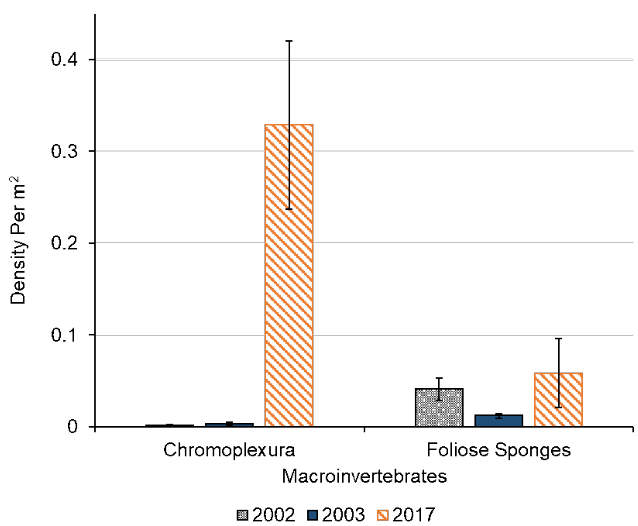
Appendix Figures



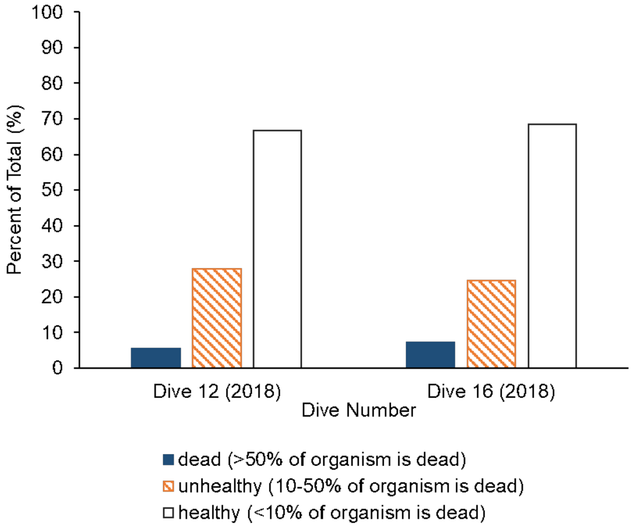
Appendix.X.12.1. Average densities (per m^2) and standard error of indicator macroinvertebrates enumerated from benthic surveys in 2003, 2017 and 2018 at a fixed sampling site named North Point on Cordell Bank at <80m depth. Image: CBNMS.



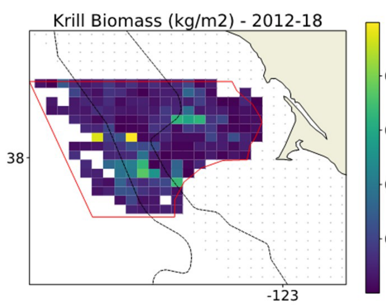
Appendix.X.12.2. Average densities (per m^2) and standard error of indicator macroinvertebrates enumerated from benthic surveys in 2003 and 2017 at a fixed sampling site named Northwest Ridge on Cordell Bank at <76m depth. Image: CBNMS.



Appendix.X.12.3. Average densities (per m^2) and standard error of indicator macroinvertebrates enumerated from benthic surveys in 2002, 2003 and 2017 at mid-water (70m-120m) rocky ridges on Cordell Bank. Image: CBNMS.



Appendix.X.12.4. Percent of total *Swifita* spp. gorgonians per condition category, healthy (< 10% of organism is dead), unhealthy (10–50% is dead), or dead (> 50% of organism dead), observed from ROV video collected in 2018 on the CBNMS slope (415m-626m depth) (Graiff and Lipski, 2020a). Image: CBNMS.



Year	Biomass (mt)	% Coverage	Scaled Up Biomass (mt)
2012	13,100	24.8	**52,900**
2013	47,900	23.4	**205,100**
2014	134,700	54.2	**248,700**
2015	51,800	39.7	**130,300**
2016	34,800	25.2	**137,700**
2017	43,700	31.8	**137,400**
2018	33,900	30.9	**109,800**

Appendix.X.12.5. Krill biomass (kg/m^2) from samples collected from the Pt. Reyes line in CBNMS from 2012-2018. Krill biomass measured in samples were scaled up for the CBNMS area. Image: NOAA JREAS/Farallon Institute.

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Question 13 (Living Resources): What is the status of other focal species and how is it changing?[1]

Status: Fair (high confidence)
Trend: Mixed (high confidence)
Status Description: Selected focal species are at reduced levels, but recovery is possible.
Rationale: Some indicator species are variable, while others are stable and some are declining. Blue and humpback whales are still recovering from past impacts, are still endangered, and are vulnerable to impacts such as ship strikes and entanglements. Commercially harvested rockfish

[1] Experts assigned a trend rating of undetermined at the workshop. However, following the workshop, a new trend "mixed" was introduced to the condition report rating scheme as a result of discussions with experts. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the combination of trends from available data.

Commented [1]: Footnote #12

Commented [2]: do you mean "all the species that were selected"? or do you mean "some of the species"?

Commented [3]: The word "selected" is standard language for the rating. No changes will be made in response to Ben's comment.

have improved since the last assessment and are at management targets, but are far below near-pristine levels in the absence of fishing pressure. Seabirds are variable but there is no evidence of long-term declining trends. Fish and invertebrates on Cordell Bank and the shelf appear stable. However, Leatherback turtles are at very low abundance throughout their range and the population has been declining. Because some species appear to be stable, some are variable, and some are declining, the trend was identified as mixed.

Commented [4]: I am not going to make a change based on this reviewers comment because the species are identified in the sections below. There is only one species of overlap between the "commercially harvested" species and the "Cordell Bank" species that are discussed.

Commented [5]: does this include the commercial rockfish above?

This question targets species of particular interest from the perspective of CBNMS sanctuary management, local partners, and experts. These “focal species” (e.g., whales, seabirds, leatherback turtles, rockfish, benthic fish on Cordell Bank, and benthic fish and invertebrates on shelf habitat) may not be abundant or control ecosystem function, but their presence and health is important for the provision of economic, cultural, recreational, ecological, and/or conservation-related values and services. Some species considered here are also threatened or endangered and are protected by state and/or federal laws.

Findings from the 2009 Condition Report

In 2009, this question was included as the status of key species (see Table S.LR.12.1). In this report, the question has been split into two separate questions to address the status of keystone and foundation species, and the status of other focal species (see appendix for an explanation on changes to the resource questions since the previous report). In 2009, the status of key species was rated as fair and the trend was improving. The taxa considered were: reef top invertebrates, krill, rockfish, sea turtles, Cassin’s auklets, black-footed albatross, sooty shearwaters, California sea lions, humpback whales, and blue whales. The report noted, “several of the indicator species appear to have been negatively impacted by the combination of natural and human-induced forces. Substantial or persistent declines, however, are not expected for most of these species and several of the indicator species that feed within the sanctuary exhibit healthy populations that are increasing.” For these reasons, the status of key species in 2009 was rated as fair and improving.

New Information in the 202__ Condition Report

Taxa considered for this new assessment include whales, seabirds, leatherback turtles, rockfish, benthic fish on Cordell Bank, and benthic fish and invertebrates on shelf habitat (Table S.LR.13.1).

Table S.LR.13.1. Status and trends for individual indicators discussed at the March 31, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data source/Data visualization	Habitat	Data Summary	Figures
Whale populations	NMFS/CBNMS	Pelagic	Status: Endangered, threatened species Trend: Low population increases, facing threats	

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Whale density models	Becker et al. 2020/Becker et al. 2020	Pelagic	Status: Blue and humpback whales have high density in CBNMS Trend: No trend data	
Whale density - ACCESS	ACCESS/Point Blue	Pelagic	Status: Blue and humpback whales are common in CBNMS/GFNMS Trend: Increasing density observations	
Seabirds	ACCESS/Point Blue	Pelagic	Status: Cassin's auklets, black-footed albatross, sooty shearwaters, and pink-footed shearwaters are common in CB/GF Trend: Variable, no trend	
Rockfish populations	NMFS/PFMC 2020	Benthic	Status: Species recovered/recovering Trend: Increasing population size	
Juvenile rockfish	NMFS/CCIEA	Pelagic	Status: Stable Trend: Peaks 2014-2016	
Rockfish survey data	NMFS/CCIEA	Benthic	Status: Stable Trend: Peaks 2014-2016	
Benthic fish - Bank	CBNMS/CBNMS	Benthic	Status: Stable Trend: No trend data	
Shelf fish and inverts	CBNMS/CBNMS	Benthic	Status: Stable Trend: No quantitative trend data, appears stable	

A number of whale species are common seasonally in CBNMS and include blue, fin, humpback, and grey whales (Table S.LR. 13.2, Figure App.E.13.1). Other species known to be present, but less commonly observed, include orca (killer) whales, sperm whales, and beaked whales. Blue whales and humpback whales are prevalent in the sanctuary seasonally as they migrate along the coast to forage. At a population level, blue whales are endangered and are experiencing low population levels and slow rates of increase (Carretta et al., 2021, Figure S.LR.13.1). Humpback whales that migrate to CBNMS include the threatened Mexico Distinct Population Segment (DPS) and endangered Central America DPS (Carretta et al., 2021). Humpback whale populations are slowly increasing (Carretta et al. 2021; Calambokidis and Barlow, 2020). Tagging studies of blue whales (Irvine et al., 2014), and data from boat-based observational surveys within CBNMS conducted by the sanctuary and partners as part of the Applied California Current Ecosystem Studies (ACCESS) project indicate the sanctuary contains hotspot habitat along the shelf break for both species of whales (Rockwood et al., 2020a) and they are seasonally abundant (Elliot et al., 2020). Both species of whales are vulnerable to ship strikes in and outside CBNMS (Rockwood et al., 2020b) and climate-induced changes in foraging and distribution (Gulland et al., 2022). Humpback whales, in particular, are vulnerable to entanglement in fishing gear, especially when oceanographic conditions compress suitable inshore habitat, resulting in foraging and fishing areas overlapping (Santora et al., 2020, Figure S.LR.13.2). This habitat compression was observed in the region during the 2014-2016 marine heatwave (Santora et al., 2020)

Table S.LR.13.2. Stock assessment for four whale species that inhabit CBNMS seasonally (Carretta et al., 2020).

Species	Min. pop size	Stock assessment published	Potential Biological Removal*	Trend	Notes
Blue	1,050	August 2020	2.1 total (1.23 US waters)	4% increase /year	• Endangered • Rockwood et al., (2017) model suggests 18 deaths annually coast-wide from ship strikes
Humpback CA-OR-WA	2,784	August 2020	33.4 total (16.7 US waters)	About 8% increase /year	• Endangered and threatened distinct population segments • Rockwood et al., (2017), model suggests 22 deaths annually coast-wide from ship strikes. Entanglements are also an issue.
Fin	8,127	2/4/2019	81	7.5% increase/ year	Endangered
Gray - (eastern North Pacific)	25,849	5/15/2019	801	22% increase/ year	Not listed

*Potential Biological Removal is defined as “the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population. The potential biological removal level is the product of the following factors: (A) The minimum population estimate of the stock. (B) One-half the maximum theoretical or estimated net productivity rate of the stock at a small population size. (C) A recovery factor of between 0.1 and 1.0.” (16 USC 1362)

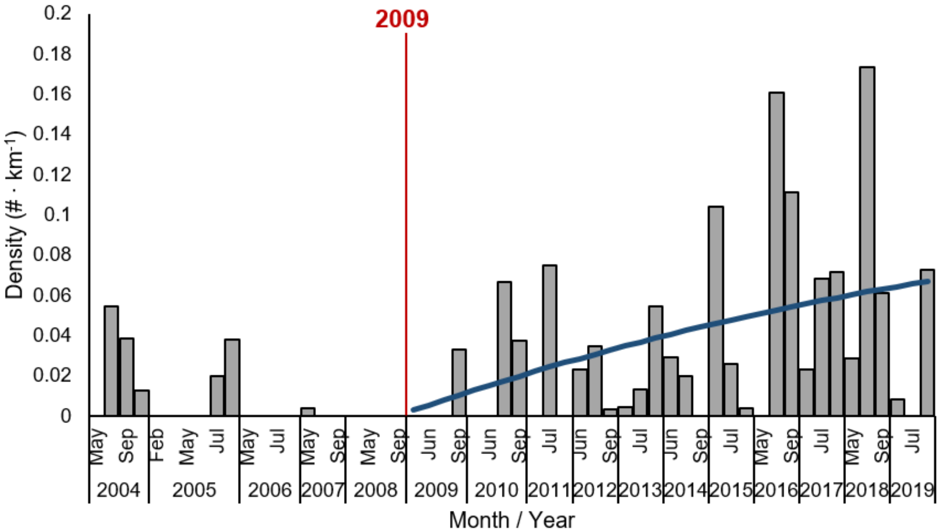

Figure S.LR.13.1. Density of blue whales from boat-based observations as part of the Applied California Current Ecosystem Studies project. Each bar represents the summed total observations for the area surveyed per cruise. The vertical red line indicates the year of the last condition report (2009). Data are from within CBNMS and GFNMS.

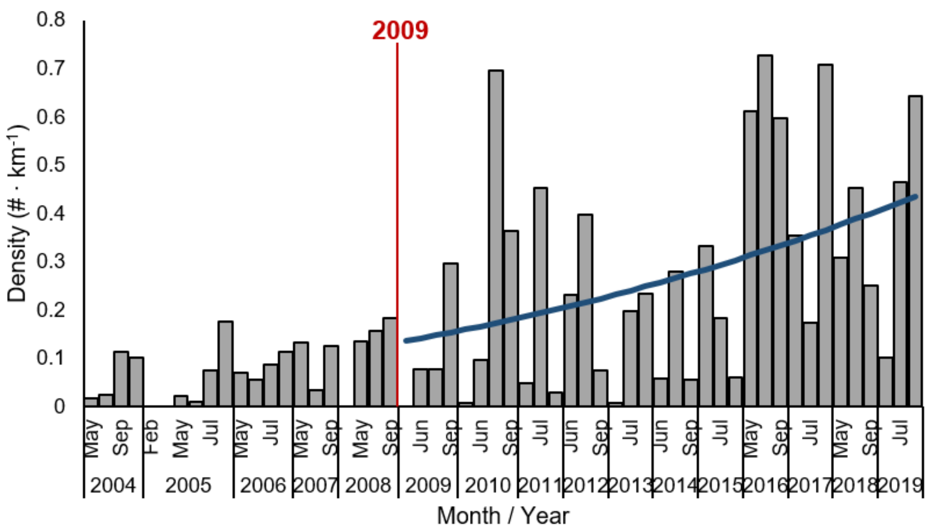

Figure S.LR.13.2. Density of humpback whales from boat-based observations as part of the Applied California Current Ecosystem Studies project. Each bar represents the summed total observations for the area surveyed per cruise. The vertical red line indicates the year of the last condition report (2009). Data: CBNMS and GFNMS

A number of resident and seasonal seabird species are common within CBNMS. Four species were included as indicator species for this report: Cassin's auklets, black-footed albatross, sooty shearwater, and pink-footed shearwater. Cassin's auklets breed locally, while the other three species migrate from Hawaii (black-footed albatross), New Zealand (sooty shearwaters), and Chile (pink-footed shearwaters) to forage in CBNMS in the summer and fall. Seabirds are vulnerable to impacts such as to fisheries bycatch and ingesting marine debris (Croxall et al., 2012; Wilcox et al., 2015) and are considered indicators of ecosystem conditions (Piatt et al., 2007). Data from ACCESS show variability in the seabird abundance for all four species, likely as a result of their travel and feeding patterns and coincidence with periodic observational surveys (Elliot et al., 2020, Figure App.E.13.2 - Figure App.E.13.5). This variability is not thought to directly correspond to increases or decreases in populations, and therefore was cautiously considered in the rating for this question.

Leatherback turtles use CBNMS habitat, particularly in the eastern portion, for foraging and traveling (Benson et al., 2011). Leatherback turtles are listed as critically endangered at the federal level (National Marine Fisheries Service and U.S. Fish and Wildlife, 2020) and endangered by the state of California (State of California, 2022) and are at low abundances throughout their range. There has been an estimated 5.6% annual rate of decline in leatherbacks foraging off central California between 1990 and 2017 (Benson et al., 2020). Their complex life cycle and migration from nesting grounds in Indonesia makes them vulnerable to a variety of threats, including entanglement, bycatch, poaching, and habitat degradation at multiple points throughout their life stages (Tiwari et al., 2013). Bycatch continues to be a risk in California waters in the gill net and fixed gear fisheries (Benson et al., 2020).

Cordell Bank is home to many species of rockfish occupying the pelagic habitat and benthic habitat on the bank, shelf, and slope. Both juvenile and adult rockfish are sampled in CBNMS by NMFS to inform stock assessments. At the time of the 2009 condition report, NMFS listed seven rockfish species as overfished: bocaccio, canary, cowcod, dark blotched, Pacific Ocean perch, widow, and yelloweye. All of these species occur in CBNMS. At the time of writing this report, six of those species are considered recovered by NMFS (above 25% of virgin biomass) and yelloweye rockfish is classified as "rebuilding" (Pacific Fisheries Management Council 2020; Harvey et al., 2021, Figure S.LR.13.3). Although the threshold for a rebuilt population is far below near-pristine levels, the trajectory does indicate that populations have recovered some since the 2009 report and the stocks are improving.

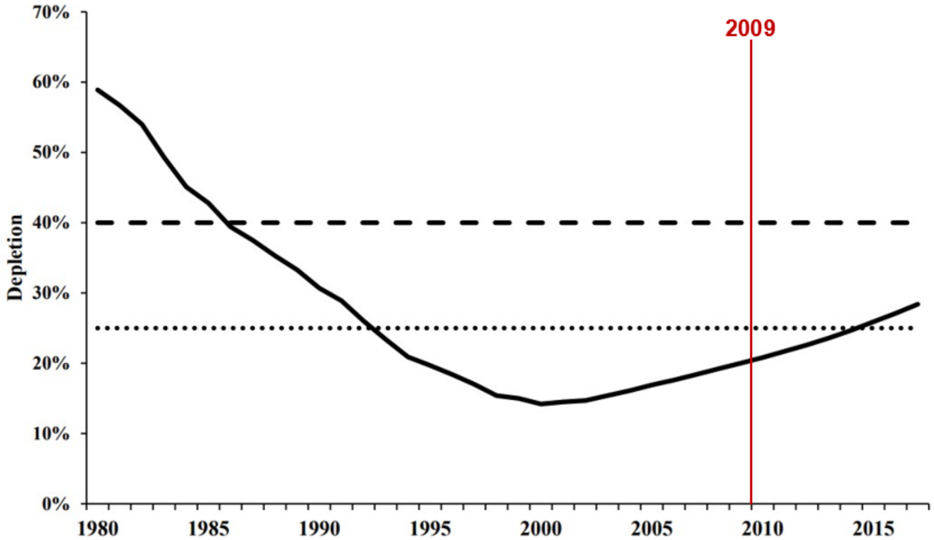

Figure S.LR.13.3. Relative depletion of yelloweye rockfish, the remaining groundfish species in the rebuilding phase. The dashed line indicates the "overfishing" threshold (catch exceeds or is expected to exceed Overfishing Limit). The dotted line indicates the "overfished" threshold (the Minimum Stock Size Threshold, the default of which is 25% of the estimated unfished biomass level). The vertical red line indicates the year of the last condition report (2009). Source: PFMC, 2020

Rockfish caught in the NMFS groundfish trawl surveys in CBNMS on the shelf from 2014-2019 show catch per unit effort (CPUE) within 1 standard deviation of the long term mean and no increase or decrease of more than 1 standard deviation, based on analysis of West Coast Groundfish Bottom Trawl Survey data (WCGBTS, 2019) by NOAA's California Current Integrated Ecosystem Assessment (CCIEA) following approaches used in the CCIEA status report (Harvey et al., 2021) (Figure S.LR.13.4) . The mean for CPUE during the previous condition report period (2003-2008) and the data available for the current condition report period (2009-2019) are similar. The CPUE on the upper slope does show a declining trend, but it is driven by a small peak with high variability in 2016. Both the shelf and upper slope show slight peaks in CPUE in 2016, and the shelf shows an increase in 2018 and 2019. These data indicate that although there is variability, the status appears stable and there is no indication of a long-term trend. These results are largely consistent with those seen across a broader region when the areas of CBNMS and GFNMS are combined.

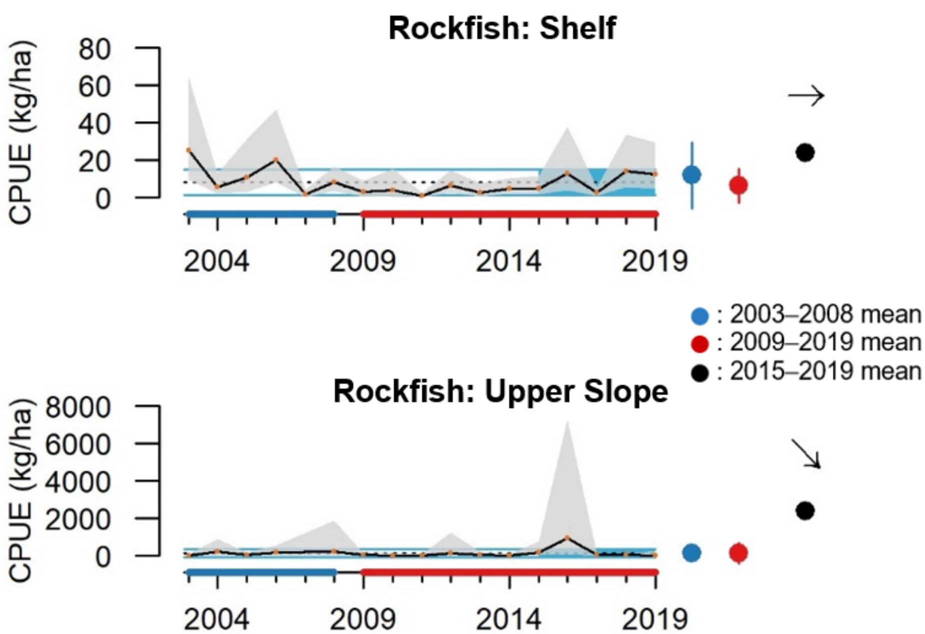

Figure S.LR.13.4. Catch per unit effort of rockfish in the National Marine Fisheries Service groundfish trawls in CBNMS in two habitats: on the shelf and on the slope (WCGBTS, 2019). The gray shading indicates +/- 1.0 standard error. The blue dots indicate the mean and 95% confidence interval from 2003-2008, the red dots indicate the mean and 95% confidence interval from 2009-2019. The black dots indicate the recent mean (2015-2019) is within 1.0 standard deviation of the long-term mean (2003-2019) and the arrow indicates the trend from 2015-2019 decreased more than 1.0 standard deviation compared to the full time series.

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Rockfish recruitment is monitored by NMFS through the Rockfish Recruitment and Ecosystem Assessment Survey, which includes sampling in the CBNMS region (Field et al., 2021). The data were analyzed by NOAA's CCIEA program (Harvey et al., 2021). The long-term trend appears stable, although there were anomalous high peaks in 2013-2016 in the region that includes CBNMS and the regions to the north and south. Even with these peaks, the pre-recruit index for 2015-2019 is within 1 standard deviation of the long term mean. There was a declining trend during this time period, which is driven by the peak in 2015-2016, but otherwise there is not a concerning trend (Field et al., 2021).

CBNMS uses a remotely-operated vehicle to survey seafloor habitat to characterize and monitor habitats and species. To evaluate benthic fish on Cordell Bank, species that are commonly observed and tracked in these visual seafloor surveys, like pygmy, rosy, squarespot, and yelloweye rockfish, were examined. A comparison of visual surveys using recent data in 2017 and 2018 to historic data in 2003 proved inconclusive due to changes in camera and vehicle technology over the time period. However, the 2017 and 2018 surveys show that fish on the bank appear to be abundant and there are no obvious signs of declines, as judged by staff members familiar with the historic and current surveys (Graiff et al., 2019; Graiff and Lipski, 2020; CBNMS unpublished data, 2021). Monitoring will continue to better track changes over time.

Likewise, recent ROV surveys on the shelf habitat were incompatible with data from camera sled surveys from 2004 so a comparison to historic data was not possible. ROV surveys from 2017 and 2018 show that flatfish and seapens appear to be abundant and stable, as judged by staff members familiar with the current and historic surveys. The habitat is fairly homogeneous and seapen densities are consistent at about 1/m^2 (Graiff and Lipski, 2020; CBNMS unpublished data, 2021a). With only two years of data to compare, we are unable to determine a trend at this time, but will continue monitoring this area.

Conclusion

The status of other focal species is fair with a mixed trend. The status is supported by the fact that species populations are reduced from near-pristine conditions (see Appendix A for definition) , but most are stable or increasing since 2009. However, leatherback turtles are facing severe declines. Also considered is the fact that many of the protected species still face threats from climate change, ship strikes, entanglement, or fishing activity. The mixed trend is due to the improvement of some species and the worsening of others. In addition, there is variability in some taxa, such as seabirds, which can be a result of their transient and episodic occurrences as they follow food sources as well as the nature of the programs that monitor them, which are typically periodic at-sea, boat-based surveys. Much of the information used in this assessment comes from ongoing research and monitoring programs, which are important to continue. Many of the species are wide-ranging and transient, coming to CBNMS to forage. Therefore, studies and management efforts that address the population throughout their range, as well as how the species fare locally, are important to understand the status of other focal species.

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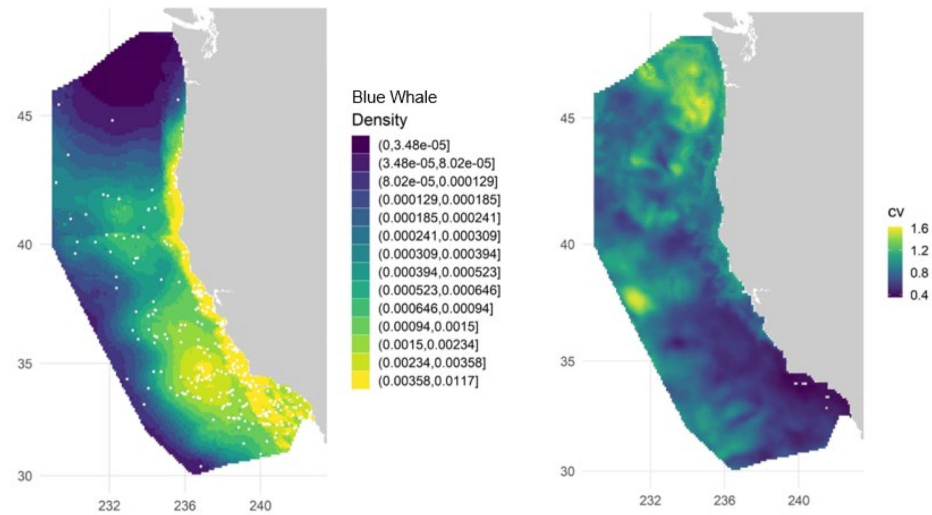
Appendix Figures


Blue Whale
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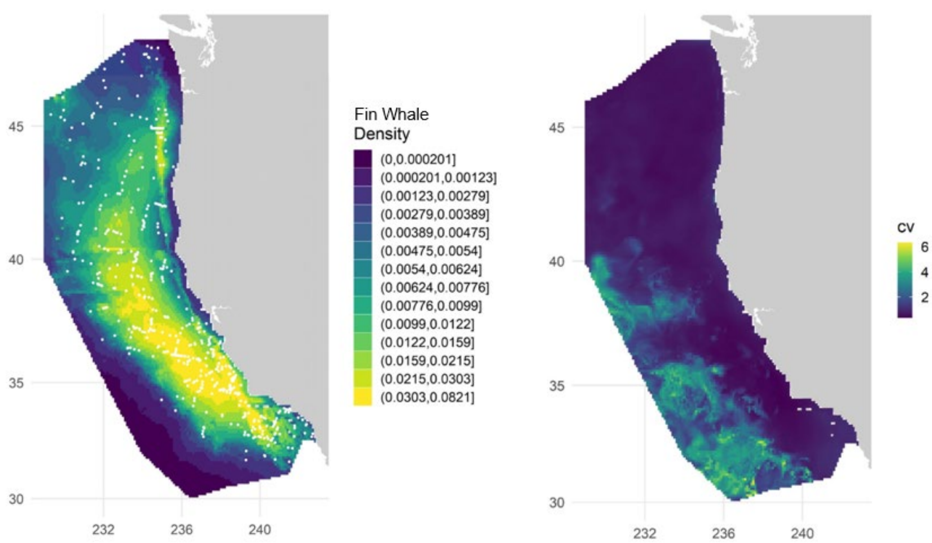
Fin Whale
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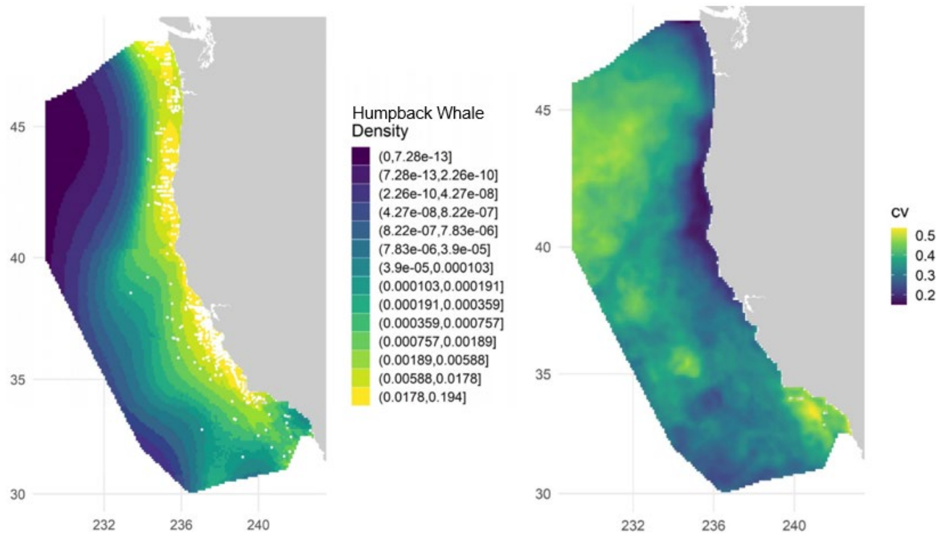

Figure App.E.13.1 "Predicted mean density (animals per km^2) and associated coefficients of variation (CV) from the 1991–2018 habitat-based density models for" blue whale (top), fin whale (middle), and humpback whale (bottom). "Panels show the multi-year average density based on predicted daily cetacean species densities covering the 1996-2018 survey periods (summer/fall). Predictions are shown for the study area (1,141,800 km^2). White dots in the average plots show actual sighting locations from the SWFSC 1996-2018 summer/fall ship surveys for the respective species." Source: Becker et al., 2020.

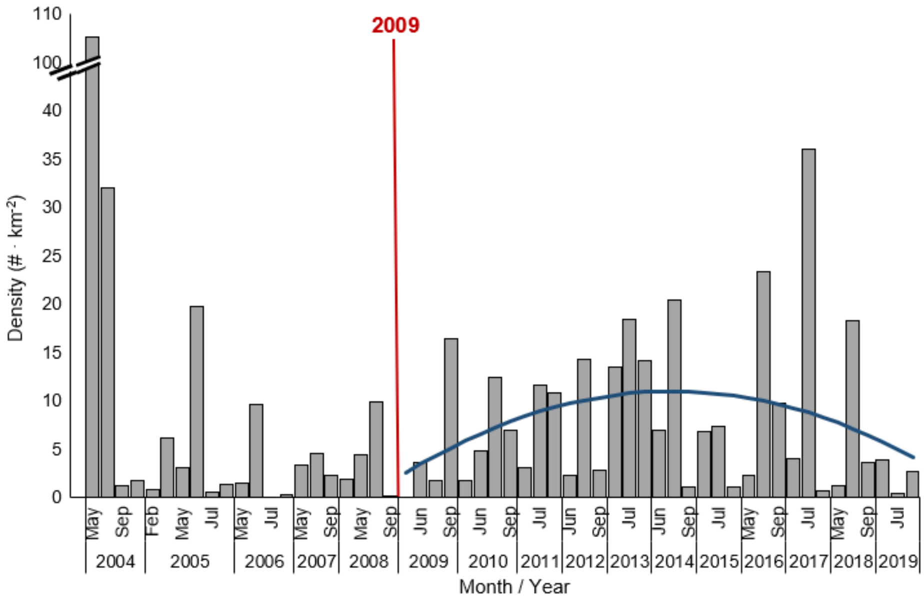

Figure App.E.13.2. Cassin's auklet densities observed on ACCESS transect lines 1-7, years 2004-2019. Line shows polynomial trend for 2009-2019. Each bar represents the summed total observations for the area surveyed per cruise. The vertical red line indicates the year of the last condition report (2009). Data source ACCESS, compiled by Point Blue Conservation Science.

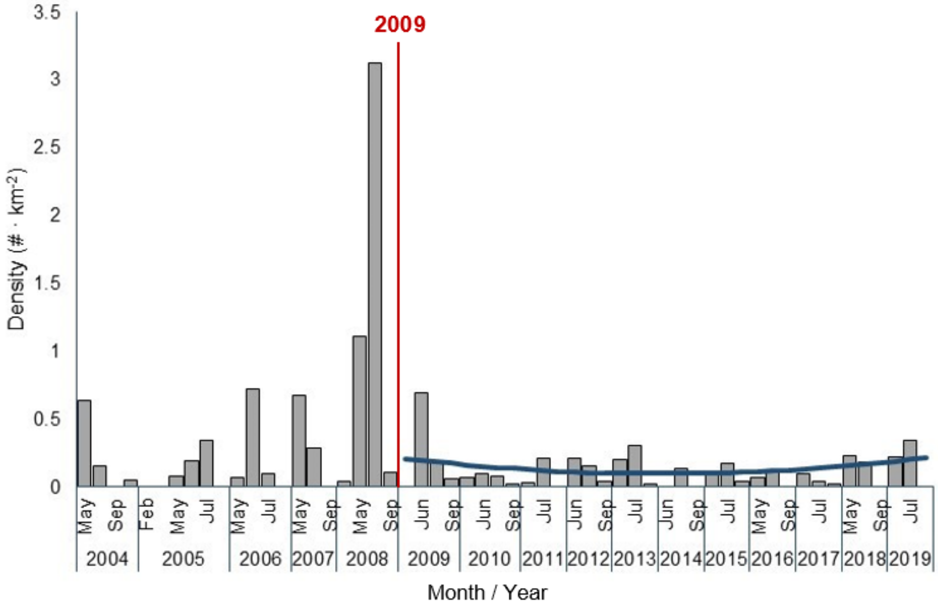

Figure App.E.13.3. Black-footed albatross densities observed on ACCESS transect lines 1-7, years 2004-2019. Line shows polynomial trend for 2009-2019. Each bar represents the summed total observations for the area surveyed per cruise. The vertical red line indicates the year of the last condition report (2009). Data source ACCESS, compiled by Point Blue Conservation Science.

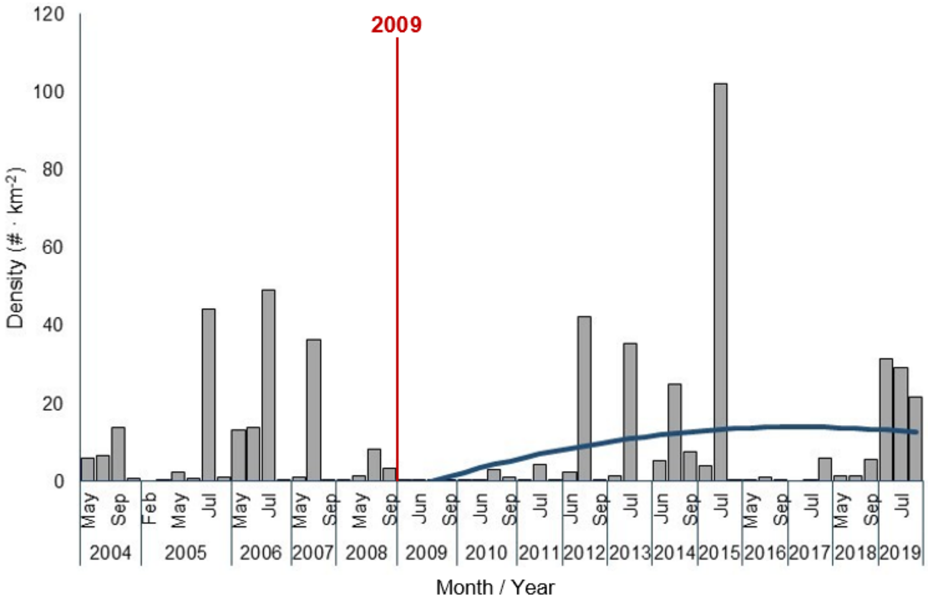

Figure App.E.13.4. Sooty shearwater densities observed on ACCESS transect lines 1-7, years 2004-2019. Line shows polynomial trend for 2009-2019. Each bar represents the summed total observations for the area surveyed per cruise. The vertical red line indicates the year of the last condition report (2009). Data source ACCESS, compiled by Point Blue Conservation Science.

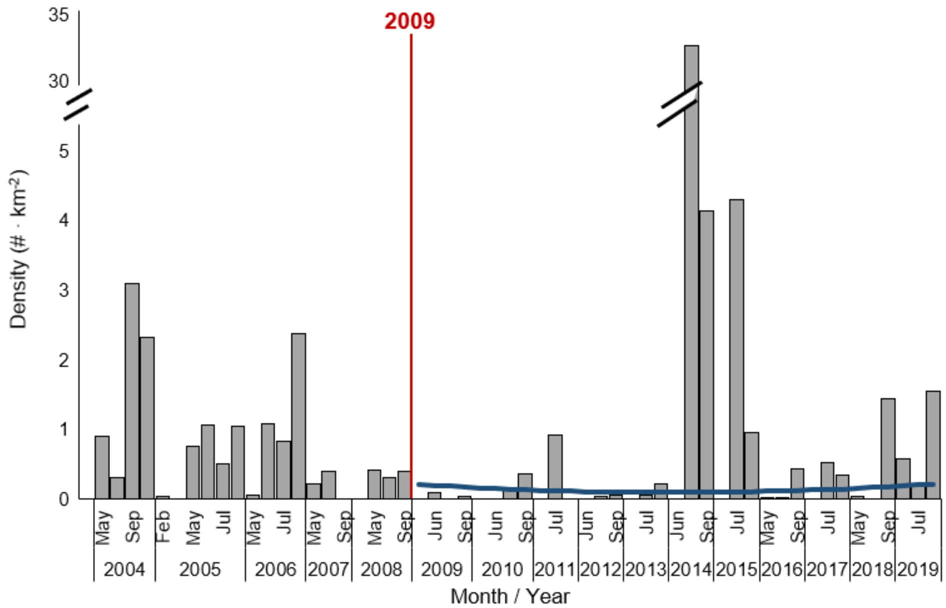

Figure App.E.13.5. Pink-footed shearwater densities observed on ACCESS transect lines 1-7, years 2004-2019. Line shows polynomial trend for 2009-2019. Each bar represents the summed total observations for the area surveyed per cruise. The vertical red line indicates the year of the last condition report (2009). Data Source ACCESS, compiled by Point Blue Conservation Science.

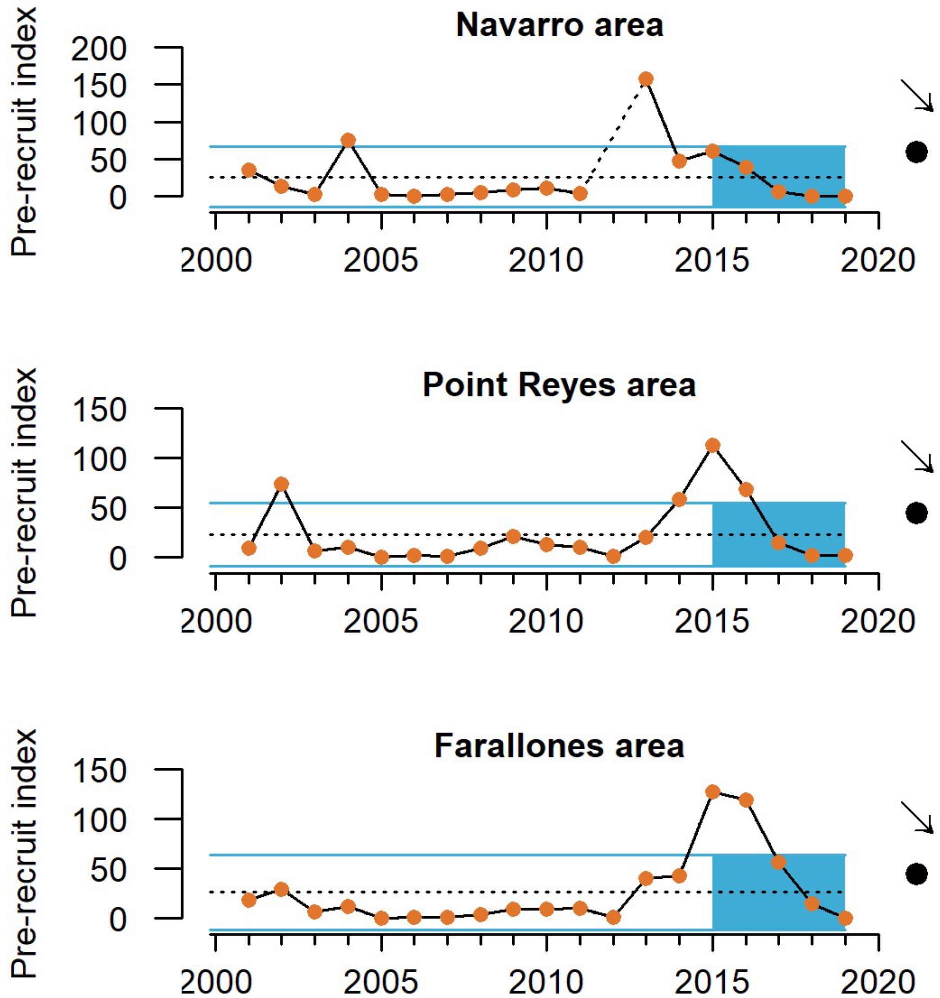

Figure App.E.13.6. Index of abundance for rockfish pre-recruits for 2001-2019. The black dots indicate the recent mean (2015-2019) is within 1.0 standard deviation of the long-term mean (2003-2019) and the arrow indicates the trend from 2015-2019 decreased more than 1.0 standard deviation compared to the full time series. CBNMS is within the Point Reyes sampling area. Data source John Field (NMFS), compiled by IEA.

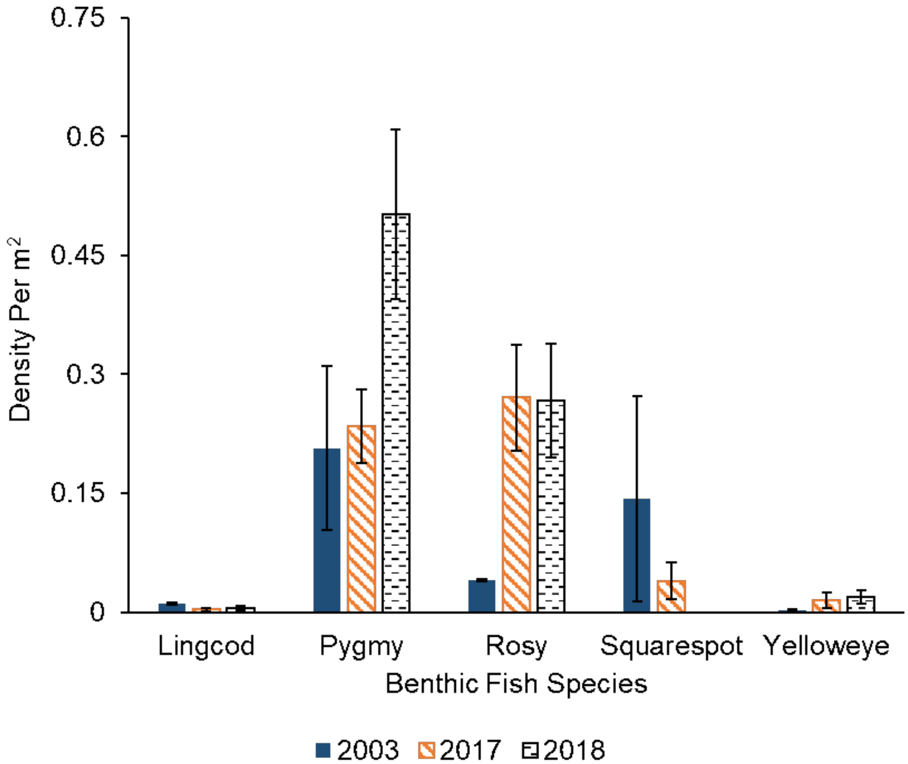

Figure App.E.13.7 Average fish densities (per m^2) and standard error from North Point on Cordell Bank. Data source: CBNMS.

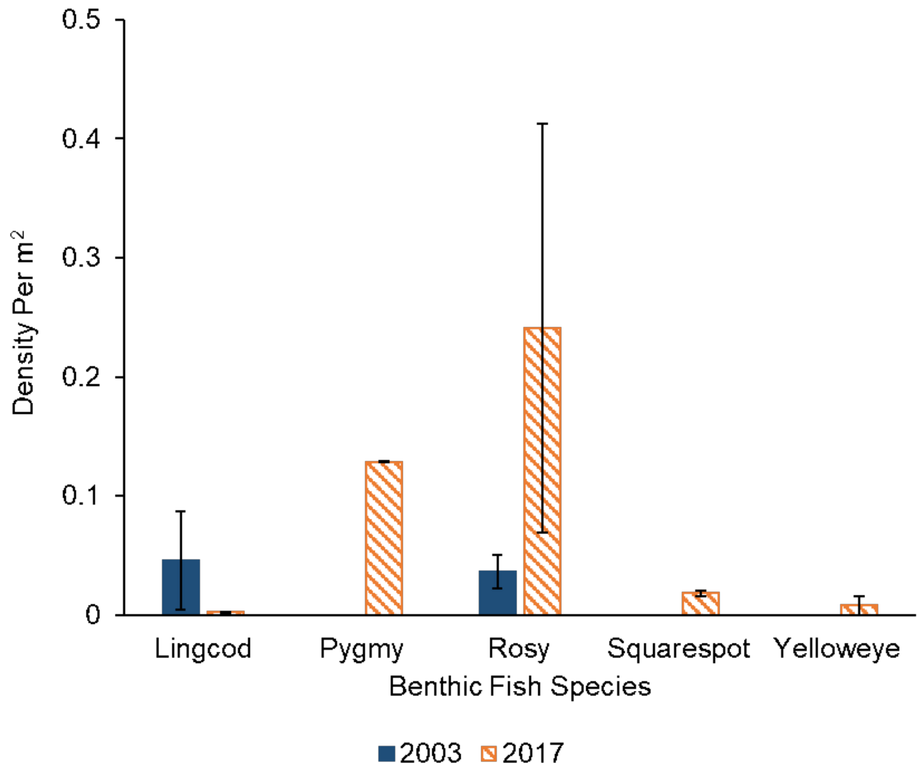

Figure App.E.13.8. Average fish densities (per m^2) and standard error from Northwest Ridge on Cordell Bank. Data source: CBNMS.

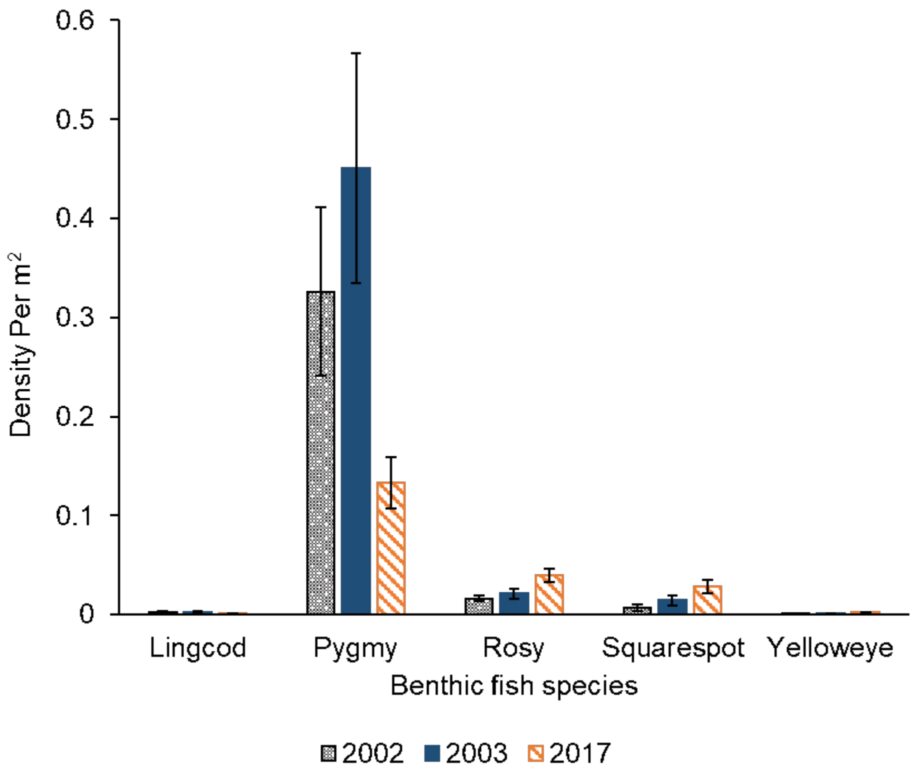

Figure App.E.13.9. Average fish densities (per m^2) and standard error from depths 70-120 meters on Cordell Bank. Data source: CBNMS.

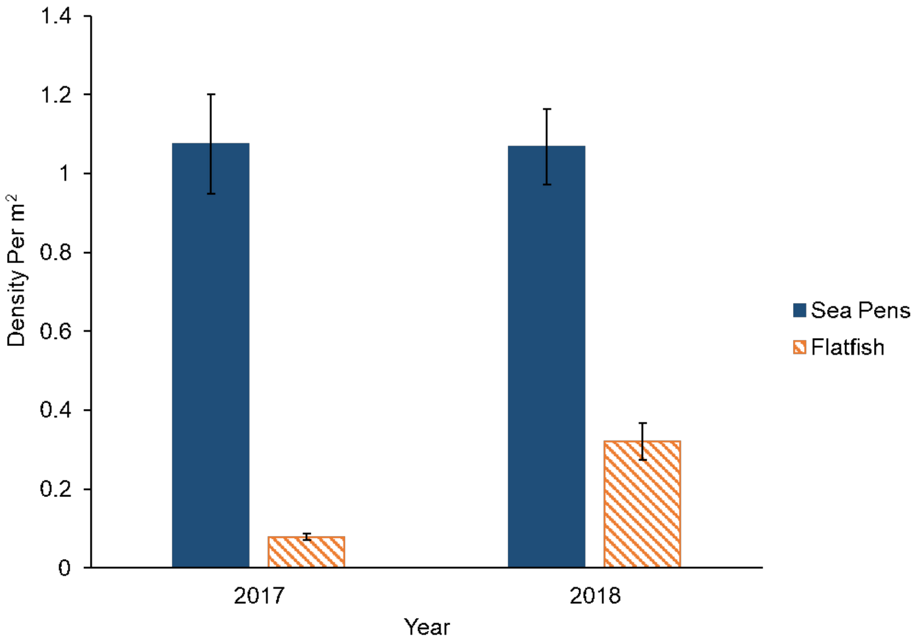

Figure App.E.13.10. Average sea pen and flatfish densities (per m^2) and standard error on continental shelf soft sediment habitat. Data source: CBNMS.

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Question 14: What is the status of non-indigenous species and how is it changing?

Status: Good (medium confidence)
Trend: Undetermined (low confidence)
Status Description: Non-indigenous species are not suspected to be present or do not appear to affect ecological integrity (full community development and function).
Rationale: Limited data from the sanctuary have documented no mature or reproductive populations of NIS taxa and there is no evidence of detrimental impact. Some species of concern exist in the region, but none have become invasive or exhibited significant growth or expansion in the sanctuary. Adequate data do not exist to assess a trend for NIS and there was low confidence based on limited data.

Findings from the 2009 Condition Report
In the 2009 condition report, the status and trend of non-indigenous species (NIS) were both rated as undetermined, though no NIS were known to exist in the sanctuary at the time (see Table S.LR.12.1).

New Information in the 20__ Condition Report
To assess the presence of NIS in CBNMS for this report, we compared species found in the CBNMS species database, an inventory of species observed within the sanctuary, with sources documenting NIS in the region or those that could be found in CBNMS (Table S.LR.14.1). Data sources for the inventory included reports, peer-reviewed literature, and consultation with experts (Table S.L.R.14.2). Since 2009, four confirmed NIS have been observed in the sanctuary: green crab (*Carcinus maenas*), Australian tubeworm (*Ficopomatus enigmaticus*), breadcrumb sponge (*Halichondria panicea*), and crumb-of-bread sponge (*Hymeniacidon perlevis)*. Additionally, one cryptogenic species (i.e., there is uncertainty about its native range), the slender ragworm (*Nereis pelagica*) was observed. *Carcinus maenas* has only been observed in larval forms and collected during net tows of pelagic habitats. *Ficopomatus enigmaticus* and *H. panicea* were collected by SCUBA divers and *H. perlevis* and *N. pelagica* were found on submerged gill nets recovered during a marine debris removal expedition, all of which were located on Cordell Bank. For these species, there has been no documentation of established benthic (mature and/or reproductive) populations, nor has there been any evidence of NIS negatively impacting the environment or communities. The status of NIS in CBNMS has therefore been rated as good. The trend is undetermined due to the low resolution of video imagery and limited specimens collected during ROV benthic surveys. Additionally, the amount of habitat surveyed by ROVs is restricted, limiting the power to detect small changes in NIS abundance.

Table S.LR.14.1. Status and trends for individual indicators discussed at the April 7, 2021 virtual workshop. There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figure
Species observed	Multiple/CBNMS	Benthic/pelagic	Status: NIS exist in the sanctuary but are not problematic Trend: Unknown	Table S.L.R.14.1

Species of concern	Multiple/CBNMS	Benthic	Status: Small number of species of concern Trend: Unknown	None

Table S.L.R.14.1. Sources consulted on the topic of NIS in CBNMS.

Source	**Title/Description**
Bullard et al., 2007	The colonial ascidian *Didemnum* sp. A: Current distribution, basic biology and potential threat to marine communities of the northeast and west coasts of North America
California Department of Fish and Wildlife Non-native Estuarine Marine Organisms (CalNEMO)	https://invasions.si.edu/nemesis/calnemo/
Carlton et al., 2017	Tsunami-driven rafting: transoceanic species dispersal and implications for marine biogeography
Cordell et al., 2008	Factors influencing densities of non-indigenous species in the ballast water of ships arriving at ports in Puget Sound, Washington, United States
de Rivera et al., 2005	Broad-Scale nonindigenous species monitoring along the West Coast in National Marine Sanctuaries and National Estuarine Research Reserves
Frey et al., 2014	Fouling around: vessel sea-chests as a vector for the introduction and spread of aquatic invasive species
Gulf of the Farallones National Marine Sanctuary, 2014	Nonindigenous Species of GFNMS and CBNMS from the GFNMS Final Management Plan
Hanyuda et al., 2018	Genetic identification of macroalgal species on Japanese tsunami marine debris and genetic comparisons with their wild populations
Kimmerer, W., personal communication, Dec. 16, 2020.	Copepod introductions to the San Francisco Estuary.
Lu et al., 2007	Preliminary investigation on aquatic invasive species of marine and estuarine macrobenthic invertebrates on floating structures in five British Columbia harbours

Multi-Agency Rocky Intertidal Network (MARINe)	https://marine.ucsc.edu/
Pederson et al., 2021	2019 Rapid Assessment Survey of marine bioinvasions of southern New England and New York, USA, with an overview of new records and range expansions
Ray, 2005	Invasive marine and estuarine animals of California.
Rubinoff, B, Chang, A. L., Grosholz, E. D., Gross, C., personal communication, Mar. 12, 2021.	Potential non-native species in Cordell Bank National Marine Sanctuary
Sanctuary Integrated Monitoring Network (SIMoN)	https://sanctuarysimon.org/
Zabin et al., 2018	Non-native species colonization of highly diverse, wave swept outer coast habitats in Central California

It is possible that the sanctuary's offshore location and lack of shallow or emergent habitat may protect CBNMS from some of the problematic coastal species nearby. But vectors of transmission (e.g., shipping and other human uses) and other factors that could promote introductions (e.g., climate change) exist in the sanctuary. For that reason, staff and partners will continue to monitor the sanctuary for pelagic and benthic NIS. Of particular concern, based on observations elsewhere in the region, are the kelp *Undaria pinnatifida* (Silva et al., 2002, Zabin et al, 2009), *Didemnid* tunicates (Bullard et al., 2007), and the bryozoan *Watersipora subtorquata* (Lonhart 2012, Zabin et al, 2018), all of which can become significant competitors for benthic habitat. For example, the colonial tunicate *Didemnum vexillum*, has smothered areas of George's Bank in the Gulf of Maine (Bullard et al., 2007).

Conclusion
Currently, data on NIS in CBNMS are limited due to low resolution video imagery and limited amount of habitat surveyed, preventing the assessment of conditions and trend. While four NIS and one cryptogenic species have been observed in the sanctuary, there do not appear to be any detrimental effects to sanctuary habitat. Sanctuary staff will continue to monitor the sanctuary for NIS, particularly for species of concern.

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Question 15: What is the status of biodiversity and how is it changing?

Status: Good/Fair (high confidence)
Trend: Not changing (high confidence)
Status Description: Selected biodiversity loss or change is suspected and may preclude full community development and function, but has not yet caused measurable degradation.
Rationale: Pelagic indicators such as zooplankton appear to have recovered to average krill and copepod biodiversity after marine heatwave-induced changes. Groundfish diversity is variable, but stable and consistent across the region. Biodiversity of macroinvertebrates and fish communities on the bank appear to be stable, yet the ability to detect trends is limited by the lack of long-term data. Knowledge of new species and range extensions in deep-water benthic communities has greatly improved with advancements in survey technologies and the increasing number of exploration missions. Seabird diversity appears to be stable and changes in species composition reflect natural seasonal variation.

Commented [11]: This is standard language in the rating scheme so it will not be changed based on Ben's comment about the text conflicting with the trend: not changing

Commented [12]: this seems to conflict with "Trend: Not Changing"

Findings from the 2009 Condition Report
In the 2009 condition report, the status of biodiversity in the sanctuary was rated as fair with an improving trend (see Table S.LR.12.1). The rating reflected changes in oceanic conditions that altered productivity in the sanctuary, with consequent changes in the abundance and distribution of krill, blue whales, and Cassin's auklets. Also considered was the historic depletion of rockfish stocks from overfishing and poor recruitment. While negative impacts were measured for some species populations, they were not substantial or persistent declines.

Communities of benthic invertebrates on the bank and shelf and many populations of marine mammals (such as North Pacific Humpback whales and California sea lions) were documented as being healthy and increasing.

New Information in the 202__ Condition Report
Zooplankton, groundfish, benthic communities, and seabirds were assessed in order to determine the overall status and trend of biodiversity (Table S.LR.15.1).

Table S.LR.15.1. Status and trends for individual indicators discussed at the April 7, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/data visualization	Habitat	Data Summary	Figures
Zooplankton	ACCESS/Point Blue	Pelagic	Status: changes with warm and cold conditions Trend: no trend	Figure S.LR.15.1 Figure S.LR.15.2
Groundfish	NOAA-NWFSC/CCIEA[1]	Benthic	Status: some variability in composition Trend: stable overall	Figure S.LR.15.3 Figure S.LR.15.4 Figure App.E.10.6
Benthic community	CBNMS/CBNMS	Benthic	Status: building knowledge of new areas Trend: increasing with more surveys	Figure S.LR.15.5 Figure App.E.15.1 Figure App.E.15.2
Macroinvertebrates	CBNMS/CBNMS	Benthic	Status: varies at sites/habitats but appears stable Trend: no trend data yet	Figure App.E.15.3 Figure App.E.15.5
Benthic fish	CBNMS/CBNMS	Benthic	Status: appears stable and varies at sites/habitats Trend: no trend data yet	Figure App.E.15.4 Figure App.E.15.6
Seabirds	ACCESS/CBNMS	Pelagic	Status: appears stable, variability with seasons Trend: no trend determined	Figure S.LR.15.6 Figure App.E.15.7

[1] California Current Integrated Ecosystem Assessment
https://www.integratedecosystemassessment.noaa.gov/regions/california-current

The sanctuary maintains a species inventory database that documents all species with a verified observation in CBNMS. The species list is the most comprehensive overview of species richness in the sanctuary. With a total of 1820 species documented to date, there are: 19 species of marine mammals, 254 species of fish (42 of these are rockfish in the *Sebastes* species group), 74 species of seabirds and at least 747 species of invertebrates.

Commented [13]: this number may be updated

Zooplankton

Zooplankton such as amphipods, copepods, decapods, and euphausiids (krill) are primary foods for many of the sanctuary's seabird, marine mammal, and fish populations. Net tow sampling in the upper 50 meters of the water column has been conducted in CBNMS at predetermined stations since 2004 by ACCESS. Average zooplankton abundance (number per m^3) from net samples analyzed from 2004 – 2015 shows an increase since 2009 (Figure S.LR.15.1). The highest abundances were seen in 2011, 2014, and 2015. Usually, krill and copepods dominate the community, but during the 2014 to 2015 heatwave, there were large increases in other zooplankton, including gelatinous zooplankton (doliolids and salps), which dominated the catches during those years (Elliott et al., 2020).

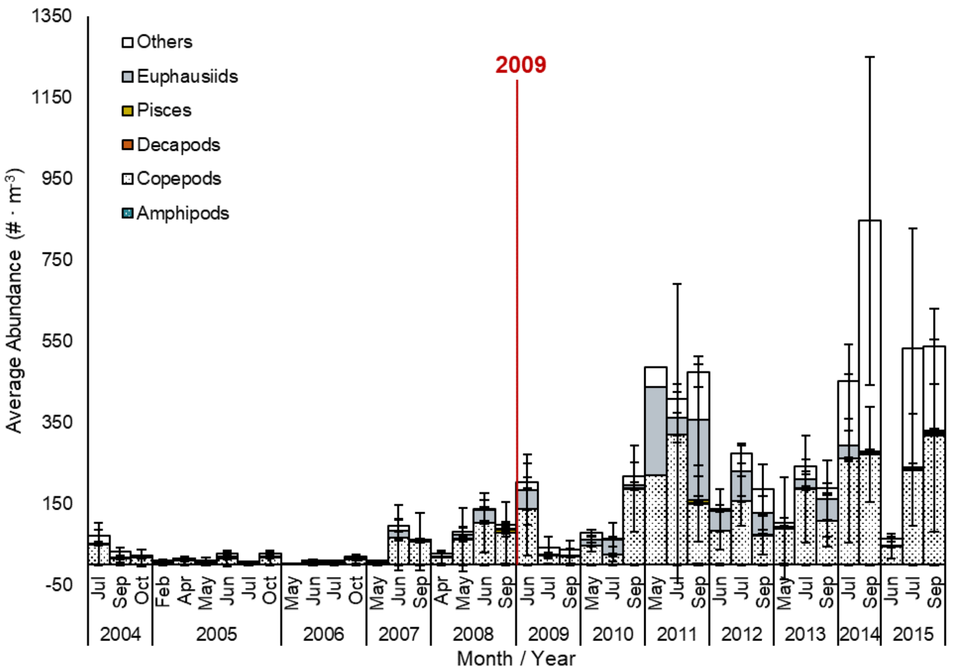


Figure S.LR.15.1. Average abundance (number per m^3) and standard deviation of zooplankton groups collected in the upper 50 meters of the water column from CBNMS ACCESS stations from 2004-2015. The vertical red line indicates the year of the last condition report (2009). Image: Elliott et al., 2020.

Natural variation in ocean conditions, as well as climate change induced variation, influences zooplankton communities. Similarities between sampled years based on ACCESS data on zooplankton species composition data from hoop net samples were analyzed by performing a non-metric, multi-dimensional scaling (nMDS) analysis for samples collected in the spring and summer months (April - July; Figure S.LR.15.2). The analysis reveals changes in community composition during the study period. The years 2004-2006 were warm, followed by a cooler period from 2007-2013, each characterized by different relative abundances and productivity in the zooplankton community. The larger and more variable 2007-2013 cluster is due to changes in mid-2009 from colder to warmer conditions, which changed zooplankton community structure (Fontana et al., 2016). The North Pacific heatwave occurred in 2014-1015 producing assemblages dominated by tunicates. This shift can have large impacts to predator species. Years that had high gelatinous zooplankton abundance corresponded to low baleen whale density (Elliott et al, 2019, S.LR.13.2, S.LR.13.3).

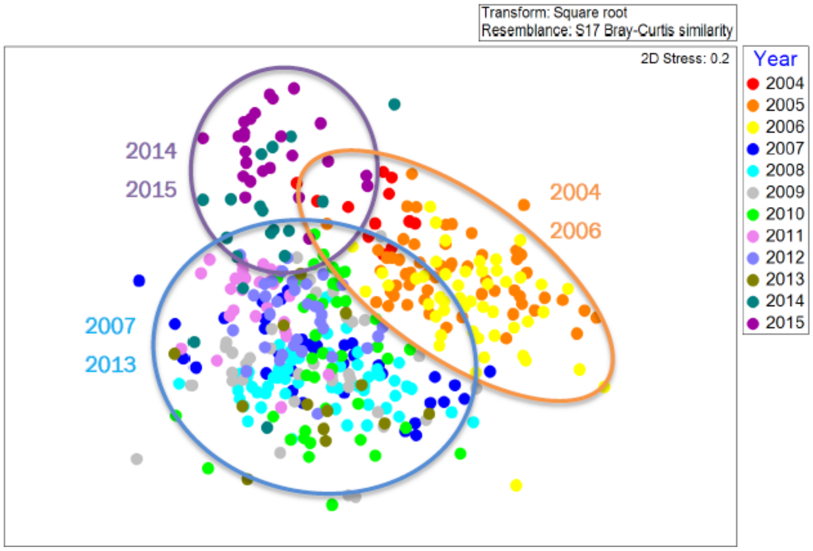


Figure S.LR.15.2. Non-metric multi-dimensional scaling (nMDS) for zooplankton species found in net tow samples (points) collected by ACCESS from 2004-2015 in the spring and summer months (April through July). The species composition of each net tow sample was used in calculating the Bray-Curtis similarity index. Samples with similar species in similar abundances are closer together on the plot, while samples that are more dissimilar in species composition and abundances are farther apart. Reference figure S.LR.15.1 for zooplankton groups per sampling year. Image: Elliott et al., 2020.

<u>Groundfish</u>

Groundfish include more than 90 different types of roundfish, flatfish, rockfish, sharks, and skates off the West Coast. Groundfish primarily live on or near the seafloor and are fished year-round with a variety of gear types. The National Marine Fisheries Service (NMFS) conducts the West Coast Groundfish Bottom Trawl Survey (WCGBTS) to collect fishery-independent data used for stock assessments and groundfish management. Data are collected on the abundance, spatial distribution, sex, length, maturity, weight, and age of groundfish in trawlable shelf and slope habitats along the U.S. West Coast. Trawl datasets from the continental shelf and slope in CBNMS were derived from the WCGBTS (WCGBTS, 2019) and analyzed by CCIEA based on the approaches used in NOAA's California Current Ecosystem Status Report (Harvey et al. 2021). To estimate species density, the number of species per trawl (species per area) was calculated and shows similar means in 2003 – 2008 and in 2009 – 2019. Spatially, in the last five years, the number of species caught on the CBNMS shelf declined (greater than 1.0 standard deviation of the full time series) and the number of species caught on the CBNMS slope was stable (Figure S.LR.15.3).

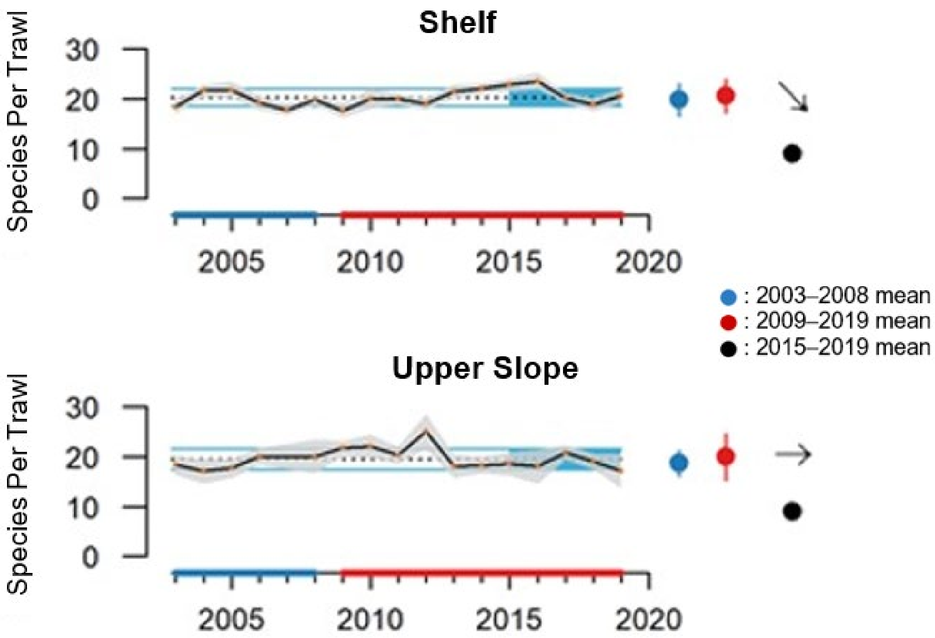


Figure S.LR.15.3. Trends in number of species per trawl collected by the West Coast Groundfish Bottom Trawl Survey (WCGBTS) from 2003 to 2019 in shelf and upper slope habitats in CBNMS. Horizontal black dotted and blue lines behind the data indicate the mean and SD of the full time series. The gray shading indicates +/- 1.0 standard error. The blue dots indicate the mean and 95% confidence interval from 2003-2008, the red dots indicate the mean and 95% confidence interval from 2009-2019. The black dots indicate the recent mean (2015-2019) is within 1.0 standard deviation of the long-term mean (2003-2019) and the arrow indicates the trend from 2015-2019 decreased more than 1.0 standard deviation compared to the full time series. Image: CCIEA

Additional analyses were performed on the mean trophic level of species caught by WCGBTS in CBNMS. Trophic level indicates where a species procures its energy and pertains to a position in a food chain. The lowest trophic level is composed of primary producers (algae, phytoplankton), the next trophic level is composed of organisms that feed on the primary producers and the highest levels are the top predators. Mean trophic level (MTL) is a biomass-weighted average of trophic levels of species that can indicate changes in trophic structure. Similar means of MTL were seen in 2003—2008 and 2009 –2019. On the CBNMS continental shelf, MTL ranged from 3.55 to 3.92 and while variable, over the last five years MTL was stable and near the long-term mean. On the upper CBNMS slope, MTL ranged from 3.51 to 3.83. MTL declined from 2015 to 2019 by more than one standard deviation of the long-term mean, reaching its lowest point across the time series (Figure S.LR.15.4). On the slope, the abundance of many species varied over the last five years. High trophic level species like lingcod (*Ophiodon elongatus*) and petrale sole (*Eopsetta jordani*) declined over the last five years on the upper slope, while some lower trophic level species like Dover sole (*Microstomus pacificus*) and shortspine thornyhead (*Sebastolobus alascanus*) increased. The combined effects of these changes likely caused the change in MTL on the upper slope.

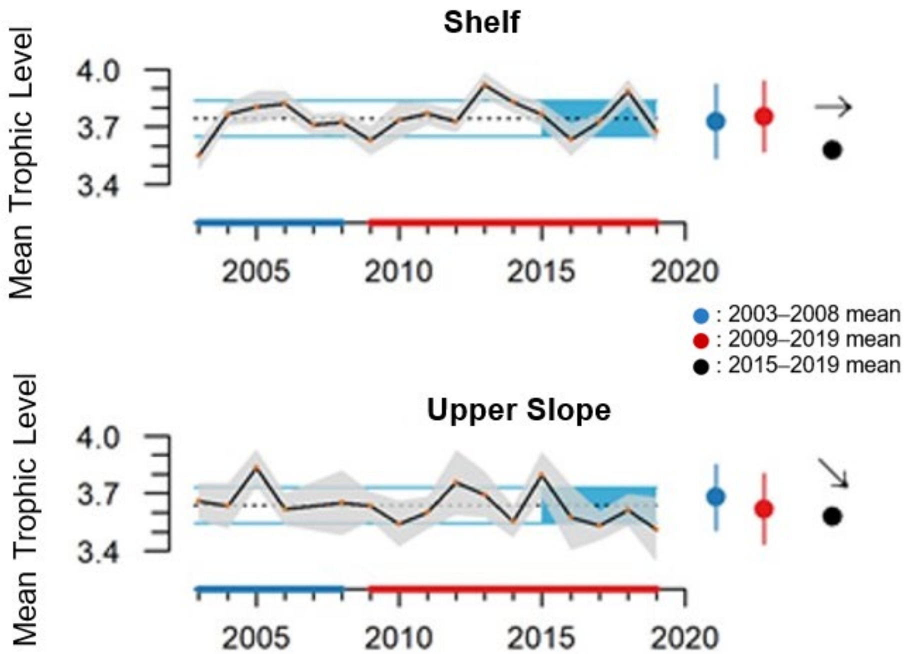


Figure S.LR.15.4. Mean trophic level (biomass-weighted average of trophic levels of species) of groundfish species caught by West Coast Groundfish Bottom Trawl Survey (WCGBTS) from 2003 to 2019 in shelf and upper slope habitats in CBNMS. Horizontal black dotted and blue lines behind the data indicate the mean and SD of the full time series. The gray shading indicates +/- 1.0 standard error. The blue dots indicate the mean and 95% confidence interval from 2003-2008, the red dots indicate the mean and 95% confidence interval from 2009-2019. The black dots indicate the recent mean (2015-2019) is within 1.0 standard deviation of the long-term mean (2003-2019) and the arrow indicates the trend from 2015-2019 decreased more than 1.0 standard deviation compared to the full time series. Image: CCIEA

Benthic community

Focused effort on species identification in recent years has led to new observations and new range extensions, made possible by improving technologies like high definition cameras and enhanced lighting, and due to prioritization of new areas of seafloor added to the sanctuary in 2015 (Appendix.X.15.1, Appendix.X.15.2). New species observations are extremely valuable for tracking long term changes in community composition.

Side Text Box with photo (TBD)

During an ROV cruise on Cordell Bank in 2018 onboard the NOAA ship *Bell. M. Shimada* a specimen of a small yellow coral was collected (under sanctuary permit CBNMS-2014-001) and identified and described as a new species, *Chromoplexaura cordellbankensis* (Williams and Breedy

2019, Figure S.LR.15.5a). *C. cordellbankensis* was thought to be a new record for CBNMS, however a subsequent review of still images taken from submersible dives at Cordell Bank in 2004 indicates a similar looking coral that may have been overlooked because of its small size, sparse occurrences, and the limited resolution of Delta's standard definition video. *C. cordellbankensis* was observed on numerous ROV transects conducted on Cordell Bank in 2017 but attempts to collect a specimen were unsuccessful at that time (Graiff et. al., 2019).

New information about the deep habitats in CBNMS was expanded when ONMS collaborated with the Ocean Exploration Trust in 2017 and 2019 using the *Hercules* ROV off the E/V *Nautilus.* Many of the species observed in 2017 between 740 and 2,700 m were new records for the sanctuary; 31 coral taxa and 11 sponge taxa were previously unknown in CBNMS (Graiff and Lipski, 2020b). Notably, the corkscrew coral, *Radicipes stonei*, was determined to be a range extension from the Aleutian Islands, Alaska (Ralf Cordeiro and Gary Williams, pers. comm.). A sponge specimen collected at 2,220 m was described as the new species *Farrea cordelli* (Reiswig, 2020, Figure S.LR.15.5b).

New knowledge was gained about the geographical and depth ranges for many sponges. The sponge *Cladorhiza bathycrinoides* was previously known from the Sea of Okhotsk (Pacific coast of the Kurile Islands); the CBNMS specimen is an astonishing geographic range extension of at least 6,382 km from its previously known occurrence. The stalked sponge, *Caulophacus (Caulophacus) schulzei,* is known to have a wide distribution from the Tasman Sea, N. Peru, Ecuador, Gulf of Panama, Central California and the Bering Sea from 3,183-4,510 m depths. The specimen collected in CBNMS is a northward range extension of 353 km from Pt Conception, CA and provides the first *in situ* image of the species. The barrel shaped sponge, *Rhabdocalyptus dawsoni,* is well known in this region, with a distribution from southern California to Cape Spencer, Alaska and probably into the Bering Sea at depths of 10-437 m, but the specimen collected from CBNMS extended the depth distribution by over five times, from 437 to 2,113 m (Reiswig, 2020).

The deepest visual surveys in the sanctuary were conducted in Bodega Canyon (3,318 m) in 2019. Collections of stalked glass sponges (pending identification) and sea pens previously unknown to CBNMS were made (Graiff and Lispki, in review). The depth distribution for at least 13 corals and nine sponges documented in 2019 were the deepest yet recorded in CBNMS. The first record of the tube worm *Lamellibranchia* in CBNMS was also made (1,790 – 1,822 m in "Box canyon"), indicating the presence of methane seeps. All of these new and exciting findings about the benthic biodiversity in CBNMS can be attributed to advancements in technology and new areas to explore.

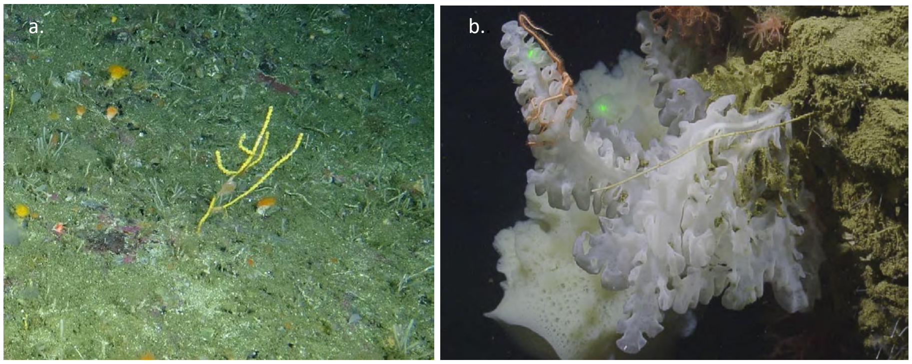


Figure S.LR.15.5. (a) Yellow gorgonian is the new species *Chromoplexaura cordellbankensis*: Photo: NOAA/MARE (b) this sponge collected at 2,220 m was described as the new species *Farrea cordelli.* Photo: OET/National Marine Sanctuaries

The most comprehensive benthic datasets are those from Cordell Bank itself. Benthic survey technologies and methods used on the bank have evolved from submersibles to ROVs, making direct comparisons of the respective datasets difficult. To assess recent biodiversity of the bank's coral, sponge, and fish communities, diversity indices including richness (S), Shannon diversity index $(H' = -\sum Pi\ log(Pi)$ where the logs are to the base e) and Pielou's evenness index $(J' = H'/logeS)$ were calculated from density data collected from ROV transects in 2017 and 2018 (CBNMS unpublished data, 2021). On a spatial scale, biodiversity on Cordell Bank is similar across the sampling sites on the bank and will continue to be monitored on future surveys to establish longer term trend data (Appendix.X.15.3, Appendix.X.15.4). On a temporal scale, biodiversity trend data over time are limited. Repeated survey sites of designated "fixed" sites on the bank's shallowest reef tops will allow tracking of long term changes in benthic communities. A comparison of diversity metrics of corals, sponges and fish at the fixed site North Point indicate similar richness (S), diversity (H') and evenness (J') in 2017 and 2018 (Appendix.X.15.5, Appendix.X.15.6).

<u>Seabirds</u>

Over fifty seabird species have been identified feeding in or near CBNMS; they are a mix of local breeding birds and highly migratory open-ocean species. Seabird species composition and abundances have been recorded annually since 2004 by ACCESS. Diversity (H') of seabirds quantified on transects in CBNMS and GFNMS were calculated for spring (May and June), summer (July and August), and fall (September and October) cruises (Figure S.LR.15.6). Overall, seabird diversity was stable from 2009-2019, and variation was likely attributable to natural processes associated with oceanographic seasonality.

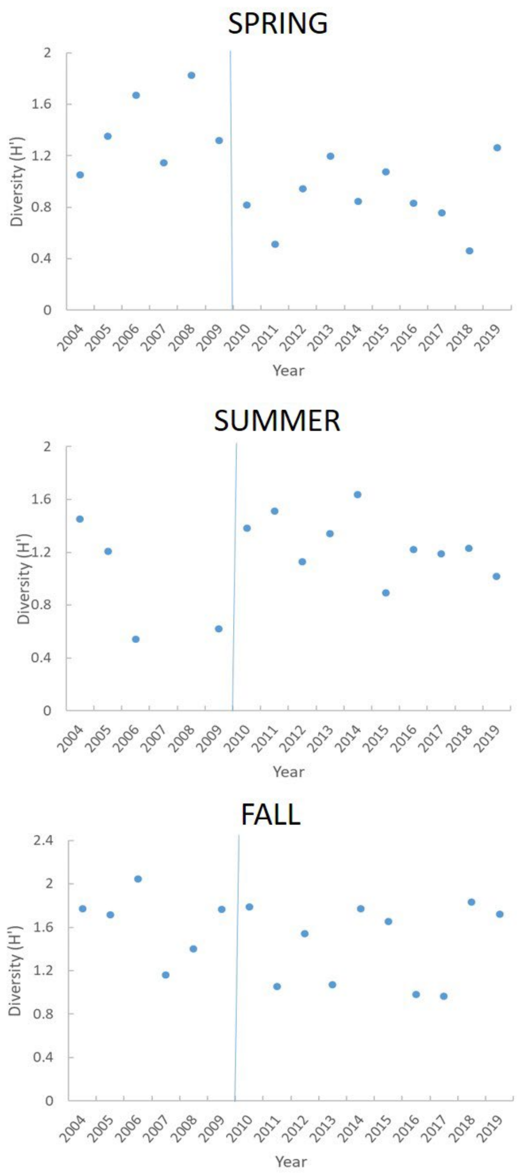
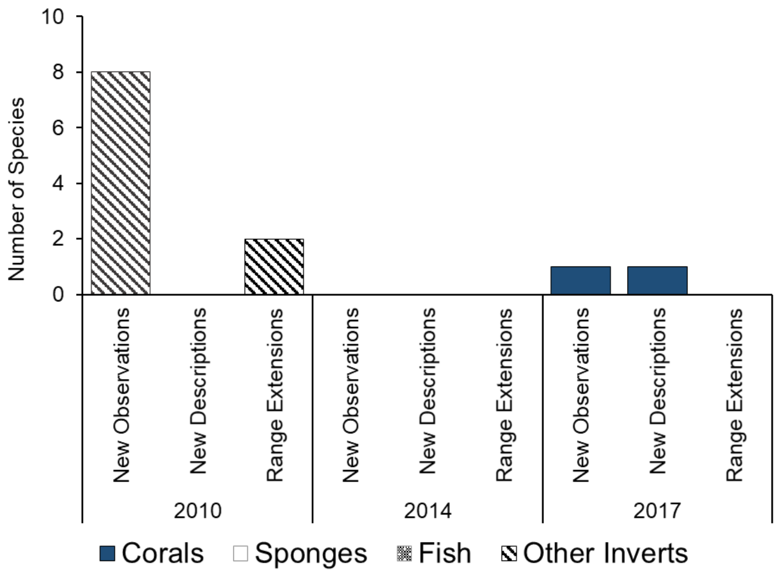


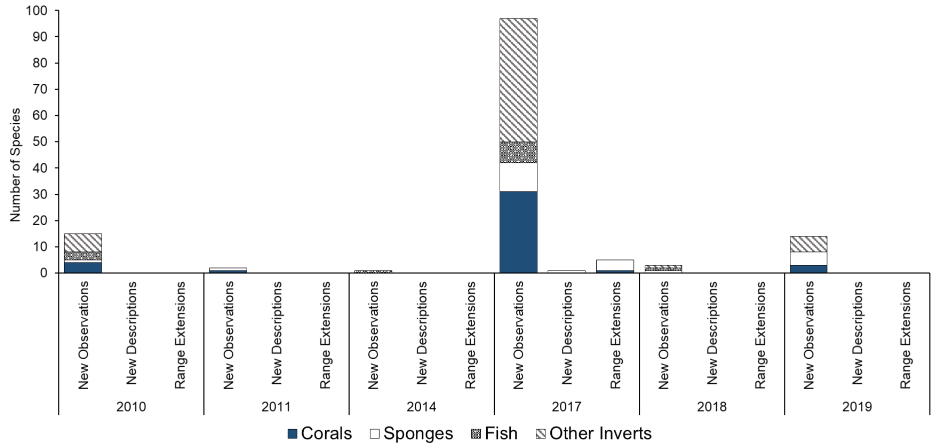
Figure S.LR.15.6. Diversity of seabirds observed from ACCESS data collected in spring, summer and fall from 2004-2019. The vertical blue line is a reference mark for data used in the assessment period of the previous condition report from data relevant to this report. Image: ONMS/Point Blue Conservation Science

Conclusion
The status of biodiversity improved since the 2009 report, largely due to stable diversity for groundfish, benthic invertebrates, and seabird communities in the sanctuary. Natural variation in ocean conditions influences zooplankton diversity and abundance. Notably, zooplankton communities appear to have recovered to typical biodiversity after marine heatwave-induced changes. Time series data are available for indicator groups, but there is no historical information >20yrs to better understand changes relative to 'pristine' conditions and there is no clear evidence of improving or worsening trends. Advancements in benthic survey technologies have allowed for more effective exploration in the sanctuary, resulting in new species records, identification of new species, and discovering range and depth extensions, leading to an improved understanding of sanctuary biodiversity.

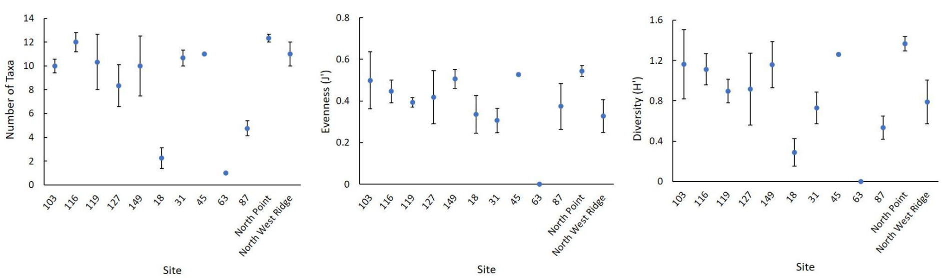
Appendix Figures



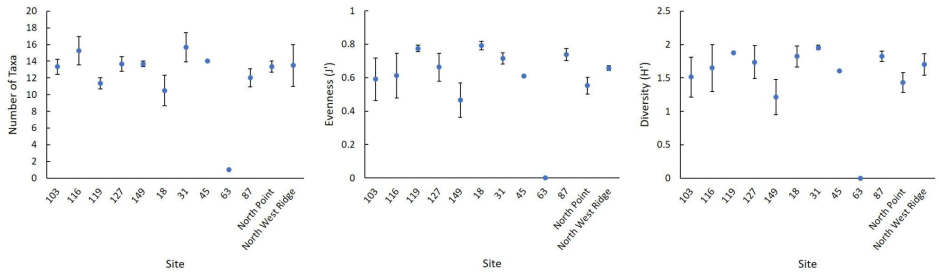
Appendix.X.15.1. Total number of new macroinvertebrate and fish species observations, descriptions and range extensions from benthic surveys on Cordell Bank. Collections by SCUBA were made in 2010 (37-59 m) and collections by ROV were made in 2014 and 2017 (46-119 m). Image: CBNMS.



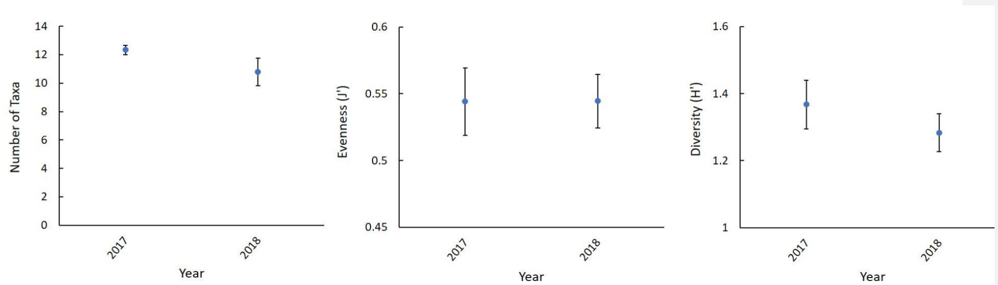
Appendix.X.15.2. Total number of new macroinvertebrate and fish species observations, descriptions and range extensions from benthic surveys on the shelf, slope and canyons in CBNMS (167-3,318 m depth). Surveys in 2010 and 2014-2019 used a ROV and 2011 survey used an AUV. More survey time and focused effort on species identification has led to new observations and range extensions as seen in the 2017 survey that had a total ROV dive time of 76 hrs among five sites. Image: CBNMS.



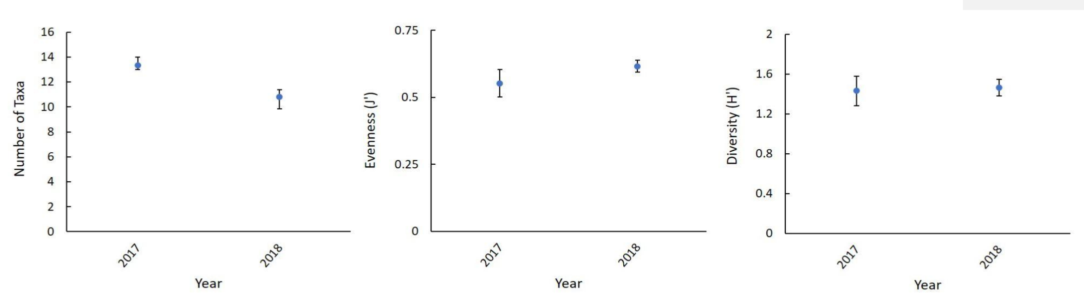
Appendix.X.15.3. Diversity metrics (mean ± standard error): number of taxa, evenness (J') and diversity (H') of coral and sponge densities observed by ROV from sites (70-120m depth) on Cordell Bank in 2017 (Graiff et al., 2019). Image: CBNMS.



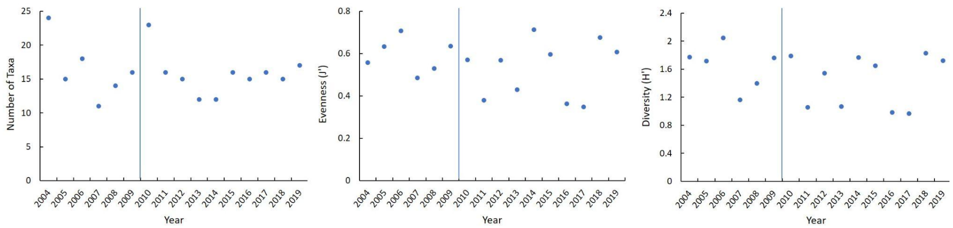
Appendix.X.15.4. Diversity metrics (mean + standard error): number of taxa, evenness (J') and diversity (H') of fish densities observed by ROV from sites (70-120m depth) on Cordell Bank in 2017. Image: CBNMS.



Appendix.X.15.5. Temporal comparison of diversity metrics (mean + standard error): number of taxa, evenness (J') and diversity (H') of coral and sponge densities from the fixed site North Point surveyed by ROV in 2017 and 2018. Image: CBNMS.



Appendix.X.15.6 Temporal comparison of diversity metrics (mean + standard error): number of taxa, evenness (J') and diversity (H') of fish densities from the fixed site North Point surveyed by ROV in 2017 and 2018. Image: CBNMS.



Appendix.X.15.7. Diversity metrics (mean + standard error): number of taxa, evenness (J') and diversity (H') of seabird densities observed on ACCESS survey lines (1-10) in CBNMS and GFNMS from fall (Sept-Oct) surveys. Image: CBNMS

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Status and Trends of Maritime Heritage Resources (Question 16)

The Maritime Heritage Resources section of this report addresses the condition and threats to heritage resources in the sanctuary. Maritime heritage can encompass a wide variety of cultural, archaeological, and historical resources. Archaeological and historical resources are material evidence of past human activities and include vessels, aircraft, structures, habitation sites, and objects created or modified by humans. Cultural resources may include specific locations associated with traditional beliefs or where a community has traditionally carried out economic, artistic, or other cultural practices important to maintaining its historic identity. The majority of existing site information currently describes shipwreck (archaeological/historical) resources. Question 16 assesses the integrity of known maritime heritage resources in the sanctuary. The integrity of a heritage resource refers to its ability to convey information about the past, and can be impacted by both natural events and human activities. Archaeological integrity is generally linked to the condition of the resource, whereas historical significance may rely on other factors.

Table S.MHR.16.1. 2009 Condition Report ratings (left) and 2009–2021 Condition Report ratings (right) status, trend, and confidence ratings for the maritime heritage question.

2009 Condition Report Question		2009 Rating	2009–2021 Condition Report Question		2009–2021 Condition Report Rating			
					Status	Confidence (Status)	Trend	Confidence (Trend)
15	Maritime archaeological resource integrity	?	16	Maritime heritage resource integrity	?		▼	

Question 16: What is the condition of known maritime heritage resources and how is it changing?[1]

Status: Undetermined
Trend: Worsening

[1] A workshop was not convened for the question that asks, What is the condition of known maritime heritage resources and how is it changing? Archaeological experts with the ONMS Maritime Heritage Program and CBNMS internally evaluated this question. These subject experts have been monitoring existing archaeological sites along the west coast since the 1980s.

Status Description: The status is undetermined.
Rationale: The status rating is undetermined. The one maritime heritage resource documented to be sunk within the sanctuary, the ex-USS S*tewart* (DD-224) (see Sanctuary Setting for more information), has not been specifically located or assessed since it sank in 1946 within what is now the sanctuary. It is assumed that the ship will have deteriorated to some degree due to being submerged in the Pacific Ocean since then; accordingly the trend for the condition of the shipwreck is that it is thought to be worsening, most likely due to natural processes, though it is possible the condition may be somewhat influenced by human activities (see question 5 in this report). Note that a confidence score was not assigned to status and trend rating for this question because an actual assessment has not yet been conducted; also, subject matter external experts were not consulted on these ratings.

Comparison to the 2009 Condition Report
In the 2009 condition report, this question was also rated undetermined (Table S.MHR.16.1), but for a different reason – there were no documented underwater archaeological sites known to exist within sanctuary boundaries. At the time of the 2009 condition report, the ex-USS *Stewart* (DD-224) was not located within sanctuary boundaries, however, documents indicate that after NOAA expanded the sanctuary's boundaries in 2015, the shipwreck is now within the sanctuary.

New Information in the 20__ Condition Report
Historic conditions on ex-USS *Stewart* (DD-224), a U.S. Navy destroyer, were documented prior to and at the time that it was used in 1946 by the Navy as a target ship. Records include archival documents, articles, books, news stories, and photographs, and this information serves as a baseline for understanding the ship's condition when it sank in May 1946.

While the vessel did suffer damages and underwent repairs earlier in its history (Klar, 1989), during its service under the Japanese Imperial Navy flag there were further repairs and modifications, including raising it from a sunken dry dock and repairing battle damage. During the conversion into a Japanese patrol boat, significant changes were made, including trunking the front funnels together into one stack, lowering the stacks, altering the bridge and other structures, and changing the guns and some of the equipment (Edwards, 2014; Tamura, 2015). Once recovered by the U.S. Navy at Hiro Bay, the Navy determined there were health and safety issues on the vessel. It was rat-infested, in decrepit condition, dirty and rusty, and had Japanese characters painted on the bulkheads and doors. The Navy had the Japanese clean and paint it, and fumigate (Edwards, 2014; Klar, 1990). Only two boilers were working. On the way back to the U.S, the ship suffered a series of problems such as mechanical issues with fuel pumps, engines and generator failures, and multiple parted towlines (Edwards, 2014; Klar, 1990). En route to Hawaii, a Navy tug accidentally buckled the ship's starboard well deck bulkhead with its port anchor (Klar, 1990). It arrived in San Francisco Bay in April 1946 and was towed to a dock in Oakland. Lack of available documentation leaves it unknown if parts of the ship, its equipment, or contents were salvaged for reuse or disposal at this time.

Figure S.MHR.16.1. Ex-USS *Stewart* (DD-224) on May 24, 1946, just before being sunk. Photo: Official U.S. Navy Photograph, National Archives and Records Administration.

On May 24, 1946, the ship was intentionally sunk by the Navy for target practice. Navy patrol craft-799 pumped twelve 40-mm and 17 three-inch shells into the ship from a range of 300 yards after five navy fighter planes fired 18 rockets and thousands of rounds of .50 caliber machine gun bullets at the ship. With gaping holes opened in the side, the ship sank (Associated Press, 1946). Despite this, based on the photographs taken at the time, the ship, though on fire, appeared largely intact, though missing its weapons and radar, as it sank 38.7 miles west of Bodega Head in about 6,000 feet of water (Naval History and Heritage Command, n.d.-a, Naval History and Heritage Command, n.d.-b; ONMS, 2014b). *DD-224* has not been assessed since its sinking in 1946 and therefore its integrity is undetermined.

Though the integrity of the wreck has not been determined, the trend for the shipwreck's condition is assumed to be worsening. Physical forces would have likely acted upon the ship due to sinking thousands of feet from the surface then contacting the submerged lands and over 75 years of continued submersion in the ocean has most likely degraded the shipwreck's components via interaction of biological, physical, and chemical processes. As was described earlier in this report, a number of variables influence the condition of metal shipwrecks (Wright, 2016), including metal composition, pH, dissolved oxygen, temperature, salinity, and water movement, among others (North and Macleod, 1987). While the chemical make-up of the environment surrounding a submerged site is a primary factor in its preservation, the impacts of ocean acidification to metal corrosion rates and potentials, effects on organic materials, and implications to artifact stability and equilibrium are not yet well understood (Dunkley, 2015). The water chemistry at a given site affects the corrosion of the metal parts of a shipwreck, at different rates for different metals, and the amount and rate of concretions and microbial activity must also be considered in determining corrosion for a specific shipwreck (Moore, 2015). Zinc and wrought iron corrodes before metals such as aluminum and brass. Steel is fairly susceptible to corrosion, but these rates are lower in deep/cold water environments (Hoyt, 2020). More acid-soluble metals, such as copper or its alloys, will have a greater sensitivity to ocean acidification, as the alkalinity of seawater hydrolyzes acidic corrosion products, forming patinas that protect the metal surface—a process inhibited by increased acidity (Spalding, 2011). The depth where the ship sank (around 6,000 feet below the surface) suggests that overall microbial activity is likely limited and concretion may not be as prevalent (Hoyt, 2020) in comparison to shallower shipwrecks. The deep location of this shipwreck precludes direct human activity disturbance such as commercial and recreational fishing (bottom trawls do not reach this deep), inadvertent damage by recreational divers, looting, or vessel anchorings.

Conclusion

Although the status of the ex-USS *Stewart* is undetermined, the condition is assumed to be worsening, albeit at a slow pace. ONMS prioritizes the preservation of the maritime heritage resource for the benefit of current and future generations and recognizes, as a matter of policy and practice, that *in situ* preservation is a widely accepted approach for resource protection. Notwithstanding the unknown current condition of the shipwreck, it likely continues to retain cultural and historical significance and educational value. Remains of the ship and any ship artifacts, depending on physical condition, may also retain those qualities, along with archaeological value.

Question 16 LIterature Cited

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Status and Trends of Ecosystem Services

Ecosystem services are the benefits that humans receive from natural and cultural resources. Generally, the taxonomy of the Millennium Ecosystem Assessment (2005) is used in ONMS condition reports. The Millennium Ecosystem Assessment (2005) was an initiative of the United Nations to assess ecosystem services, including cultural, provisioning, regulating, and supporting services. Categories of ecosystem services include "final" services, which are directly valued by people, and "intermediate" services, which are ecological functions that support final services (Boyd & Banzhaf, 2007). In ONMS condition reports, only final ecosystem services are rated, which is consistent with the anthropogenic focus of the reports and highlights priority management successes and challenges in sanctuaries. The complete definitions of ecosystem services considered by ONMS are included in Appendix ___.

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***<<<GRAY TEXT WILL BE A TEXT BOX TITLED* Intermediate and Final Ecosystem Services>>>**

There are two categories of ecosystem services: intermediate and final. Ecosystem services that are evaluated in condition reports are final ecosystem services. Intermediate services support other ecosystem services, whereas a good/service must be directly enjoyed by a person to be considered a final ecosystem service. For example, nutrient balance leads to clearer water and higher visibility for snorkeling and scuba diving. Nutrient balance is an intermediate service that supports the final ecosystem service of non-consumptive recreation via snorkeling and scuba diving.

***<<<GRAY TEXT WILL BE ANOTHER TEXT BOX TITLED* Ecosystem Services>>>**

Thirteen final ecosystem services may be rated in ONMS condition reports

Cultural (non-material benefits)

1. Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources
2. Non-consumptive recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources
3. Science — The capacity to acquire and contribute information and knowledge
4. Education — The capacity to acquire and provide intellectual enrichment
5. Heritage — Recognition of historical and heritage legacy and cultural practices
6. Sense of Place — Aesthetic attraction, spiritual significance, and location identity

Provisioning (material benefits)

7. Commercial harvest — The capacity to support commercial market demand for seafood products
8. Subsistence harvest — The capacity to support non-commercial demand for food and utilitarian products

9. Water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash
10. Ornamentals — Resources collected for decorative, aesthetic, or ceremonial purposes
11. Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use
12. Energy — Use of ecosystem-derived materials or processes for the production of energy

Regulating (buffers to change)

13. Coastal protection — Flow regulation that protects habitats, property, coastlines, and other features

Notably, some consider consumptive recreational fishing as a provisioning service, but it is included here as a cultural ecosystem service. Also, even though biodiversity was listed as an ecosystem service by the Millennium Ecosystem Assessment (2005), ONMS decided to remove it, recognizing that biodiversity is an attribute of the ecosystem on which many final ecosystem services depend (e.g., recreation, harvest); therefore, it is addressed in the State of the Resources section of this report. Lastly, although ONMS listed climate stability as an ecosystem service in 2015, it is no longer considered an ecosystem service in ONMS condition reports because national marine sanctuaries are not large enough to influence climate stability on a large scale (Fisher & Turner, 2008; Fisher et al., 2009).

For CBNMS, seven of the 13 final ecosystem services were rated during virtual workshops held in May and June 2021: commercial harvest, consumptive recreation, non-consumptive recreation, science, education, heritage, and sense of place. The other six ecosystem services were evaluated by staff, but were determined to not be applicable to the site.

Ecosystem Services Indicators

The status and trends of ecosystem services are best evaluated using a combination of three types of indicators: economic, non-economic, and resource. Economic indicators may include direct measures of use (e.g., person-days of recreation, catch levels) that result in spending, income, jobs, gross regional product, tax revenues, and non-market economic values (the difference between what people pay to use a good/service and what they would be willing to pay). Non-economic indicators can be used to complement economic indicators and include importance-satisfaction ratings for natural and cultural resources, facilities and services for recreation uses, limits of acceptable change for resource conditions, social values and preferences (measured by polls), social vulnerability indicators, perceptions of resource conditions in the present and expectations for the future, and access to resources. Finally, resource indicators are considered in determining status and trend ratings for each ecosystem service. Resource indicators are used to determine if current levels of use are sustainable or are causing degradation to resources. If resources cannot support current levels of use, this may downgrade a rating that may otherwise be higher based on economic and non-economic indicators alone. Together, these three types of indicators are considered when assessing the status and trends of ecosystem services in national marine sanctuaries.

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Status and Trends of Ecosystem Services

The following provides an assessment of the status and trends of seven ecosystem services that were rated during virtual workshops held in May and June 2021: commercial harvest, consumptive recreation, non-consumptive recreation, science, education, heritage, and sense of place (see Appendix __).

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Commercial Harvest — The capacity to support commercial market demands for seafood products[1]

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Status: Fair
Trend: Mixed
Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Rationale: Some fisheries in CBNMS have been impacted by changing environmental conditions, including ocean temperature and algal blooms, as well as management interventions, such as fishery closures to mitigate whale entanglement risk.

Commercial harvest is defined as the capacity to support commercial market demand for seafood products. These products may include fish, shellfish, other invertebrates, roe and algae. In Cordell Bank, commercially-targeted species include Dungeness crab, Chinook salmon, and multiple groundfish species, among others (Table ES.CH.1). Data suggest a decline in commercial harvest for several of these species in recent years. Declines in harvest seem to be driven by both environmental conditions and management regulations. For example, commercial Dungeness crab seasons have been curtailed due to elevated levels of domoic acid as well as the need to mitigate entanglement risk for whales. At the same time, performance of other fisheries has improved in recent years as management interventions, like the Pacific Fishery Management Council's (PFMC) rebuilding plan for over-harvested groundfish stocks, have taken effect. Given that the performance of some fisheries is compromised and additional management actions may be warranted, the status of commercial harvest in Cordell Bank has been rated fair. The commercial harvest trend has been rated mixed to reflect varying trends in the stocks of commercially-targeted species.

Table ES.CH.1. Status and trends for individual indicators discussed at the June, 2021 virtual workshop. There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/Data	Data Summary	Figure

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[1] Because of a limited number of experts providing input, staff rated this service after the workshop. Therefore, a confidence rating was not assigned.

	visualization		
Commercial landings by species	CDFW/ONMS	Status: Dungeness crab, chinook salmon, sablefish, Dover sole and petrale sole are top 5 species from 2013-2018 Trend: Dungeness crab and sablefish have been variable, salmon and Dover sole has been declining, and petrale sole has shown a slight improvement	
Fishing vessels and hours	USCG/NCCOS	Status: Most activity, regardless of gear type is concentrated in the eastern boundary Trend: Over time there appears to be an increase in activity (however, AIS requirements have changed).	
Fishing vessels and hours	GFW/NCCOS	Status: Most activity, regardless of gear type is concentrated in the eastern boundary Trend: Over time there appears to be an increase in activity (however, AIS requirements have changed). Trawling activity seems to be fairly stable over time	
Rockfish populations	NMFS	Status: Species recovered/recovering Trend: increasing population size	
Juvenile rockfish	NMFS	Status: Stable Trend: peaks 2014-2016	
Rockfish survey data	NMFS	Status: Stable Trend: peaks 2014-2016	
Benthic fish - Bank	see CBNMS State Section	Status: Stable Trend: no trend data	
Shelf fish and inverts	see CBNMS State Section	Status: Stable Trend: no quantitative trend data, appears stable	
Chinook Salmon	see 2014 FEIS Expansion Document	Status: Threatened Trend: California Coastal ESU is slowly increasing	Figure ES.CH.4

The top ten species by harvest revenue are presented in Table ES.CH.2. Values for harvest revenue and pounds represent five-year averages from 2015-2019. The top ten species harvested from Cordell Bank[2] are Dungeness crab, Chinook salmon, sablefish, petrale sole, dover sole, longspine thornyhead, market squid, shortspine thornyhead, chilipepper rockfish, and hagfish (CDFW, 2020a). These ten species account for nearly 97% of the total value and 93% of the total pounds landed in the sanctuary from 2015 to 2019. California halibut, which is ranked 11th in overall harvest revenue from 2015 to 2019, is frequently in the top 10 most valuable species for individual years (CDFW, 2020a). While not a significant component of the fishery during the study period, species like Pacific sardine (commercial harvest closed in 2015) and albacore tuna occur episodically as they are strongly influenced by oceanographic conditions (Miller et al., 2017; Giron-Nava et al., 2021).

Table ES.CH.2. Top Ten Species in CBNMS by Harvest Revenue (Annual Average, 2015-2019). Source: CDFW 2021

Rank	Species	Harvest Revenue	Pounds
1	Dungeness Crab	$1,001,530	298,158
2	Chinook Salmon	$552,786	90,387
3	Sablefish	$436,353	147,460
4	Petrale Sole	$58,587	49,220
5	Dover Sole	$56,478	133,925
6	Longspine Thornyhead	$36,277	83,885
7	Market Squid	$32,343	101,099
8	Shortspine Thornyhead	$27,594	21,052
9	Chilipepper Rockfish	$15,974	26,949
10	Hagfish	$14,214	19,522

To summarize landings by gear type, commercial records for specific fishing gears were grouped according to the methods described in Leeworthy et al., 2013. Table ES.CH.3 shows a summary of gear types ranked by five-year average harvest revenue from 2015 to 2019. Pot or trap gear, which is employed in the Dungeness crab fishery, accounts for the largest amount of harvest revenue from species captured in the sanctuary (CDFW, 2020a). Pot/trap gear ranks second in terms of pounds landed from the sanctuary with around 333,000 pounds annually. More biomass is landed by trawl gear, which accounts for nearly 364,000 pounds annually (CDFW, 2020a). Following pot/trap gear, the next most valuable commercial gear types by harvest revenue are trolling gear, longlines, trawls, and purse seines. Table ES.CH.3 also

[2] Landings data was available at the level of California Department of Fish and Wildlife's statistical fishing blocks, which are 10 minutes by 10 minutes in resolution. Annual catch and harvest revenue was estimated by grouping the 39 fishing blocks that best correspond to the sanctuary area.

summarizes the average annual number of vessels reporting catch with each gear type from 2015-2019, along with standard deviations. Since vessels may report catch using multiple gear types, a single vessel may be counted in multiple gear categories. More vessels reported using trolling gear than any other gear type, followed by pots/traps (CDFW, 2020a). These two gear types also exhibit the highest degree of variability in the number of vessels employing them. Although trawls capture more biomass than any other gear type, relatively few vessels (an annual average of 3.6) report using trawl gear. An annual average of 21.4 vessels report catch by hook and line and an average of 13 vessels report catch by longlines (CDFW, 2020a).

Table ES.CH.3. Summary of landings and number of vessels by gear type, 2015-2019. Source: CDFW 2021

		Landings		Number of Vessels	
Rank	**Gear Type**	**Harvest Revenue**	**Pounds**	**Average**	**Standard Deviation**
1	Pots/Traps	$ 1,037,086	333,022	54	18.7
2	Troll	$ 550,630	90,406	72.6	40.1
3	Longlines	$ 368,938	118,155	13	4.3
4	Trawl	$ 256,170	363,961	3.6	0.9
5	Purse Seine	$ 61,104	193,005	1	0
6	Other Seine/Dip Nets	$ 41,558	87,088	1.3	0.6
7	Hook/Line	$ 39,388	12,307	21.4	7.1
8	Hooka/Diving	$ 2,717	429	1	0

Based on VMS records, fishing activity within CBNMS is concentrated in the eastern part of the sanctuary, where the majority of fishing for Dungeness crab and Chinook salmon occurs (NCCOS, 2020). The number of commercial trips reporting catch in CBNMS has varied without trend from 2012 to 2020 (CDFW, 2020a). No data were found providing a direct measure of fishing effort in the sanctuary, although estimating effort for certain fisheries may be possible using VMS records. This presents a data gap, as catch trends cannot be scaled by level of effort (i.e., catch-per-unit-effort (CPUE) cannot be calculated) to indicate trends in the local abundance of target species. Grouping together catch records for all species, there is a statistically significant increase in the total weight landed from CBNMS from 1994 (the first year for which catch records were available) to 2020 (Mann-Kendall; tau = 0.328; p-value = 0.017) (Figure ES.CH.1). This trend is driven, in part, by high harvest years for market squid, Dungeness crab, and groundfish caught by trawl during and after 2010 (Figure ES.CH.2) (CDFW, 2020a). From 2012 to 2020, total pounds landed look to be declining, but the trend is not statistically significant at the 5% level (GLM; coefficient = -73,255; p-value = 0.12) (Figure ES.CH.1) .

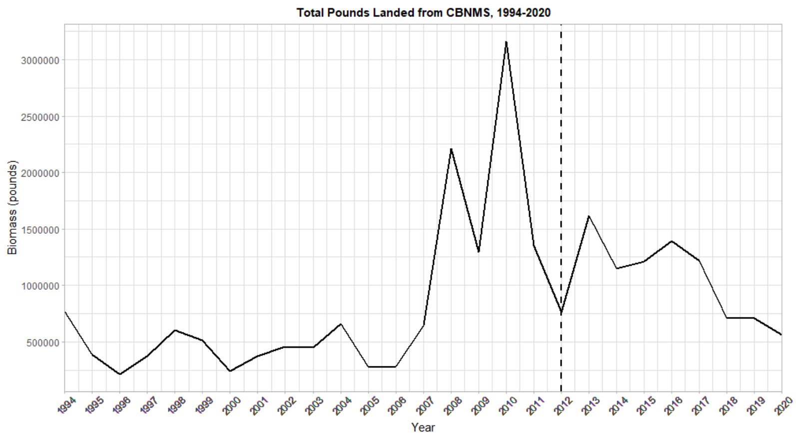

Figure ES.CH.1. Total Pounds Landed from CBNMS from 1994-2020. Source: CDFW 2021.

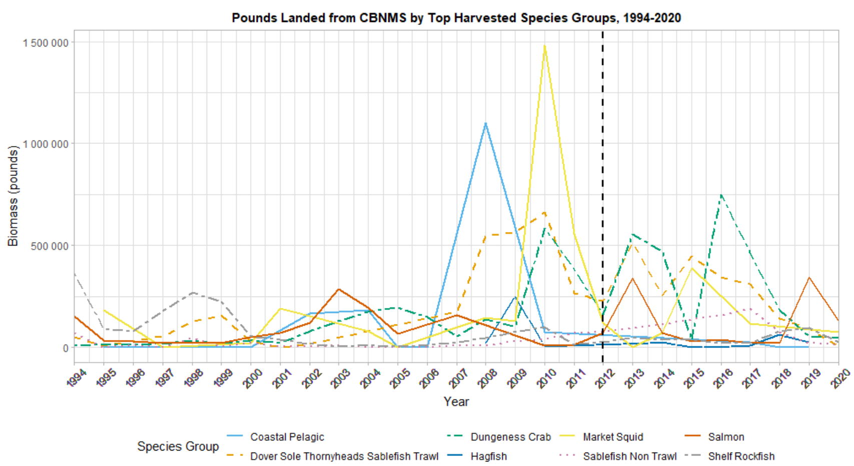

Figure ES.CH.2. Pounds Landed from CBNMS by Species Group from 1994-2020. Source: CDFW 2021.

The Dungeness crab fishery has been subject to several management actions in recent years. During the 2012-2020 period, there were relatively high Dungeness crab landings in 2013 and 2016 (Figure ES.CH.3) (CDFW, 2020a). In 2015, landings decreased to a time series low as elevated levels of domoic acid, a neurotoxin produced by a harmful algal bloom (HAB), triggered health advisories and fishery closures for Dungeness crab (California Ocean Science Trust, 2016). Following another peak in 2016, landings decreased to low levels in 2019 and 2020. The fishery was subject to delays and closures in 2019, 2020, and 2021 due to elevated risk of whale and sea turtle entanglement in gears used by the fleet (CDFW, 2019; CDFW, 2020b; CDFW, 2021b; CDFW, 2021c). Another concern for the fishery is ocean acidification, which reduces prey availability, inhibits larval development, and leaves freshly molted crabs vulnerable for a longer period of time (ONMS, 2020c; NMSF, 2019). The fishery closes during the molting season between August and December, and ocean acidification could lengthen the time needed for closures and reduce the number of crabs reaching adulthood (NMSF, 2019). Despite these concerns, population estimates indicate that the West Coast Dungeness crab population is stable or increasing (NOAA Fisheries, 2020a; Richerson et al. 2020).

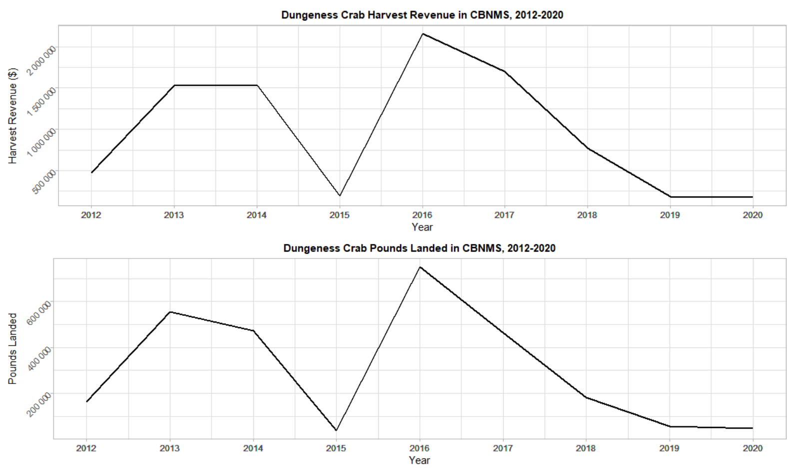

Figure ES.CH.3. Dungeness Crab Harvest Revenue and Pounds Landed from CBNMS, 2012-2020. Source: CDFW, 2021d.

From 2012 through 2020, Chinook salmon harvest peaked in 2013 and 2019 at over 340,000 pounds (Figure ES.CH.4) (CDFW, 2020a). Those bumper years were interrupted by a period of low harvest from 2014 to 2018. The Chinook salmon observed in CBNMS belong primarily to the Sacramento River stock. However, other evolutionarily significant units (ESUs) are dependent on sanctuary waters for part of their life cycles as well. Together, these ESUs include California Coastal Chinook (threatened, no trend), Central Valley spring-run Chinook (threatened, stable/increasing trend), Central Valley fall and late-fall Chinook (species of concern, undetermined trend), and Sacramento River winter-run Chinook (endangered, increasing trend) (ONMS, 2014b; CDFW, n.d.; NMFS, 2016a; NMFS, 2016b; NOAA Fisheries, 2020b). The harvest trends depicted in Figure ES.CH.4 track closely with trends in statewide harvest as well as the observed Sacramento Index (SI), a metric representing the total number of adult fall-run Chinook salmon in the ocean that will be harvested or that will escape to spawn in the Central Valley (FISHBIO, 2020; Pacific Fishery Management Council, 2020).

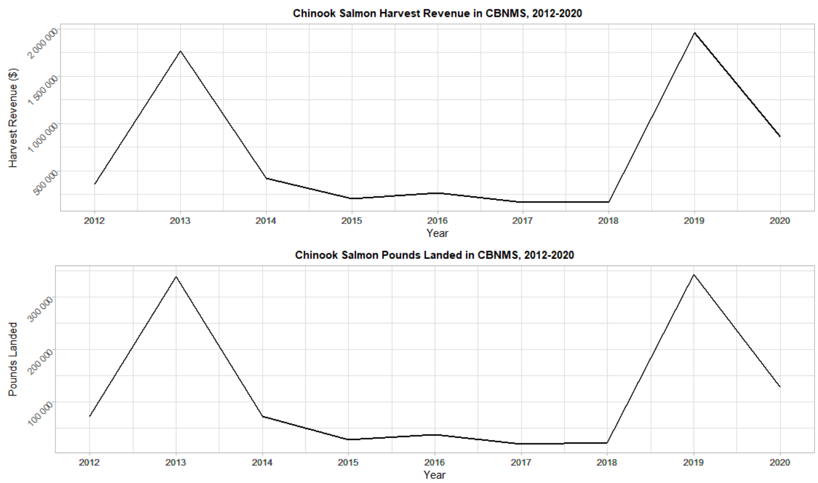

Figure ES.CH.4. Chinook Salmon Harvest Revenue and Pounds Landed from CBNMS, 2012-2020. Source: CDFW, 2021d.

Shelf rockfish landings in CBNMS varied without trend over the 2012-2020 period, peaking in 2019 at over 95,000 pounds (CDFW, 2020a). A number of rockfish stocks declined from the 1980s through the early 2000s as a result of fishing pressure and periodic, environmentally-driven recruitment failure (SIMoN, 2020). Commercial fishing has since been limited in several areas of CBNMS as part of the Pacific Fishery Management Council's groundfish rebuilding plan (ONMS, n.d.). These closed areas include both essential fish habitat conservation areas (EFHCAs), which are closures to limit habitat impacts from bottom trawl gear other than demersal seines, and rockfish conservation areas (RCAs), which are areas where fishing for groundfish is prohibited for three modes of fishing – trawl, non-trawl, and recreational (CBNMS, n.d.; ONMS, 2009b). Currently, nine of ten West Coast groundfish stocks are considered rebuilt since being declared overfished or depleted in 1999 (the exception being the yelloweye rockfish stock, which is rebuilding faster than expected) (PFMC, 2021). The success of the groundfish rebuilding plan suggests potential for increased commercial groundfish harvest from CBNMS in the future.

Generally, fishery management affecting Cordell Bank has shown improvement. The collaborative Dungeness Crab Fishing Gear Working Group is developing measures – ranging from gear modifications to training to risk assessment tools – to reduce whale entanglements while minimizing costs to commercial fishermen (California Ocean Protection Council, 2020). NOAA, through a cross-line office initiative, has worked to develop and implement recovery actions for above-mentioned Chinook salmon ESUs (NMFS, 2014). Fishery managers have demonstrated success in achieving the groundfish biomass targets outlined in the Pacific Council's rebuilding plan (PFMC, 2021).

Conclusion

While National Marine Fisheries Service and California Department of Fish and Wildlife management actions have shown improvement in stock levels, there remains a need for continuation and improvement in some areas of management, for example restoring impaired riverine and estuarine habitat, mitigating human-wildlife conflict such as reducing entanglement in fishing gear, and adapting fisheries management to increasing environmental variability (Brady et al., 2017). As a result, the status of commercial harvest in Cordell Bank has been rated fair. The trend has been rated mixed: several commercially-important stocks are depleted, whereas others are stable or increasing.

Figures for APPENDIX (to be moved when report is compiled)

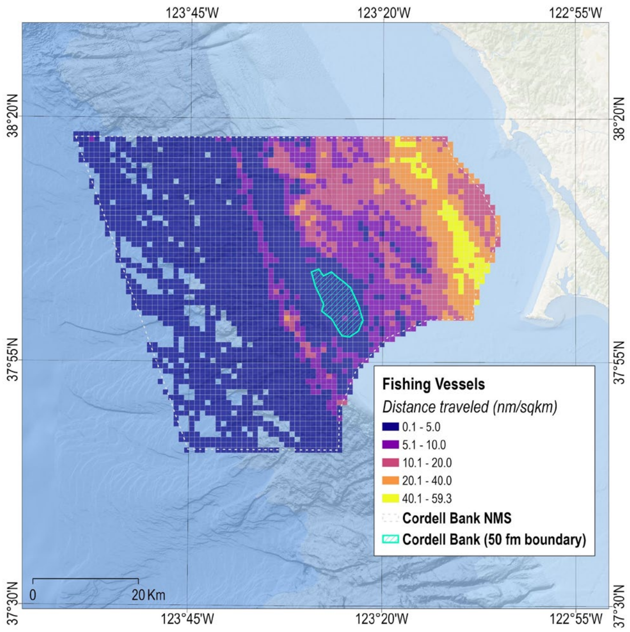

Table APP.F.5. Distance traveled per grid cell (nm/sq km) by all fishing vessels from 2009-2020. Note: no way to sort commercial fishing vessels from recreational fishing vessels from AIS data across all years. Source: AIS data.

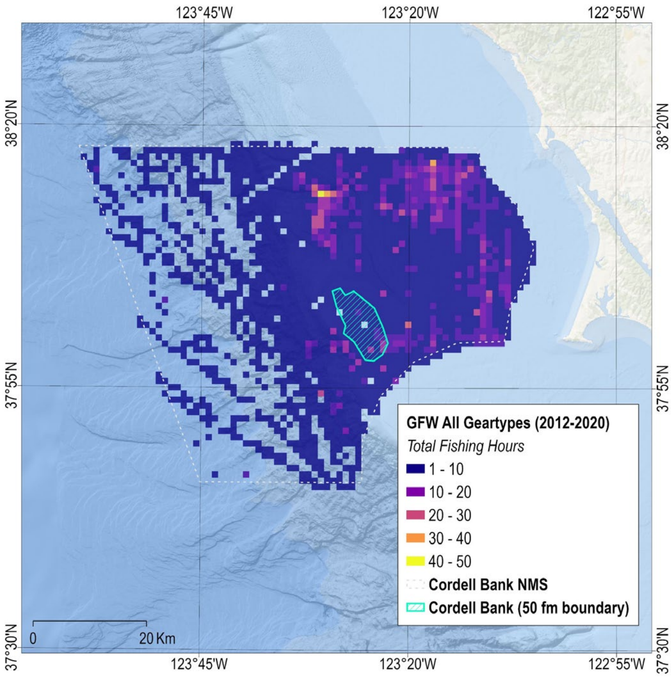

Table APP.F6. Total fishing hours for all gear types, 2012-2020. Source: Global Fishing Watch.

Consumptive Recreation — Recreational activities that result in the removal of or harm to natural or cultural resources[3]

Commented [4]: Footnote #15

Status: Fair
Trend: Stable
Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Rationale: For species such as Chinook salmon, Dungeness crab, and the rockfish complex, enhancing existing management would help to improve resource conditions and satisfy demand.

The status of consumptive recreation is fair and the trend is stable. Consumptive recreation includes recreational activities that result in the removal of or damage to natural and cultural resources. For CBNMS, this activity is primarily recreational fishing, either by private/rental boats or by Commercial Passenger Fishing Vessels (CPFVs) (Table ES.CR.1). NOAA Fisheries manages recreational fishing activities; these are not managed by the sanctuary. CPFVs include both charter and party boats. The annual number of CPFV angler-days in Cordell Bank varied without trend from 2013-2019, with a relatively low level in 2016 (CDFW, 2021d; Figure ES.CR.2). The number of pleasure boat registrations in the study area[4] decreased significantly from 2013 to 2018 (GLM; p-value = 0.04) (California State Parks, 2021). Resource indicators for commonly targeted recreational species show mixed trends with some depleted stocks undergoing recovery (see State of Living Resource chapter).

Commented [5]: Footnote #16

Table ES.CR.1. Status and trends for individual indicators discussed at the June 30, 2021 virtual workshop. There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/ Data visualization	Data Summary	Figure
Top recreational for-hire species	CDFW/ ONMS	Status: Dungeness crab, rockfish (unspecified, black and blue) and Chinook Salmon (2013-2018) Trend:	
Quantity kept of top species	CDFW/ ONMS	Status: The fish continued to be caught and kept during the study period Trend: There are no clear trends, but 2015-2017 do shower lower levels of landings across all the top species	

Commented [6]: This column will be filled in with corresponding figure numbers when the report is finalized.

[3] Because of a limited number of experts providing input, staff rated this service after the workshop. Therefore, a confidence rating was not assigned.
[4] The study area includes Mendocino, Sonoma, Marin, San Francisco, San Mateo, Contra Costa, and Alameda counties. See ONMS, 2014.

Jobs, income, GDP supported by CPFVs	CDFW/ ONMS	Status: CPFV continue to support a small nominal amount of economic activity Trend: Indicators of economic activity varied without trend, but 2015-2017 do show lower levels of economic activity being supported, consistent with what is observed at the state level	
Unique fishing vessels with AIS	USCG/N CCOS	Status: Fishing vessels continue to use CBNMS Trend: The total number of unique fishing vessels over the study period and hours continue to increase	Figure S.HA.4.5
CPFV angler-days	CDFW/ ONMS	Status: the number of CPFV angler-days in CBNMS varied between roughly 200 and 550 Trend: No significant trend	
Rockfish populations	NMFS/P FMC 2020	Status: Species recovered/recovering Trend: increasing population size	
Juvenile rockfish	NMFS/C CIEA	Status: Stable Trend: peaks 2014-2016	
Rockfish survey data	NMFS/C CIEA	Status: Stable Trend: peaks 2014-2016	
Benthic fish - Bank	CBNMS/ CBNMS	Status: Stable Trend: no trend data	
Shelf fish and inverts	CBNMS/ CBNMS	Status: Stable Trend: no quantitative trend data, appears stable	
Data gap: Potential users' knowledge, attitudes, and perceptions (KAP)			

There are several types of boats that may be used in recreational fishing: private, rental, charter, and party boats. A private boat belongs to an individual, not for rent and not with paying passengers. A rental boat is rented by an individual, without crew or a guide. A commercial passenger fishing vessel (CPFV) may be in one of two categories: a charter boat operates under charter for a specified price, time, etc.; a party boat provides fishing space and privilege for a fee per recreational fishermen (Leeworthy & Schwarzmann, 2015).

The top ten species kept by CPFVs are presented in Table ES.CR.2. During the study period, the most commonly kept species was Dungeness crab followed by unspecified rockfish, Chinook salmon, and black rockfish. However, if considered together, the rockfish complex is the most landed recreational target by CPFVs. Blue rockfish and lingcod are also commonly captured in the sanctuary, along with canary rockfish, albacore tuna, white croaker, and striped bass.

Table ES.CR.2. Top Ten Species Kept by CPFVs from 2013-2018. Source: CDFW, 2021d

Species	Number Kept
Crab, Dungeness	1730
Rockfish, unspecified	1396
Salmon, Chinook	1150
Rockfish, black	1033
Rockfish, blue	684
Lingcod	522
Rockfish, canary	271
Tuna, albacore	190
Croaker, white	170
Bass, striped	168

Figure ES.CR.1 shows trends in the number of animals harvested by CPFV anglers from 2013 to 2018 for the top five most kept species. Low levels of Dungeness crab catch in 2015 and 2018 coincide with health advisories to avoid consumption of crab viscera due to high concentrations of domoic acid (Figure ES.CR.1; Joint Committee on Fisheries and Aquaculture, 2016; CDFW, 2018). In 2021, for the first time ever, recreational crabbers were prohibited from using traps during the Dungeness crab season in an effort to mitigate adverse interactions with whales and sea turtles, though hoop nets and snares could still be used (CDFW, 2021b). Chinook salmon catch by CPFVs shows a gradual U-shaped trend over the study period, with higher levels of harvest in 2013 and 2018 (Figure ES.CR.1). Chinook salmon stocks found in the sanctuary (California Coastal, Central Valley spring-run, Central Valley fall and late-fall, and Sacramento River winter-run) are listed as either endangered, threatened, or species of concern, and stocks have shown mixed progress toward recovery (ONMS, 2014b; CDFW, n.d.; NMFS, 2016a; NMFS, 2016b; NOAA Fisheries, 2020b).

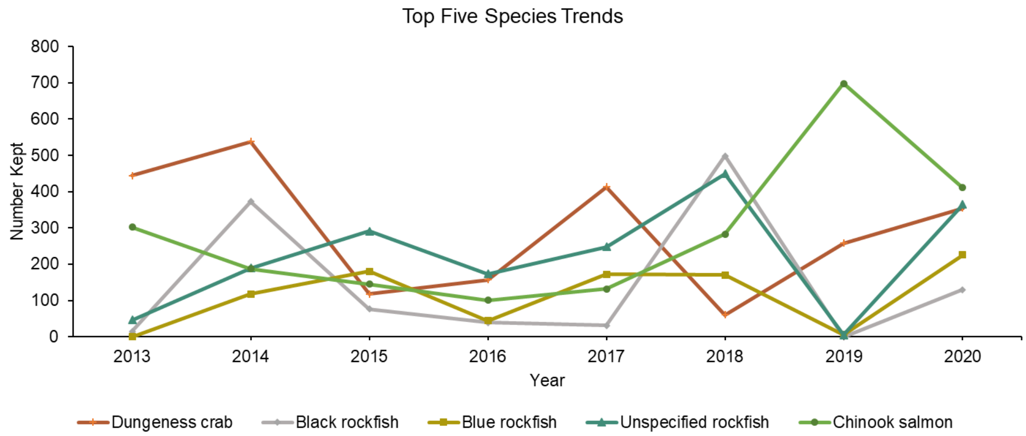

Figure ES.CR.1. Trends in Top Species Kept by CPFVs from 2013-2018. Source: CDFW, 2021d.

Catch of unspecified rockfish by CPFVs generally increased over the study period (Figure ES.CR.1). Black rockfish catch peaked in 2014 and 2018 with low levels of catch from 2015 to 2017 (Figure ES.CR.1). Blue rockfish catch varied without trend from 2014 to 2018, with relatively low catch by CPFVs reported in 2016 (Figure ES.CR.1). Recreational fishing for rockfish (along with most other groundfish species) is closed in much of Cordell Bank, including in all waters less than 100 fathoms (50 CFR § 660.360). According to the Pacific Fishery Management Council (PFMC), nine of ten West Coast groundfish stocks have recovered to target levels as defined in the Council's groundfish rebuilding plan (PFMC, 2021). The remaining stock, yelloweye rockfish, is recovering faster than expected (PFMC, 2021). Successful groundfish recovery could lead to expanded opportunities for recreational fishing in the sanctuary if depth restrictions are further reduced.

The 2016 fishing season was characterized by relatively low levels of CPFV catch for the top five most kept species. This corresponds with a decrease in effort during that year, as measured by the number of CPFV angler-days inside CBNMS (Figure ES.CR.2). One explanation for low effort in 2016 is weather conditions: the winter season of 2016 had more hours under Small Craft Advisory conditions than any other season from 2009-2020 (NOAA National Data Buoy Center, 2021). Also in 2016 ocean conditions continued to be poor with low productivity, as a result of the prolonged marine heatwave that began in 2014. Two of the top recreational fisheries, Dungeness crab and salmon, had very poor years in 2016. 2016 was also an off-year in terms of the economic contribution of CPFVs using the sanctuary – only $9,250 of income was generated by CPFV activity in the sanctuary in 2016 compared to a five-year average (2014-2018) of nearly $22,000 (Figure APP.F7). Excluding 2016, the average economic contribution from 2014-2018 was roughly $24,900 in income.

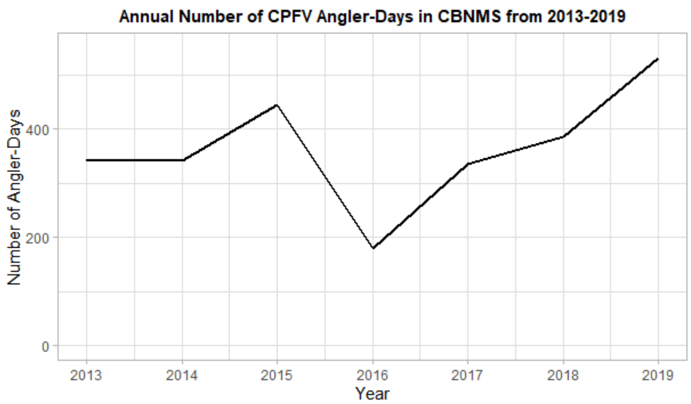

Figure ES.CR.2. Trends in CPFV Effort (Angler-Days) in CBNMS from 2013-2019. Source: CDFW, 2021d

Information on fishing effort and catch by private and rental vessels within Cordell Bank is not presented in this report due to unexplained irregularities in the data. However, a prior ONMS study on recreational fishing from 2010 to 2012 found that recreational private/rental boat fishing in Cordell Bank accounted for an average of 0.5% of total person-days in District 4[5] and 0.1% of person-days in California (Leeworthy & Schwarzmann, 2015). As a proxy for trends in private/rental vessel fishing effort, the number of pleasure boat registrations within the CBNMS study area were analyzed. The number of pleasure boat registrations in the study area decreased significantly from 2013 to 2018 by about 2700 vessels per year (California State Parks, 2021; GLM, p-value = 0.04). Pleasure boat registrations declined from nearly 97,000 in 2013 to over 79,000 in 2018 (California State Parks, 2021). The largest single-year decline occurred between 2015 and 2016 (California State Parks, 2021).

Commented [7]: Footnote #17

One data gap in assessing the state of consumptive recreation in Cordell Bank is a lack of information on potential users' knowledge, attitudes, and perceptions (KAP). Among other things, this information would be useful for evaluating users' level of satisfaction with sanctuary resources and management and for determining whether there is unmet demand for recreational fishing in CBNMS. KAP data could also be used to identify barriers to accessing the ecosystem service (e.g., weather, cost, uncertainty over regulations) and develop target areas for improvement.

Conclusion

Important recreational fisheries within Cordell Bank are compromised. CBNMS can support recreational fishing indirectly by promoting a healthy ecosystem (e.g., by managing impacts to

[5] The sanctuary is located within District 4 of the State of California, (for purposes of the California Recreational Fisheries Survey. District 4 includes San Francisco District: Sonoma, Marin, San Francisco, and San Mateo Counties on the coast and the eight counties surrounding San Francisco and San Pablo Bays [Alameda, Contra Costa, Solano, Sonoma, Marin, San Francisco, San Mateo, and Santa Clara counties]) (CDFW, 2020c).

habitat and water quality) and coordinating outreach efforts. However, many actions that could support the ecosystem service are the authority of fishery management bodies (PFMC, NMFS, CDFW) or environmental agencies that manage watersheds. While the National Marine Fisheries Service and Pacific Fishery Management Council have made progress rebuilding rockfish populations following historical declines, recreational fishing opportunities for rockfish remain limited within CBNMS. The California Department of Fish and Wildlife is working towards reducing entanglement risk for large whales, but the recreational Dungeness crab fishery may continue to face closures until significant strides are accomplished. Additional management actions in riverine systems, particularly habitat restoration and improved flow conditions, could enhance prospects for the Chinook salmon fishery in CBNMS. For these reasons, the status of consumptive recreation in Cordell Bank is determined to be fair.

CPFV effort has varied without trend over the study period, while the number of pleasure boat registrations within the study area has declined slightly. Improvements in technologies, like offshore vessels and navigational aids, may partially offset access challenges created by weather and rough conditions. The trend in consumptive recreation in the sanctuary is therefore rated as stable.

Figures for APPENDIX (to be moved when report is compiled)

Year	Employment	Income	Output
2013	0.25	$15,249	$31,670
2014	0.46	$28,249	$58,668
2015	0.29	$17,749	$36,862
2016	0.15	$9,250	$19,210
2017	0.44	$26,999	$56,072
2018	0.43	$26,499	$55,034
Total	2	$123,995	$257,516

Figure App.F7. Economic Contribution of CPFVs from 2013-2018. Economic contributions in 2016 were low compared to other years. Source: CDFW

Non-Consumptive Recreation — Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Status: Good/Fair (very high confidence)
Trend: Worsening (very high confidence)
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Rationale: Public access to the sanctuary can be challenging due to extreme and unpredictable weather conditions, offshore location, lack of infrastructure, and limited number of tour operators. However, despite the challenges, businesses and individuals in the area are performing acceptably, and there is still demand to travel to the sanctuary. Populations of certain species that are of interest to wildlife viewers, like humpback and blue whales and some seabirds, are compromised. The worsening trend is driven by extreme weather conditions, which have impacted the number of wildlife-viewing businesses operating in the sanctuary.

Recreational activities that do not result in the intentional removal of, or damage to, natural and heritage resources are considered non-consumptive. The status of non-consumptive recreation in CBNMS is good/fair (very high confidence), and the trend is worsening (very high confidence). The primary non-consumptive recreational activities in or adjacent to CBNMS are wildlife viewing, especially whale and bird watching, and boating (Table ES.NCR.1). CBNMS is located offshore, precluding shore-based or nearshore recreational activities in the sanctuary. Recreational diving is not recommended or common at Cordell Bank due to the depth of reef areas and the site's extreme, variable weather and ocean conditions.

Table ES.NCR.1. Status and trends for individual indicators discussed at the May 21, 2021 virtual workshop. There are no confidence scores for individual indicator status and trends.

Indicator	Data Source/Data visualization	Habitat	Data Summary	Figure
Reported seabird sightings	eBird/NCCOS	Pelagic	Sightings have increased in recent years for top 5 most sighted species in CBNMS	
Number of eBird observers	eBird/NCCOS	Pelagic	The number of eBird observers with reports in CBNMS has increased from 2009-2020	
Distance traveled by vessels in CBNMS	AIS data/NCCOS	Pelagic	Distance traveled in CBNMS by pleasure boats and sailing vessels has increased in recent years, excluding 2020, but this may be a result of more vessels carrying AIS. Distance traveled by passenger vessels shows a declining trend from 2009-2020.	

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Whale populations	NMFS/NMFS	Pelagic	Status: Endangered, threatened species Trend: low population increases, facing threats	
Whale density models	Becker et al., 2020/Becker et al., 2020	Pelagic	Status: Blue, HW high density in CBNMS Trend: no trend data	
Whale density - ACCESS	ACCESS/Point Blue	Pelagic	Status: Blue, HW common in CBNMS/GFNMS Trend: increasing density observations	
Seabirds	ACCESS/Point Blue	Pelagic	Status: Cassin's, BFAL, SOSW, PFSW, common in CB/GF Trend: variable, no trend	

Cordell Bank offers unique opportunities for wildlife viewing. A wide variety of whales, pinnipeds, seabirds, and sea turtles can be seen throughout the sanctuary seasonally. Higher numbers of cetaceans, including whales and dolphins, are present from June through November. Resident and migratory seabirds make use of the site's productive waters, drawing in birders from around the world. As of 2021, following an owner's retirement, there is only one operation offering regular (once a year) trips to CBNMS, down from two in previous years. As with many activities in CBNMS, wildlife viewing is constrained by variable offshore conditions like unpredictable and occasionally extreme weather, including wind, fog, and rough seas. From 2009-2020, 45% of days in CBNMS had small craft advisory conditions for at least an hour (NOAA NDBC, 2021). Thirty-six percent of days had small craft advisory conditions for at least four hours (NOAA NDBC, 2021). Unpredictable weather creates a barrier for small businesses, like charter operations, which face substantial revenue losses due to canceled trips (D. Gurrola & S. Allen, personal communication, May, 21, 2021).

Whale Alert is a free app that allows users to report whale sightings, which are then logged in a central database (Whale Alert West Coast, 2021). Being a voluntary reporting system, Whale Alert data do not provide information on the true abundance of whales in CBNMS; however, it can give some indication of whale watching in the sanctuary. From 2016 to 2020, there was an average of one whale sighting in CBNMS reported annually. This represents a decline from 2014, when there were nine (Whale Alert, 2020). These sightings are predominantly blue and humpback whales. According to habitat-based density estimates for cetaceans in the California Current Ecosystem, there is a high, increasing density of blue and humpback whales in CBNMS

(Becker et al., 2020; ACCESS, 2020). Other commonly sighted marine mammals near the sanctuary include Pacific white-sided dolphins, Dall's porpoise, and fur seals.

Bird watching is another popular activity in CBNMS. At least 75 species of seabirds have been documented in the sanctuary, including some migrating from as far as Alaska, Hawai'i, Australia, New Zealand, and South America (NOAA n.d.). From 2009 to 2020, the top five bird species reported on eBird (2021), a popular birding app, in CBNMS were sooty shearwaters, western gulls, pink-footed shearwaters, common murres, and California gulls. Species like Cassin's auklets, black-footed albatross, sooty shearwaters, and pink-footed shearwaters are common in CBNMS, and their populations have varied without trend in recent years (ACCESS, 2020). The number of annual bird sightings on eBird has increased in recent years, but this is driven in part by an increase in the number of eBird users (eBird, 2021). The number of individual eBird observers has increased significantly from 2009-2020 by close to 500 individuals per year (generalized linear model; p-value < 0.001) (Figure ES.NCR.3).

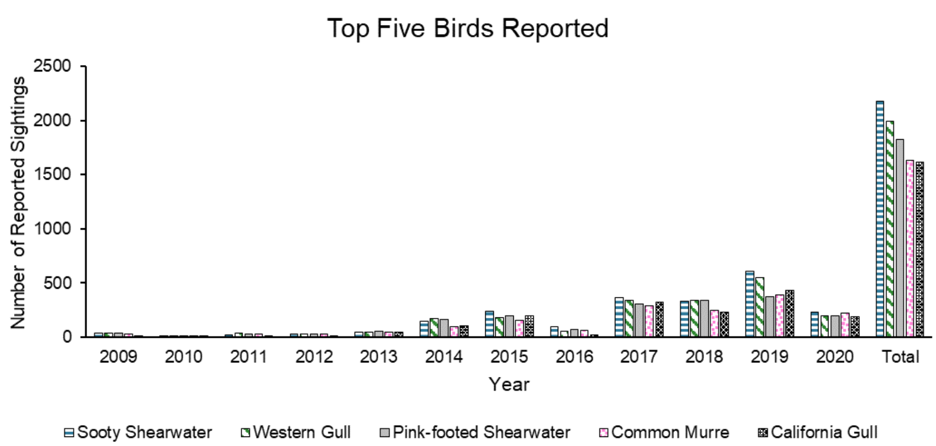


Figure ES.NCR.1. Top 5 seabird species reported by eBird users in CBNMS, 2009-2020. Reported sightings of these five species have increased in recent years. Source: eBird 2021.

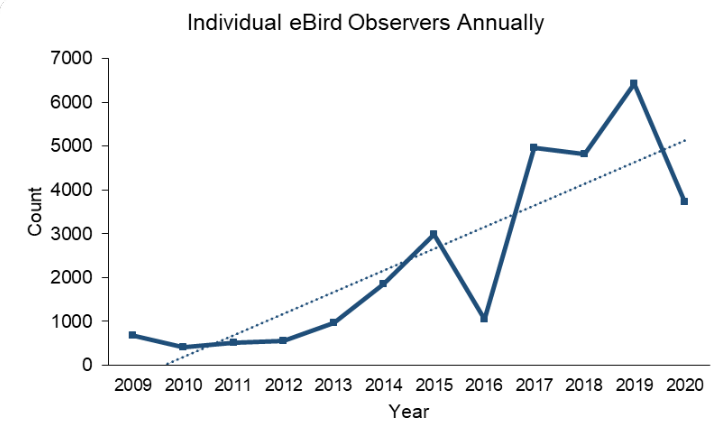


Figure ES.NCR.2. Number of unique eBird observers annually from 2009-2020. The number of eBird users reporting bird sightings near Cordell Bank has increased by around 500 individuals per year over the time period (dotted trendline). These counts may include eBird users traveling through the study area by cruise ship. Users logging bird sightings in CBNMS on multiple eBird accounts will be counted more than once, resulting in an overestimate of the true number of users.

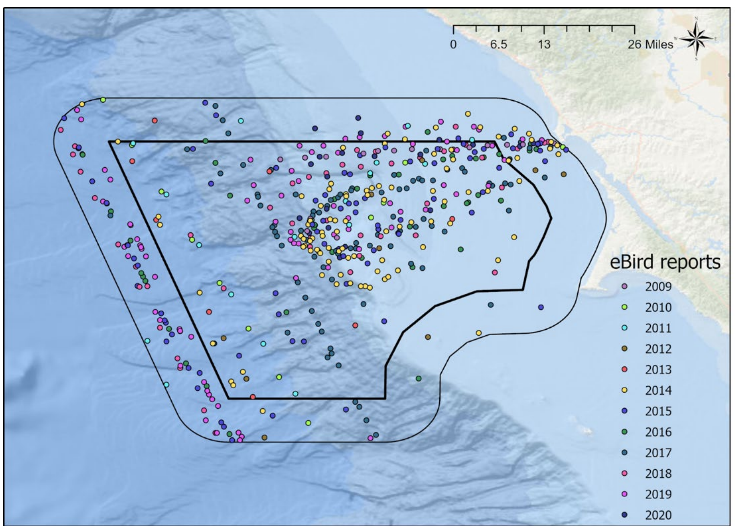


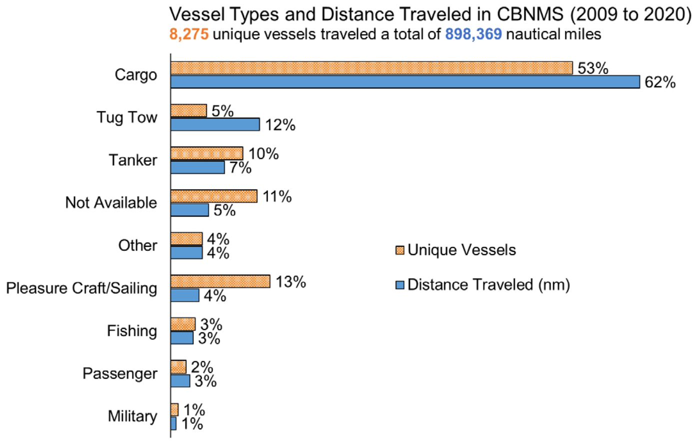
Figure ES.NCR.3. eBird reports in CBNMS with 10km buffer, 2009-2020. Source: eBird 2021.

Recreational boating is another non-consumptive activity in CBNMS. Recreational traffic tends to be concentrated toward the eastern, nearshore portion of the sanctuary. From 2009-2020, non-consumptive recreation vessels traveled a total of 33,789 miles in CBNMS (NCCOS, 2020). Those vessels comprised 13% of the total number of unique vessels in the sanctuary (471 pleasure craft, 412 recreational vessels, 274 sailboats, and 2 diving operations out of 8,275 total unique vessels). The distance traveled by pleasure craft and sailing vessels carrying AIS was stable from 2009-2014, increased from 2014-2019, and then decreased in 2020 (NCCOS, 2020). However, the rate of AIS use by private vessels likely increased over that time, which may account for the increase in distance traveled observed from 2014-2019 and may not reflect an increase in the true distance traveled. Passenger vessels, including cruise ships and charter operations, also provide opportunities for non-consumptive recreation. Passenger vessels make up 2% of the total number of unique vessels and 3% of the total distance traveled in CBNMS (22,459 nm out of 898,369 nm). Passenger vessel activity is concentrated in highly trafficked areas and tends to follow more distinct pathways than pleasure craft vessels. Distance traveled by passenger vessels remained relatively stable from 2009-2018 and declined drastically in 2020, during the COVID-19 pandemic (NCCOS, 2020).

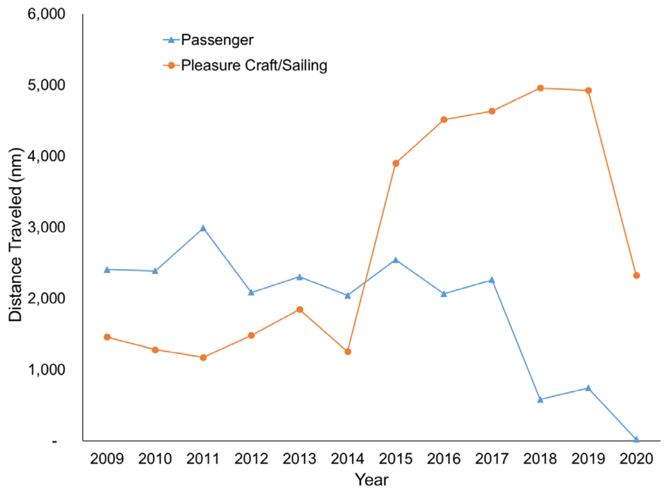
Conclusion

Non-consumptive recreation in Cordell Bank National Marine Sanctuary is rated good/fair with a worsening trend. CBNMS continues to provide opportunities to view marine mammals, sea turtles, and seabirds, although some wildlife populations that frequent or reside in the sanctuary remain compromised. Though there was no clear trend in the number of hours under small craft advisory conditions (2009-2021) (NOAA NDBC, 2021), there was consensus among workshop experts that weather conditions are worsening. The number of wildlife tours operating within the sanctuary has declined, largely due to the challenges of scheduling tours around extreme weather conditions. In the past, CBNMS partnered with a non-profit to host field trips to the sanctuary from Bodega Bay, but those trips were discontinued due to financial and at-sea liability. Based on public interest and participation in that program, it is likely that more people would visit and view wildlife in the sanctuary if more tours were available. Currently, with fewer tours operating, there are fewer opportunities for the public to experience non-consumptive recreation in Cordell Bank.

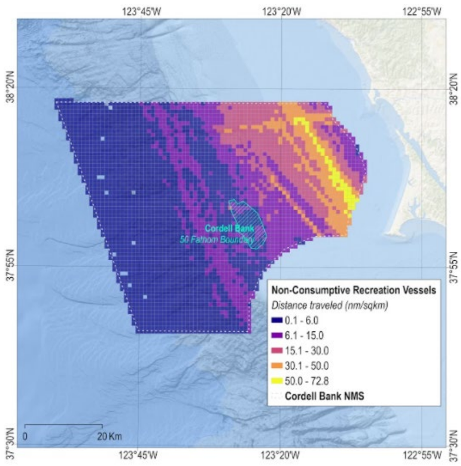
Figures for APPENDIX (to be moved when report is compiled)



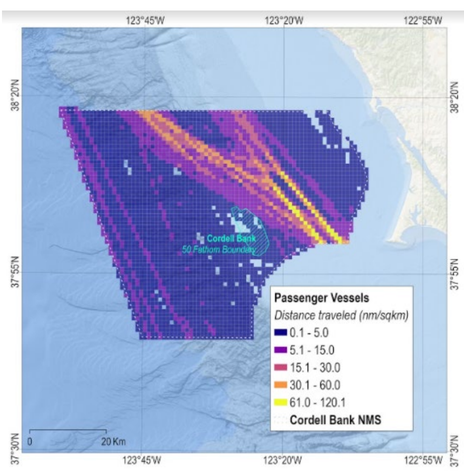
Appendix Figure 1. Unique vessels and distance traveled by all vessels in CBNMS, 2009-2020. Source: AIS data 2021



Appendix Figure 2. Trends in distance traveled of AIS vessels in CBNMS, 2009-2020. Distance traveled by passenger vessels shows a declining trend over the time period. The distance traveled by pleasure craft and sailing vessels increased to a decadal high of nearly 5,000 nm in 2018 and 2019, then declined dramatically in 2020. Source: AIS data 2021.



Appendix Figure 3. Non-consumptive recreation vessel presence, 2009-2020. Much of the vessel traffic is concentrated in the eastern portion of the sanctuary, closer to the coast. Each grid cell represents 1 km^2 with the cell color corresponding to the distance traveled through that cell over the time period. Source: AIS data, 2021.



Appendix Figure 4. Passenger vessel presence, 2009-2020. Passenger vessel traffic is concentrated in distinct lanes of travel. Source: AIS data, 2021.

Science — The capacity to acquire and contribute information and knowledge

Status: Fair (high confidence)
Trend: Improving (medium confidence)
Status description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Rationale: Compared to some other marine sanctuaries, the ability of CBNMS to support science is constrained by challenges associated with accessing the sanctuary, particularly for students and external researchers. The remote offshore location, frequently rough sea conditions, and inconsistent access to a research vessel are some of the challenges. In addition, the small number of science staff and limited funding hinder the ability of the sanctuary to expand the science program and develop new partnerships. Though these limitations led to a rating of fair, the trend was rated as improving, primarily because the expansion of the sanctuary has spurred additional research activity.

Science as an ecosystem service is defined as the capacity to acquire and contribute information and knowledge. National marine sanctuaries serve as natural laboratories that support researchers from a variety of institutions and provide opportunities to apply scientific information to resource management. Science as an ecosystem service in the sanctuary can be evaluated by examining the number and type of research cruises taking place, research permits that are issued, number of partners that the sanctuary collaborates with, and publications on the sanctuary (Table ES.S.1).

Table ES.S.1. Status and trends for individual indicators discussed at the May 26, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Source	Data Summary	Figure
Research cruises	CBNMS	Total of 77 research cruises providing data to the sanctuary from 2009-2021	
Research permits	CBNMS	37 research permits for research in the sanctuary from 2009-2021	
Partners	CBNMS	At least 16 partners and collaborators working with us in the sanctuary	
Publications	Literature search	Total of 147 publications on the sanctuary	
Limitations	CBNMS	Limitations on access to the sanctuary; staffing and support for science; limited ability to support students and external researchers	

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The waters around Cordell Bank have a rich history of science and exploration, dating to before its designation as a sanctuary. In the years since the last condition report, the sanctuary has continued to support this ecosystem service with cruises, permits, partnerships, and publications.

There have been 77 research cruises since 2009 that have generated data or information to which the sanctuary has access (CBNMS, 2021a). The majority of these (85%) were led or co-led by the sanctuary and its partners. The remainder were led by partners. This is an indication of both the strong scientific presence of the sanctuary work in the area, but also the challenges for external researchers to work in the area, partially due to the remote location. In contrast to many other sanctuaries, CBNMS is not located in close proximity to a multitude of academic and research institutions. Still, the sanctuary has developed strong relationships with at least 16 partners and collaborators from universities, government, and non-profit organizations.

From 2010 to 2019, the sanctuary issued 37 research permits to their own staff or to other researchers to conduct work in the sanctuary that would otherwise violate a sanctuary regulation, such as disturbance of the seafloor and discharge of materials (CBNMS, 2021b). Not all research requires a permit, so the number of permits issued does not provide a full count of the projects conducted within the sanctuary. An increase in permits issued, which numbered three in the year before the 2015 expansion, to 9 in 2019, is a result of the increase in area in which research permits are required, as well as increasing awareness over time about sanctuary permit requirements.

These expeditions, projects, and partnerships have resulted in over 140 publications on Cordell Bank, including articles, dissertation and theses, conference proceedings, presentations, and other reports.

However, there are significant barriers for the sanctuary to support this ecosystem service. The offshore location, lack of a shoreline and associated infrastructure, inaccessibility to non-technical divers, challenging sea conditions, need for a midsize to large vessel, transit time of 1-3+ hours (depending on location), and the limited number of scheduled trips to the sanctuary are all factors that limit the ability of researchers to conduct work in the sanctuary. For partners and other researchers, the limited number of research institutions nearby, and the limited opportunities for undergraduate and graduate students to access the sanctuary, also reduce the amount of scientific work in the sanctuary. In addition, the small number of sanctuary science staff, a lack of discretionary funds, and limited access to the sanctuaries' Research Vessel *Fulmar* (homeported in Monterey Bay, CA), reduce the ability of the sanctuary to conduct its own research. There are few other vessels in the area capable of supporting scientific research in the sanctuary. These limitations and challenges have been fairly consistent throughout the time period 2009-2021.

Conclusion

In summary, although the sanctuary has consistently supported science,limited staffing, financial support, access to vessels, and challenging weather and ocean conditions make working at Cordell Bank difficult. As a result of these challenging conditions, CBNMS has been under-studied compared to nearby coastal regions. Nevertheless, the uniquely productive ecosystem continues to attract interest from students and researchers in a variety of disciplines ranging from physical oceanography to fisheries to ornithology, and the sanctuary will continue attempts to increase scientific endeavors. There remains much to learn about the species inhabiting the sanctuary, as well as transient species benefiting from the high productivity around the Bank, and how they may deal with changes in physical and chemical conditions. In benthic habitat, further exploration, characterization, and continued monitoring is needed. Although nearly over 90% of the sanctuary seafloor is mapped for bathymetry, only a small percentage has been visually surveyed, and questions remain about the species and habitats in the sanctuary. In addition, repeated monitoring is needed to understand changes over time and in response to management actions. In pelagic habitat, continued monitoring of climate indicators and ocean noise is needed. Understanding the biological response to physical and chemical conditions is critical to effective management. The condition report identified data gaps in understanding the impacts of human activities, other stressors, and contaminants, and a lack of long-term monitoring led to an ability to determine trends in many parameters. Data gaps should be further assessed during management plan development.

Citations for Science

Cordell Bank National Marine Sanctuary (2021a). Analysis of Office of National Marine Sanctuary permit database. Unpublished data.

Cordell Bank National Marine Sanctuary (2021b). Analysis of CBNMS Cruise Register database. Unpublished data.

Education — The capacity to acquire and provide intellectual enrichment

Status: Good/Fair (very high confidence)
Trend: Improving (high confidence)
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Rationale: There was high confidence and support among workshop participants for sanctuary education efforts, programs, and outcomes to date, but the lack of labor and sustaining funding for education and outreach has prevented them from meeting some of the community needs.

Education as an ecosystem service is defined as the capacity to acquire and provide intellectual enrichment. At CBNMS, the status of education is rated good/fair (very high confidence) with an improving trend (high confidence). CBNMS is a place of national, regional, and local significance. CBNMS staff engage audiences through education and outreach using a variety of methods (Table ES.E.1).

Table ES.E.1. Status and trends for individual indicators discussed at the May 27, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Description of program	Key indicators that were used to determine the status and trend of the education ecosystem service were:
Sanctuary exhibits bring the sanctuary to the people through high quality visuals in partner institutions that increase awareness about the sanctuary and increase ocean and climate literacy.	Visitorship and quality of experience at CBNMS exhibits created in partnership with sanctuary staff
Sanctuary staff-led field excursions promote adult learning opportunities and improve awareness about ocean ecology and encourage ocean stewardship.	Participation and quality of experience during sanctuary-led excursions
Distance learning and telepresence experiences improve awareness about the sanctuary and ocean ecology to school groups and the general public.	Number of distance learning and telepresence outreach programs
Social media and websites improve awareness about the existence of the sanctuary, the purpose of its designation, and its ecology.	Number of people reached

Outreach programs include a monthly radio program, presentations to community groups, exhibiting at community events, printed products, and film and videos. These products provide opportunities to communicate about the sanctuary with broad audiences.	Invitations and participation in outreach events
Formal education curriculum and training programs train educators about sanctuary curriculum resources and the sanctuary ecosystem.	The number of teachers reached through workshops (and quality of their experience) and indication of intent to incorporate into classroom curriculum
Student In Person Programming - increasing awareness about sanctuaries and ocean literacy with students.	The number of students reached by sanctuary in person education programs.
Provide learning opportunities for volunteers and interns - providing learning opportunities that advance skills in students pursuing careers related to sanctuaries and providing opportunities for motivated community members to contribute their skills and efforts to support sanctuary programming.	The number of interns and volunteers the sanctuary has hosted

Although creating intellectual enrichment through experiencing the sanctuary first-hand is limited by the site being entirely offshore as well as limited staff capacity (only one education staff person), the education and outreach programs at CBNMS that create awareness about the sanctuary and enhance ocean and climate literacy and stewardship have expanded since 2009, largely through partnerships and collaborations. While many products and programs have been created or launched efficiently, the ability to expand existing and add new programs is difficult due to the lack of resources. To help increase intellectual enrichment, the sanctuary has created many virtual opportunities for learning about the sanctuary.

Sanctuary Exhibits

Because CBNMS is entirely offshore, bringing the sanctuary to people in communities on land through permanent and traveling exhibits has been a key strategy for increasing awareness about the sanctuary's existence. There are six permanent exhibit locations (see Table ES.E.2 for locations). Exhibits highlight the biodiversity above and below the surface with educational and interpretive panels, photos, videos, and, in some cases, interactive elements. Visitors to these exhibits totaled 3,799,914 between 2009 and 2020, with an upward trend, until COVID related closures began in 2020.

Point Reyes National Seashore has three visitor centers, two of which feature sanctuary-specific exhibits (Figure ES.E.1). At the Point Reyes Lighthouse Visitor Center, visitors can view educational and interpretive panels outside the center. When touring inside they can view immersive and accurate painted murals depicting habitats in the sanctuary as well as view life size models of marine life, and have sweeping views of the ocean. At the Bear Valley Visitor Center, visitors can view educational panels, life-like models of marine life and a video highlighting underwater video footage taken during research missions to the sanctuary. Between 2009-2020 over 3 million people visited these National Park Service visitor centers where sanctuary educational and interpretive exhibits are located. The Oakland Museum of California hosted over 400,000 visitors between 2013-2020, including docent-led student programs. This museum hosts the largest of all the CBNMS exhibits and highlights the sanctuary through video, models, educational panels and a hands-on exhibit on ocean plastics. The museum also has a traveling photo exhibit about the sanctuary featuring high quality images of sanctuary life. This exhibit reached over 7,000 visitors. The Bodega Marine Lab (with exhibit panels around aquariums) and Gualala Visitor centers (with high quality photos, a map, and a video) each have exhibits that feature CBNMS, and collectively hosted over 100,000 visitors. In summary, by partnering with other agencies and institutions 3,799,914 people had the opportunity to view sanctuary exhibits between 2009 and 2020.

> *"I want to go there again because I can tell my family about the Cordell Bank. I could tell them that I like a sea animal that lives there, like the California Cucumber."* Christian, Oakland Museum of CA CBNMS exhibit visitor

> *"This is a superb exhibit showcasing the miracle of diverse life here at home on our beautiful planet. May it inspire those who view it to act with an ocean-conscious mind to protect, preserve, and appreciate the paradise we live in. The selection of photographs is absolutely incredible."* CBNMS traveling photo exhibit guest logbook entry

Table ES.E.2. Total visitors per exhibit location from year exhibit installed to 2020. Source CBNMS and exhibit partner locations.

Exhibit Location	**Year Opened**	**Total Visitors from opening date through 2020**
Point Reyes National Seashore Bear Valley Visitor Center (CBNMS and GFNMS)	2007	2,880,772 visitors
Bodega Marine Lab panels (CBNMS and GFNMS)	2008	92,968 visitors to lab (faculty, students, visiting students, public programs, docent led tours)
Oakland Museum of CA (CBNMS)	2013	432,350 visitors (docent led tours, student programs, general public)
CB Traveling photo exhibit (CBNMS)	2013	7023 visitors (includes opening events, student programs, special events)
Gualala Visitor Center (CBNMS and GFNMS)	2015	16,034 public visitors, student programs

Point Reyes National Seashore Lighthouse Visitor Center (CBNMS and GFNMS, see Figure ES.E.1)	2016	370,767 visitors

Figure ES.E.1. The Ocean Exploration Center at Point Reyes National Seashore Lighthouse Visitor Center provides a windowed portal to both Greater Farallones and Cordell Bank national marine sanctuaries with murals, models and a hands-on touch station depicting habitats in sanctuary waters right off Point Reyes National Seashore. Photo credit: Tyler Chartier
Alt text for Figure ES.E.1: People walking around a small room with a large window on one side and murals depicting ocean habitats with blue water, fishes and invertebrates. Models hanging from the ceiling of the room include a CA sea lion, Dall's porpoise, white shark and sooty shearwater.

Sanctuary Staff-Led Field Excursions
CBNMS is entirely offshore and due to its often rough sea conditions, there is limited recreational access to enjoy wildlife watching. For over a decade, the sanctuary co-hosted an annual field seminar with Point Reyes National Seashore Association's Field Seminar program, which consisted of a half day classroom event with informative lectures, followed by a full day boat trip to the sanctuary.

> *"This gave me an appreciation of Cordell Bank and why it is a national marine sanctuary, what wonderful marine wildlife we have off our coast and must be protected*"- field seminar participant

Between 2009-2016, 121 seminar participants visited the sanctuary. These trips greatly enhanced appreciation and awe for the sanctuary and provided unique photography opportunities. Due to changes in the association's management of field seminars and because sea conditions are physically challenging, the trips were discontinued in 2017. In addition to the physical challenges of accessing the sanctuary (sea conditions), when conditions are amenable, it is a costly program, presenting equity challenges, where only those with the financial means to participate can join the trip. Many participants often experience sea sickness while on the boat, and it can result in a negative association with the sanctuary (Jennifer Stock, pers. obs.).

Distance Learning and Telepresence

With technology greatly increasing and becoming more available in the last decade, the sanctuary was able to take advantage of telepresence opportunities that accompany research expeditions, allowing sanctuary staff to connect with audiences on land via internet connections. Through the Ocean Exploration Trust/EV *Nautilus* work in 2017 and 2019 in West Coast sanctuaries, CBNMS had extensive reach through "ship to shore", or telepresence interactions with schools and museums, social media, and live streaming. People around the world could watch the live broadcast and ask questions through the nautiluslive.org platform. (Table ES.E.3). Sixty-seven ship to shore video-based interactions occurred between sanctuary staff and schools and museums on land between 2017 and 2019 (each research cruise was one-week in length) and reached 2,439 students, teachers and museum/aquarium visitors. Social media (see Table ES.E.3) outreach between Facebook, Twitter and Instagram during these expeditions resulted in 678,564 social media content reaches.

In addition to at-sea telepresence opportunities, the sanctuary staff have also presented numerous online webinars targeting educators and the interested public. Webinar and digital classroom technology has allowed CBNMS staff to interact with students in a "virtual classroom visit", or distance learning format, presenting on topics ranging from sanctuary science to ocean and climate literacy. While staff time is limited to meet the needs of the communities, training and mentoring interns and volunteers to fill the gap is time consuming, and these positions are usually short term.

Table ES.E.3. CBNMS outreach during Ocean Exploration Trust/EV *Nautilus* deep sea explorations in 2017 and 2019 Source: Ocean Exploration Trust

2017/2019 E/V Nautilus Expedition Outreach	Data Summary highlighting number of reaches
Live "ship to shore" interactions	67
Number of people reached during "ship to shore" interactions	2,439
Facebook reach during ship to shore interactions	260,995
Twitter reach during ship to shore interactions	327,200
Instagram reach during ship to shore interactions	90,369

Social Media and websites

Social media can be a useful digital media platform to convey information about the sanctuary to the general public. Social media platform users and interactions via Twitter/Facebook have increased from the inception of use at the sanctuary between 2016-2020 (Figures ES.E.2-3).

However, while we have statistics on numbers of people who like the page, the analytics provided by these social media channels do not provide information about the impact on viewers viewing posts about Cordell Bank National Marine Sanctuary. That can only be collected through a public survey, which is beyond the current means of this sanctuary.

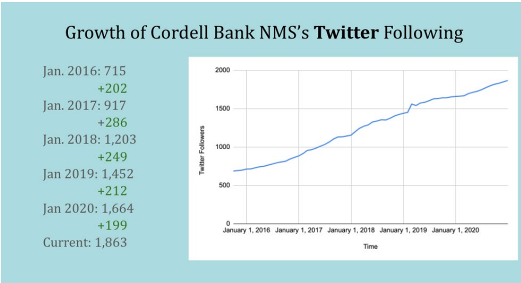


Figure ES.E.2. (temporary screenshot- link to Google spreadsheet with data to recreate for final report https://docs.google.com/spreadsheets/d/17KXVxhgCib3BxYGFIaCZEzTNr-tdV1wg7j_5dHkHmC4/edit?usp=sharing (Tab 2) (source: Twitter analytics)
Caption: The number of Twitter page followers has steadily increased since the page was created in 2016.

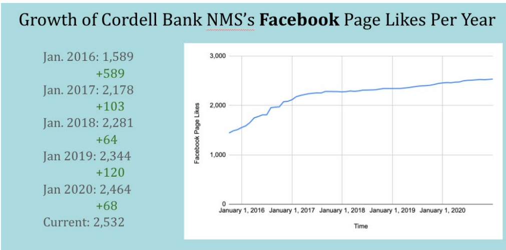


Figure ES.E.3. (temp screenshot- link to Google spreadsheet with data to recreate for final report https://docs.google.com/spreadsheets/d/17KXVxhgCib3BxYGFIaCZEzTNr-tdV1wg7j_5dHkHmC4/edit?usp=sharing (Tab 1)
(source: Facebook analytics)

Outreach using multimedia

Public engagement, using a variety of multimedia, including sanctuary print products, media, and videos are meant to provide opportunities for a user to learn about the sanctuary and be inspired (Table ES.E.4). The intention is to empower users to further share or teach about the information they informally learned.. Videos include those produced by ONMS for posting on the website and disseminated via social media, videos shown at events, such as film festivals and in visitor centers, and externally produced films, such as a recent South Florida PBS series about sanctuaries that was distributed to public broadcasting stations nationwide, and was shown in film festivals. Since 2009, demand for print products has decreased substantially as digital media access has increased in popularity (J. Stock, pers. comm.).

CBNMS staff have reached audiences via radio as well. Ocean Currents, a radio program hosted by sanctuary staff live on KWMR, Community Radio for West Marin, California brings ocean-themed topics, with a strong focus on local sanctuary issues, to the coastal broadcast area. Each broadcast is also streamed live on the internet and saved as a downloadable podcast on the sanctuary website, potentially reaching a wider audience. The Ocean Currents broadcast has aired monthly since 2006 (with the exception of a hiatus starting in 2020 due to the COVID pandemic) and during that time has produced over 120 live programs. “Podcast Connect” monitors podcast usage on Apple devices. Their data shows that between 2009-2020 there were 2,900 listeners, 1,600 engaged listeners (meaning they listened to some or all of the episode), and 29,428 total plays of episodes. There is limited data available for usage outside of Apple devices. The program has received many accolades, including numerous positive customer comments and ratings in iTunes, with an average 5 star rating (out of 5). One review states:

> *“This is a fantastic podcast for anyone that lives on the Pacific coast and for anyone that is concerned about the health of our ocean. Jennifer does an incredible job at bringing important coastal issues to the pod. Her interviews and guests do more than provide knowledge and insights, they inspire action!!” SF Sean-March 15, 2019*

The sanctuary has also exhibited at community events to share sanctuary information with special event audiences. But because these events require planning and staff time, and with limited staff, the sanctuary has had to decline numerous invitations to participate in special events. Examples of events at which the sanctuary had an interactive presence are: Bodega Bay Fish Fest, Earth Day, Ocean Film Festivals, World Ocean Day, Sharktoberfest, Earth Fest, and Get Into Your Sanctuary Dayothers (J. Stock, pers. comm)

Table ES.E.4. Summary of outreach products for online, print, media, and film mediums.

Outreach Product	Audience	Examples
Online platforms	Public	CBNMS website, social media platforms
Media	Public	Featured articles in press (radio, television, print, web)
Film	Public	Earth is Blue films, South Florida PBS film/Changing Seas, Film festival viewings of films, film panel discussions with sanctuary staff
Community events	Public	Sanctuary outreach presence at Bodega Bay Fish Fest, Earth Day, Ocean Film Festivals, World Ocean Day, Sharktoberfest, Earth Fest, Get into your Sanctuary Day and others

Print products	Public, teachers	CBNMS brochure, posters, informational handouts

Formal education curriculum and training programs
CBNMS has worked with other sanctuaries and partners to create high quality curriculum , educator training, and other programs to help bring sanctuary-messaging and ocean and climate case studies into classrooms. These products have a long-lifespan when they get in the hands of teachers. The sanctuary has led teacher professional development courses to expose teachers to these resources. Between 2009 and 2020, sanctuary staff led training and workshops for teachers that varied from 2 to 40 hours over the course of a year. These professional development training reached 411 total teachers. Table ES.E.5 provides a summary of some CBNMS curriculum products.

Table ES.E.5. Curriculum products CBNMS has developed that focuses on ocean issues through case studies associated with CBNMS.

Curriculum products	Topic focus	Info	Reach
West Coast Deep Sea Community Curriculum	Includes CBNMS ROV transects and background information about deep sea habitats	Promote to teachers via workshops, no data on use by teachers	1. Webinar presentations about curriculum reached 350 people during live presentation 2. Reached 50 different teachers through teacher workshops- introduction to resource 3. Reached 150 students during in class presentations using the resource
Dungeness Crab Comm. Toolkit	West coast wide focus, ocean acidification and dungeness crab	Use at sanctuary workshops and outreach products	1. Webinar presentations reached 200 people during live presentation 2. Reached 40 different teachers through teacher workshops using resources in toolkit 3. Web stats? TBD
Winged Ambassadors	Albatrosses, upwelling, marine		Curriculum download by teachers from 5,278

	protected areas, seafloor features, ocean plastic ingestion/health effects		teachers from 38 countries reaching 358,787 students. Evaluation report in 2015 demonstrated how lessons were supporting ocean literacy. Presentations and trainings featuring Winged Ambassadors for teacher professional development: 15

Student Programming

The sanctuary educator has worked with partners to offer immersive beach experiences that include a pre-activity, field trip to a beach, and post activity. The pre-activity typically includes a classroom visit (either in-person or virtual) by the sanctuary educator, who engages students through use of photos, videos, stories, and data in order to create excitement about the field trip and awareness of some of the concepts.

A significant partnership with the Oakland Museum of California has allowed the sanctuary to engage with traditionally underrepresented communities in science. The sanctuary worked with the museum to create a permanent gallery about Cordell Bank National Marine Sanctuary that opened in 2013. The museum also created and continues to lead an elementary school program called Under the Sea: Exploring Cordell Bank National Marine Sanctuary, where students engage in a classroom activity at the museum, then experience a docent-led tour of sanctuary exhibits. Between 2013 and 2019, this program served 8,214 students, teachers, and chaperones.

> *“We discovered something new--The Cordell Bank exhibit reinforced the concept of the food web and some geography through maps. Doing the dissection was a great new experience!”* teacher evaluation after field trip

This partnership creates an opportunity for students who do not live along the coast to learn about the ocean in a museum through engaging exhibits and vivid imagery.

Supporting Volunteers and Interns

Sanctuary staff have supported nine undergraduate and graduate level interns by providing professional development opportunities through projects that enhance sanctuary education and outreach efforts. It is a priority of NOAA to increase opportunities for typically underrepresented people in sciences.

The sanctuary had 23 volunteers between 2009-2020 to support various education and outreach programs such as creating material for the Ocean Currents radio program, transcribing programs to increase accessibility, editing and archiving video footage, and creating listening guides. Requests for internship and volunteer opportunities have increased between 2009-2020 as students seek to build skills and experience with NOAA and National Marine Sanctuaries. While the management plan prioritized developing a broad volunteer program, the sanctuary did not have the staffing or financial resources to do it. Most volunteers and interns have helped with specific projects with a specific timeframe.

Limitations and challenges

Cordell Bank National Marine Sanctuary is entirely offshore and surrounded on three sides by another national marine sanctuary that is adjacent to the shoreline. Access to the sanctuary is extremely difficult due to challenging sea conditions, lack of available and capable vessels to go offshore, and travel distance and time to the sanctuary. Therefore, creating a community identity and following of supporters is challenging. With only one federal employee the sanctuary chose to experiment with multiple types of engagement opportunities; however, to manage all the communication, training, outreach, and education needs for the sanctuary, the ability to sustain, grow, and add new programs is very limited, despite requests from the community for additional engagement.

As experts noted at the workshop, the accomplishments to date have been extensive and have had a far reaching impact. Without either more resources or by reducing the variety of educational opportunities, the ability to expand is constrained. Volunteers and interns, while supportive for a short period of time, require training and ongoing supervision. Experts also noted that one person is not enough to reach the diverse audiences of the local sanctuary community, let alone at a national scale. While the management plan prioritized a variety of education and outreach programs and priorities, the site did not have enough staffing resources to carry out some of the strategies on an ongoing basis and focused on programs and products that had the most ongoing impact and broadest reach with the staffing resources it had in this time period.

Conclusion

Overall, education and outreach efforts have increased the reach of the sanctuary in the last ten years through products like exhibits, signage, and digital media, and have had direct impact with students and teachers. Feedback from teachers regularly emphasizes the importance of the sanctuary providing content via training to teachers and to students to both increase their awareness about the regional ocean environment and to build their personal connection to it. The investments made in exhibits have had the longest lasting impact on the local community and have strengthened partnerships. CBNMS has had the greatest educational reach through educational exhibits. Opportunistic virtual programming through live research expeditions also have a big impact, with a high number of reaches in a short period of time.

Heritage — Recognition of historical and heritage legacy and cultural practices

Status: Fair (medium confidence)
Trend: Improving (medium confidence)
Status description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Rationale: The heritage of CBNMS includes commercial and recreational fishing, science and exploration, and the presence of maritime heritage (archaeological, cultural, historical properties) resources. The quality of information related to recent fishing and science activities within CBNMS is high, but other heritage activities lack information. There is currently no information that suggests a connection of Indigenous peoples specifically to the sanctuary prior to contemporary usage of motorized fishing vessels in the region, though there are demonstrated connections to coastal and ocean resources in the general region. In addition, the expansion of the sanctuary in 2015 increased the area where sanctuary maritime heritage resources may be located and increased the coastal area where communities may have connections to the sanctuary. However, information about maritime heritage resources in the sanctuary and its historical and heritage legacy in the broader sanctuary community are areas for further investigation.

The heritage ecosystem service is defined as the recognition of historical and heritage legacy and cultural practices. This includes the shared history of the sanctuary and the communities around them, including present day and ancient cultures. This can include public benefit derived from both tangible and intangible aspects. Heritage may be reflected through modern-day economies, celebrations or recognition of past events, cultural landscapes, and community values. Commercial fishing, recreational fishing, science and exploration, interpretation of maritime heritage resources, and cultural connections were considered in rating this service (Table ES.H.1). The status was rated as fair with an improving trend. The fair rating was based on evidence of a strong science heritage, but also changes to fishing heritage due to changes in the type of fishing allowed, as well as a need for the site to put effort into gaining better understanding of cultural connections, including ancient connections. The improving trend is due to the sanctuary expansion in 2015 that resulted in more area for connections to maritime heritage resources and to coastal communities, as well as a shift in ONMS mission focus to include a more holistic consideration of cultural landscapes, rather than solely focusing on tangible maritime archaeological resources.

Table ES.H.1. Status and trends for individual indicators discussed at the May 26, 2021 virtual workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Source	Data Summary	Figure
Commercial Fishing		CBNMS plays a role in the local commercial fishing heritage; this has changed over time with regulations	

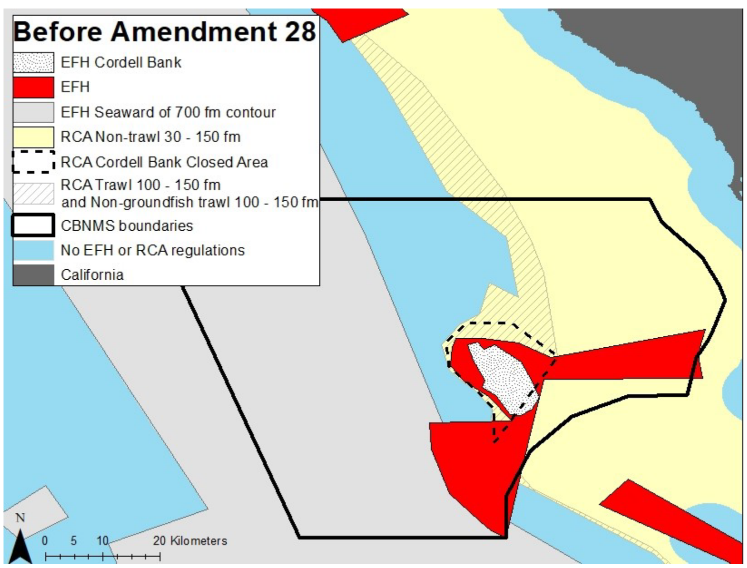
Commented [10]: This column will be filled in with corresponding figure numbers when the report is finalized.

Recreational Fishing	CBNMS, ONMS, general knowledge	CBNMS plays a role in the local recreational fishing heritage; this has changed over time with regulations; conditions limit some recreational users	
Science and exploration - historic		Historic exploration and mapping was key to documentation of the bank	
Science and exploration - 70s-80's		Pioneering scuba surveys in the 1970s and 1980s led to the designation of the sanctuary and greatly expanded knowledge about Cordell Bank	
Science and exploration - 2000's		New technologies and imagery, science programs	
Science and exploration - modern		New technologies, rigorous monitoring are furthering knowledge about the bank, including expansion area, and informing management	
Maritime archaeological resources		One known maritime archaeological resource exists in the sanctuary. There could be undiscovered resources. The sanctuary interprets and protects maritime heritage resources.	
Indigenous community cultural heritage		ONMS is currently working on expanding its knowledge of historical and present day connections of Indigenous peoples to CBNMS.	

Fishing
Commercial and recreational fishing is part of the heritage of CBNMS. Fishing activity in CBNMS primarily originates from Bodega Bay and San Francisco. Occasionally other boats from Half Moon Bay, Fort Bragg, and Oregon will access the sanctuary. As the closest port to the sanctuary, Bodega Bay has the strongest connection to the sanctuary and the town is defined by fishing-related activities. It has a tourism draw as a small working fishing town, the restaurants advertise and sell locally caught seafood, and the marina and associated businesses rely on the fishing activity. As the sanctuary is a minimum of six miles from the port, not all fishing vessels from Bodega Bay will enter the sanctuary as many of the small boats will stay close to shore in Greater Farallones National Marine Sanctuary.

Commercial fishing in the sanctuary primarily targets crab, sablefish, groundfish, and salmon. The Pacific Fisheries Management Council (PFMC) closed Cordell Bank and some of the surrounding areas to fishing in 2005-2006 to protect stocks and allow them to recover. Therefore, the role that CBNMS has been able to play in the local commercial fishing industry and the ability to support a commercial fishing heritage has changed over time. During the assessment period for this condition report, spatial closures remained in place for most of the time period and some stocks have recovered. In 2020, some changes to Essential Fish Habitat were made, and the Rockfish Conservation Area for trawling was reopened.

Recreational fishing (see consumptive recreation ecosystem service) has a heritage component as well. Dating back to the late 1800's, recreational fishing at Cordell Bank was historically very popular with news articles reporting large catches (Schwemmer 2021). The PFMC closed Cordell Bank to all bottom contact recreational and commercial fishing since 2005-2006 through implementation of the "Cordell Bank Closed Area" RCA. There is an exception for "other flatfish" in this area. There is also a Cordell Bank EFH Conservation Area to 50 fathoms on Cordell Bank which prohibits bottom contact gear from recreational and commercial fishing (Figure Appendix.X.10.2). Recreational fishing for crab and salmon are currently allowed in the sanctuary. However, access to the sanctuary from small boats can be difficult due to the offshore location and frequently rough seas. The sanctuary has supported fishing as part of the heritage of the area by protecting the resources. The restrictions implemented by PFMC have allowed the stocks to largely recover to management targets, but not pristine conditions.



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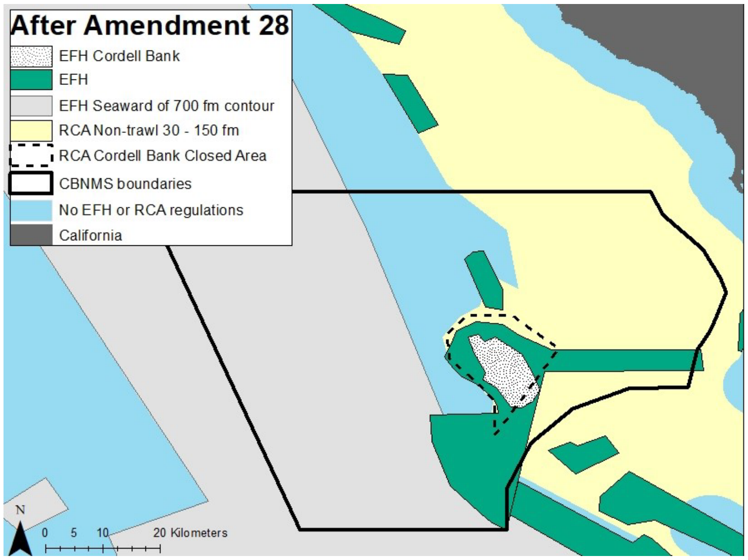

Appendix.X.10.2. Fisheries management areas (EFH and RCA) in CBNMS managed by the Pacific Fisheries Management Council a) first implemented in 2005-2006 and b) modified through Amendment 28 in January 1, 2020. Image: CBNMS.

Science and Exploration

Cordell Bank has a legacy of science and exploration dating back to long before it was a sanctuary and thus it is part of the heritage of the area. George Davidson discovered the bank in 1853 and it was mapped by Edward Cordell in 1869 using lead line. In the late 1800's some of the earliest research cruises on the west coast of the US collected dredge samples at Cordell Bank, which are archived at the Smithsonian Museum. In 1977, Cordell Expeditions, led by Robert Schmeider, conducted the first scuba dives on the bank. Subsequent trips were made through 1986 where photos and specimens were collected and the bank was mapped (Figure ES.H.1, Schmeider, 1991). These early specimens, along with those collected more recently in the sanctuary, are archived in the research collections at the California Academy of Sciences in San Francisco, preserving a record of findings from the sanctuary (California Academy of Sciences, 2022). The images collected by Cordell Expeditions were the first underwater photos of Cordell Bank and were instrumental in gaining support for the designation of the sanctuary in 1989. After the sanctuary was established a science program was developed. Eventually the Delta Submersible, and later a remotely-operated vehicle, were used by the sanctuary to explore the seafloor (Figure ES.H.2). The sanctuary also began a pelagic monitoring program, first called Cordell Bank Ocean Monitoring Program, that focused on Cordell Bank and then merged into a larger program called ACCESS with Greater Farallones National Marine Sanctuary and Point Blue Conservation Science. Other science projects have been added recently including acoustic and oceanographic studies, in partnership with many collaborators. These efforts are preserved in mission documentation, archived data, and publications and are part of the heritage of the area. They are also used in the story telling about CBNMS in public presentations, media, exhibits, and videos. Large scale science projects not primarily focused on CBNMS but collecting data in and around the sanctuary, such as the long-term monitoring project CalCOFI, also contribute information that help scientists understand how conditions of the sanctuary compare and are influenced by larger scale patterns.

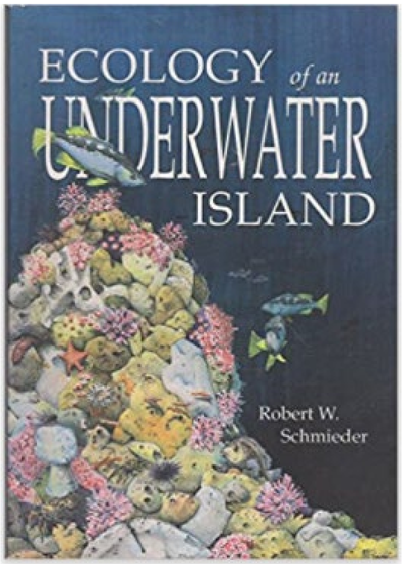

Figure ES.H.1. The findings from the historic dives at Cordell Bank by Cordell Expeditions are documented in “Ecology of an Underwater Island”.

Figure ES.H.2. Surveys of Cordell Bank were made using the Delta Submersible from 2000-2005.

Interpreting the Heritage of Maritime Archaeological Resources

There is one suspected shipwreck in CBNMS, the *USS Stewart*, a Navy Patrol craft (Figure ES.H.3, Schwemmer, 2021). Built in 1920, it operated in the Pacific in World War II but was captured by the Japanese in 1942, then recaptured by the US in 1945. In 1946, the US intentionally scuttled the vessel in what is now CBNMS and it is thought to be in or near Bodega Canyon. Although the vessel has not been visually surveyed on the seafloor, the sanctuary helps to support the heritage of maritime archaeology by sharing the history and interpretation of potential archaeological sites and protecting all shipwrecks and other maritime archaeological resources in the sanctuary. Other archaeological resources may be in the sanctuary and yet to be discovered. Both ONMS and CBNMS provide outreach and programming about maritime heritage in sanctuaries.

Indigenous peoples on the west coast of North America had many connections to coastal and ocean resources in ancient times. Our understanding of paleo shorelines and periods of lower sea level stands which coincide with coastal migration and habitation underscore the potential for past connections to now-submerged lands. However, at this time, the sanctuary is unaware of any information that suggests historical connections of Indigenous peoples to CBNMS specifically, prior to contemporary usage of motorized fishing vessels. There are possible contemporary connections of Native Americans to CBNMS who may fish or recreate in the sanctuary.

Figure ES.H.3. The *USS Stewart* when it was in US Navy service.

Conclusion

Because of the offshore location, CBNMS may have less of a direct, strong heritage component in the nearby communities than some other sanctuaries. However, CBNMS plays a role and supports the heritage of commercial and recreational fishing, science and exploration, and maritime heritage resources. The role that the sanctuary plays in supporting the heritage of fishing has changed over time. At the time of the report, because of regulations from other agencies to allow fish stocks to recover, there are fewer types of opportunities for fishing than in the past. Science and exploration have a strong foundation at CBNMS and the sanctuary continues to support this ecosystem service. At this time, the sanctuary is unaware of past or present cultural connections of Indigenous communities to the sanctuary specifically, prior to contemporary usage of motorized fishing vessels. Information about maritime heritage resources in the sanctuary and its historical and heritage legacy in the broader sanctuary community are areas for further academic study. The sanctuary expansion and commitment to a more comprehensive approach to maritime heritage to include cultural connections led to the improving trend rating.

Sense of Place — Aesthetic attraction, spiritual significance, and location identity

Status: Good/Fair (medium confidence)
Trend: Improving (high confidence)
Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Rationale: The rating had high confidence with participants in the ecosystem services workshop for the condition report indicating satisfactory outcomes from efforts and programs to date, but with a lack of labor and sustained funding for education and outreach, it hasn't been able to fulfill some community needs.

Sense of place is the aesthetic and spiritual attraction, and level of recognition and appreciation, that humans derive from a location given efforts to protect its iconic elements. Designation as a national marine sanctuary provides the special recognition and appreciation the American public has for protecting the resources in the sanctuary. It can inspire many things in people from creation of arts to a change in perspective. Just knowing a place of such biodiversity and wildness exists often inspires and supports conservation and protection efforts. Cordell Bank NMS is not an easy place to visit and experience, but the small number of people that have had the opportunity have a strong connection and memory of their time spent in the sanctuary and reverence for what it is. For people that can not visit the sanctuary, their sense of place can be built through education and outreach programs they may experience.

Indicators for rating sense of place at Cordell Bank National Marine Sanctuary include measures associated with exhibits, film, outreach, people who have had first hand experiences in the sanctuary, books inspired by experiences in CBNMS, online photographs by wildlife photographers, researchers and divers, and people who want to engage with the sanctuary mission. The sense of place created by these measures is central to the sanctuary's mission of conserving and protecting this special place.

The status of sense of place is good/fair with an improving trend. The advancement of technology is allowing for improved imagery (photos and video), which is helping the sanctuary reach more people and create a sense of place remotely. Exhibits with partner institutions and the sanctuary's traveling exhibit target audiences that can not easily access the sanctuary, but can remotely experience its beauty and wonder through images (see the Education Service for more detail regarding these initiatives). Films produced about the sanctuary enhance viewers' awareness about the biodiversity in this offshore federal protected area.
Remote "live dive" broadcasts of seafloor exploration from the sanctuary, transmitted digitally by satellite and internet to people at home, school, and museum venues have greatly aided in bringing the sanctuary to the people.

Bringing the Place to the People

Exhibits

From 2009-2020 exhibits reached over 3 million visitors. This included new exhibit installations like a traveling photo exhibit that brings images from the sanctuary to various community venues in Marin, Sonoma, and Mendocino counties in California (Figures ES.SP.1-2). Comments from the photo exhibit's logbook exude the enthusiasm and sense of place it inspires:

> *"Thank you for taking me where I never could have gone!! Protect more!"*
>
> *"Thanks for sharing that which I will not see in person. Beautiful"*
>
> *"Fantastic! We didn't even know this existed, but it was very educational! Thank you!"*

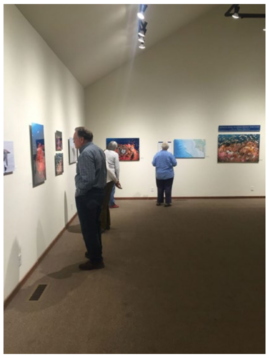

Figure ES.SP.1. Viewers look at photos as part of the Cordell Bank National Marine Sanctuary traveling photo exhibit. Credit: Jennifer Stock/CBNMS
File location: https://drive.google.com/file/d/1w-CL2Z_LEjoq1ilNMa18xw1ZsM21bRHn/view?usp=sharing
Alt text: people looking at pictures on the wall

Figure ES.SP.2. Images of the offshore Cordell Bank National Marine Sanctuary travel to various public locations to enhance awareness about the sanctuary and what it is protecting.
File location: https://drive.google.com/file/d/1yAP89VI783ZFsKjpIs93estsnIBZy1Jg/view?usp=sharing
Credit: Jennifer Stock/CBNMS

Alt text: photos of ocean wildlife on a wall

Film

The sanctuary is featured in some Office of National Marine Sanctuaries (ONMS) produced short films that circulate on social media. The sanctuary, due to facilitation through the Cordell Marine Sanctuary Foundation, was approached by *South Florida PBS, Changing Seas* series to create a film about Cordell Bank National Marine Sanctuary. This film aired on public broadcasting stations nationwide and at various ocean film festivals nationwide. CBNMS staff participated in panel discussions about the film and the sanctuary at different film festivals highlighting the film.

Outreach Events

While bringing people to the sanctuary is one way to acquire a sense of place, it is expensive and often inconsistent given weather and ocean conditions. In addition, sanctuary staff led boat trips allow for only a small number of people (one boat trip can take up to 35 people at a time) to visit the sanctuary, most of which are repeat visitors due to their high interest in wildlife watching (personal communication). While for those that have had success reaching the sanctuary, accessing the sanctuary directly has equity challenges due to the cost, physical challenges, and offshore location. The sanctuary co-hosted an annual wildlife watching boat trip between 2009-2017, but due to various factors (primarily unpredictable weather and rough ocean conditions) the offering was discontinued.

"Thanks to the hydrophone, we were able to listen to sea lions barking underwater and dolphins! That was incredible!"- Cordell Bank wildlife watching trip participant

"I will never forget the dolphins! A mega pod"-Cordell Bank wildlife watching trip participant

Outside of the on-the-water field trips, the sanctuary has seen invitations from federal agencies, Bay Area museums, community events, nonprofit organizations to participate in outreach events, community talks and presentations increase, as well as invitations to host and lead outdoor events like coastal walks and wildlife watching boat trips on charter vessels, indicating a desire for organizations and agencies to promote the sanctuary.

Sense of Place for People who have visited the Sanctuary

The people who have traveled to CBNMS overcame several challenges to seek out visiting the sanctuary firsthand. With a limited number of suitable seaworthy vessels to charter, and highly variable and at times challenging sea conditions and weather, the people that have gone have done so with determination and will to experience the waters throughout the sanctuary. Overcoming such planning challenges and highly variable physical conditions, a small number of visitors have nonetheless had unique, firsthand and memorable experiences.

Prior to the sanctuary being designated, a team of volunteer divers called Cordell Expeditions dove on Cordell Bank in the early 1980's and discovered its biodiversity worthy of sanctuary protections. Their explorations led to the sanctuary being designated in 1989. Oral history interviews conducted with these Cordell explorers reveal that their experience diving Cordell Bank and exploring its biodiversity was, for some, the highlights of their lives. They also expressed appreciation for how sanctuary programs have developed and how their original explorations led to the conservation of such an important place.

“We could fill volumes of our life experiences of what we've done, and we've all lived fairly adventurous lives. But for me Cordell Bank was the highlight of it all." -Dave Cassotta, Cordell Explorers Oral History

"Cordell Bank, having the opportunity to dive there, help describe it, is the number one high point in my life, excluding family…… It’s a place that should not be forgotten. It should be kept in the limelight, keep the public aware of such a special place right off our coast, unlike any other -Don Dvorak

"Cordell Bank was for about ten years...my obsessive driving interest to see this project through to the establishment of a National Marine Sanctuary."
-Dr. Robert Schmieder

Some fishermen refer to Cordell Bank as a revered place, not just for fishing, but for encounters with seabirds and marine mammals. Tech divers have approached CBNMS staff in recent years wanting to dive in the sanctuary and support the sanctuary mission by contributing to sanctuary research and education by acquiring photography and video, or collecting samples. Such access requires a permit for placing a temporary reference line contacting seafloor. Nonetheless, these recreational divers have explored and contributed their findings to the sanctuary for resource management purposes. These diverse communities all share a common impression, that while inaccessible to most, those that have conducted research, fishing, or are avid wildlife enthusiasts appreciate the sanctuary and its resources and find a way to access this special place, despite the hardships involved.

Sharing Sense of Place: Literature and Photos shared about Cordell Bank

Cordell Bank has inspired the writing of at least four different books. Avid pelagic wildlife enthusiasts post their top photos of birds and whales on social media and web pages.

Book titles either featuring Cordell Bank National Marine Sanctuary or including it in text within a book:

- Ocean Birds of the Nearshore Pacific-author-Rich Stallcup
- Ecology of an Underwater Island-author-Robert W. Schmieder
- Edward Cordell and the Discovery of Cordell Bank- author-Robert W. Schmieder
- The Whale that Lit the World-author: Josh Churchman

Websites with images taken in Cordell Bank National Marine Sanctuary:

- The Natural History of Bodega Head blog (Sones, 2022)
- Bay Area Underwater Explorers (2013)
- Flickr (2022)
- Debi’s Shearwater’s Journeys blog (Shearwater, 2013)

People who want to engage with the sanctuary mission

While Cordell Bank is offshore and away from land and out of sight for most people, there are various groups of people that have sought association with Cordell Bank National Marine Sanctuary. Cordell Bank National Marine Sanctuary has historically been supported by a small staff, and there is a reliance on partners to increase the awareness of the sanctuary to the regional community. For example, the Oakland Museum of California approached sanctuary staff to feature Cordell Bank in its Natural Sciences Gallery renovation. Point Reyes National Seashore invited sanctuary staff to collaborate on interpretive exhibits in key locations to promote sanctuary awareness throughout this highly visited park. Members of the community who are Cordell Bank enthusiasts formed a non profit organization, the Cordell Marine Sanctuary Foundation to support the sanctuary with financial support. Over the years, potential volunteers have reached out wanting to help and get involved in the sanctuary's mission. In addition members of the public apply to the Sanctuary Advisory Council as seats become available, wanting to learn more and support the sanctuary with input from their respective constituencies. While the numbers of people overall engaging with Cordell Bank National Marine Sanctuary have been small, the dedication and passion for this unique sanctuary is present through their invitation and association with the sanctuary and its programs.

Conclusion

Due to its physical barriers for in-person access, the sanctuary has focused on bringing the sanctuary to the people through various means. Cordell Bank National Marine Sanctuary, as unique and difficult to visit as it is, has cultivated a sense of place through a small but dedicated group of ocean-users and has extended that sense of place to others remotely through education and outreach programming. Distance learning programs through research expedition telepresence and temporary and permanent exhibits have been ways 1000's of people have been able to gain a sense of appreciation and sense of place to the sanctuary while not physically accessing it. The visual resources created over the years through research photography and video imagery have greatly aided in building this sense of place to audiences in coastal communities of Marin and Sonoma counties primarily extending further north and south and to communities in the East Bay and beyond nationally and internationally. and beyond.

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Response to Pressures

The Pressures section of this report describes a variety of issues and human activities occurring within and beyond CBNMS that warrant attention, tracking, study, assessment and analysis and, in some cases, specific management actions. Addressing any of these issues requires participation by and coordination with a variety of agencies and organizations. CBNMS works with entities such as federal, state, and local government agencies and non-profit organizations that contribute to managing human activities and addressing marine conservation issues. The Sanctuary Advisory Council is the primary way that the sanctuary receives input from these groups and the public on management of the sanctuary (see text box).

<<<Gray text should be a text box titled: **CBNMS Sanctuary Advisory Council**>>>
The Sanctuary Advisory Council was established in 2001 under the authority of the NMSA. It was formed to serve as a forum for consultation and deliberation among its members and as a source of advice and recommendations to the sanctuary superintendent. Advisory council seats are occupied by members representing research, conservation, maritime activities, fishing, education, the community at-large, and two federal agency partners. In addition to providing advice as a body to the sanctuary superintendent, individual advisory council members act as liaisons between the sanctuary and their constituent groups.

For each of the main issues and human activities presented in the Pressures section of this report, this Response section provides a summary of related activities and management actions led or coordinated by sanctuary staff. The activities described below are not exhaustive of all the ways the sanctuary serves the community and the marine ecosystems encompassed within the sanctuary, but highlight significant contributions that are responsive to known or emerging pressures. Changes to management actions are not recommended in this section; however, in 2023, CBNMS staff will begin updating the sanctuary's management plan, and this condition report's findings will serve as an important foundation on which to build new action plans designed to address priority needs.

Described below is a summary of activities the sanctuary has completed since the last condition report that address the influential pressures discussed throughout this report.

Climate Change and Ocean Acidification
Climate change is a global issue, and while there are many agencies, organizations, and individuals at global, regional, and local scales responding to it, NOAA has been working to better understand and communicate how the sanctuary is affected by climate change and ocean acidification. Since the last condition report, the scale, magnitude, and impacts of climate change have become more clear. The highlights summarized below focus on CBNMS and its partners' efforts to address climate change and ocean acidification in the sanctuary and surrounding region.

Conservation Science Program
To enable effective management, scientists characterize and seek to understand how the resources and habitats in the sanctuary are responding to changes in the climate and the ocean while recognizing that the sanctuary is ecologically interconnected to the ocean and atmosphere

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regionally and globally. NOAA scientists, including sanctuary staff, have identified potential climate impacts and climate indicators and are monitoring many of these indicators through partnerships with nonprofits and universities in various long-term projects. Examples include the ACCESS ecosystem monitoring, hypoxia monitoring, and CBNMS Benthic Science Program (Table R.1). These projects support management of the sanctuary, and particularly the sanctuary's response to climate change, by providing data on the conditions of the resources in the sanctuary (e.g., on the seafloor and in the pelagic zone) under varying ocean conditions. The information can be used in climate-related resource protection and management efforts. In addition, and described in further detail in the following subsections, information from these projects has been applied to other management issues.

Table R.1. Conservation science programs that monitor climate indicators and identify potential impacts.

Program Name	Partners/Collaborators	Timeframe	Primary Indicators Measured	Outputs
ACCESS	GFNMS, Point Blue/UC Davis Bodega Marine Laboratory	2004–present	Oceanography, acoustics, prey sampling, predator abundance and distribution (and others)	Annual Ocean Climate Indicators Reports compile time series data of variables and summarize responses to environmental conditions (Elliott et al., 2019). Data has been used to understand conditions in the sanctuary and local responses to events like the marine heatwave.
Cordell Bank Hypoxia monitoring project	U.C. Davis, Bodega Marine Laboratory	2014–present	Dissolved oxygen, salinity, temperature	Summaries of seasonal and annual patterns of oceanographic conditions at Cordell Bank (Hewett et al., 2017)
CBNMS Benthic	California	2000–present	Abundance and	New

Science Program	Academy of Sciences		distribution of benthic taxa	explorations and characterizations of sanctuary habitat and environmental conditions (Graiff et al., 2017, 2020a, 2020b; Lipski et al., 2018)

Management, Administration, and the Resource Protection Program
Several reports have been produced that help inform and guide CBNMS activities related to climate change. In addition. CBNMS staff members have participated in ONMS regional and national climate teams to plan and implement climate initiatives. These teams also worked to coordinate efforts to learn about and address climate change and ocean acidification with the NOAA Climate Program Office and NOAA Fisheries.

Reports relevant to CBNMS climate change efforts:

- *Climate Change Impacts: Report of a Joint Working Group of the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries Advisory Councils* (2010)
- *Ocean Climate Indicators: A Monitoring Inventory and Plan for Tracking Climate Change in the North-central California Coast and Ocean Region: Report of a Working Group of the Gulf of the Farallones National Marine Sanctuary Advisory Council* (2013, adopted by CBNMS Advisory Council)
- *Climate Change Vulnerability Assessment for the North-Central California Coast and Ocean* (2015)
- *Climate-Smart Adaptation for North-central California Coastal Habitats Report of the Climate-Smart Adaptation Working Group of the Greater Farallones National Marine Sanctuary Advisory Council (2016, includes CBNMS)*
- *Climate Change Impacts: Cordell Bank National Marine Sanctuary (2020)*
- *Climate Change Impacts: National Marine Sanctuaries West Coast* Region (2021)

These reports laid the groundwork to understand potential climate change impacts to sanctuary resources, identify indicators to monitor, and assess and understand the vulnerability and adaptive capacity of sanctuary resources.

The CBNMS staff also took a number of actions to improve the efficiency of its facilities and operations, including moving into newly renovated, energy efficient office buildings that are outfitted with high thermal resistance insulation, dual pane windows, LED lighting, ultra-high efficiency tankless water heaters, high-efficiency central propane furnaces, and solar electric panels. Staff also compost waste from meals and lease hybrid-electric government vehicles for work use.

Education and Outreach Program
To raise awareness about the threats and impacts of climate change, CBNMS staff have initiated a number of activities focused on climate change and ocean acidification, including web postings, symposiums, workshops, classroom curricula, field trips, telepresence and other virtual-learning opportunities, social media, segments on a local radio show, exhibitry, and short films.

Climate Change Response Conclusion
Impacts of climate change on sanctuary resources, particularly those related to temperature, OA, and species composition, distribution, and abundance, have become more evident since the 2009 Condition Report and tend to follow trends being observed globally. Though we have an improved understanding of those impacts through monitoring and research, management action has focused largely on increasing awareness of the issue to the public. Further work is needed to understand what additional management actions could be taken to directly address and mitigate resource impacts from climate change in the sanctuary.

Fishing
CBNMS does not manage fisheries, though it can restrict destructive fishing activities. Rather, federal fisheries in CBNMS are managed by NOAA National Marine Fisheries Service and the Pacific Fisheries Management Council. State fisheries in CBNMS (e.g., Dungeness crab) are managed by the California Department of Fish and Wildlife. CBNMS staff work with these partners to address fishing-related pressures.

After a multi-year process, in 2019 NMFS changed Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act, in Amendment 28 of the Pacific Coast Groundfish FMP. West coast wide changes to descriptions and management measures for EFH and to specific EFH Conservation Areas (EFHCAs) were developed through a collaborative process among trawl fishermen and scientists and managers from federal and state agencies and environmental organizations. The trawl RCA was also removed in federal waters off Oregon and California, re-opening these waters to fishing with groundfish bottom trawl gear. CBNMS scientists contributed information on habitats and species that had been observed in some of the areas within the sanctuary, and the information was used to identify areas that eventually gained protection. The EFHCAs in CBNMS currently comprise 170 square miles of benthic habitat protected from bottom trawl gear other than demersal seine. Within the sanctuary, the EFH changes opened 19 square miles of primarily sandy-mud habitat on the continental shelf to bottom trawl fishing that were historically productive fishing grounds, while closing 19 square miles of shelf and slope habitat composed of hard and mixed substrate. It modified the boundaries of the existing Cordell Bank Biogenic EFHCA by extending part of it to be protected from bottom trawling and removing part of it, and also established a new EFHCA, Gobbler’s Knob. Following these changes to the habitat protections, CBNMS has identified new areas to survey to assess the impacts of fishing and protections.

CBNMS management considers potential impacts to fishing and other human activities prior to taking certain actions, such as revising the CBNMS management plan and finalizing regulations. For example, prior to the expansion of the sanctuary in 2015, ONMS studied the economic impacts the expansion would have on the commercial and recreational fisheries in CBNMS. An environmental impact statement (EIS) was also compiled that reviewed the status of and projected impacts the expansion would have on living resources, commercial fishing, and recreation in the then-proposed expansion area (ONMS, 2014b). In brief, the EIS found that the expansion of sanctuary boundaries would not negatively affect living resources, commercial fishing, and recreation. Similarly, NOAA projected impacts of certain U.S. Coast Guard vessel and training-related discharges on fishing in the expanded portion of the sanctuary in an environmental assessment and proposed rule, prior to release of the final decision in 2018. NOAA determined that the impacts to natural resources, historic resources, and human uses (including fishing) would not be significant.

To ensure that sanctuary interests and regulations are considered in fisheries management and enforcement, sanctuary staff have built productive working relationships with fishery management agencies and other organizations with fishing interests. In particular, staff have worked closely with law enforcement partners and with the Pacific Fishery Management Council (PFMC). Staff provide training on sanctuary regulations for enforcement officers and alert enforcement officers about potential or actual regulatory violations in the sanctuary. This has led to a collaborative enforcement approach with law enforcement personnel from multiple agencies who are well-informed about and able to enforce sanctuary regulations. Staff regularly provide written and oral overview reports to the PFMC on West Coast national marine sanctuaries to keep them informed about the surveys and assessments that are conducted so that they can incorporate them into their actions. Also, the sanctuary issues permits to allow for specified fisheries research activities within the sanctuary, such as groundfish stock assessments that disturb the submerged lands or testing new fisheries assessment methods. By permitting these activities, the sanctuary supports good fisheries management through data collection.

As representative to the Sanctuary Advisory Council, the NOAA Fisheries and fishing seats advise the sanctuary superintendent on issues related to sanctuary management, and serve as liaisons to the sanctuary community. These representatives regularly communicate fisheries updates to the council and weigh in on management actions that could affect fisheries and the fishing community.

Education and Outreach Program
CBNMS seeks to raise awareness about how the sanctuary can support healthy fisheries. CBNMS staff have provided topical fishing-specific outreach at local festivals, such as the Bodega Bay Fishermen's Festival. A toolkit was created and distributed through symposia, workshops, and on the web about how ocean acidification affects Dungeness crab. Segments on a local radio show have featured interviews with guests about fishing, conservation and management of fished species, among other topics. Fishing at Cordell Bank is featured in the exhibit on Cordell Bank at the Oakland Museum of California. The sanctuary has also worked to install interpretive exhibit panels about sanctuary resources at popular local fishing spots. Through these outreach efforts, CBNMS has reached stakeholders that otherwise may not be engaged on these issues.

Fishing Response Conclusion
The sanctuary has taken actions to understand the impacts of fisheries on habitats and living resources, to inform fisheries management actions, and to educate the public about the importance of healthy ecosystems. The sanctuary benefits from many positive interactions and support from the fishing community. At the same time, the status and trends section of this report identified areas where fishing is impacting habitats and living resources. Data gaps that were noted included limited data availability and analysis of impacts and long term trends.

Vessel Use

Noise
Following several high-profile ship strikes to whales in 2009, CBNMS began to study how vessels impact wildlife in the sanctuary. Ocean noise was identified as a potential vessel impact to whales and in 2012 the CBNMS and GFNMS advisory councils recommended that the sanctuary take action to reduce vessel strike and acoustic impacts. In response, CBNMS began studying ocean noise in the sanctuary in 2015. In partnership with Oregon State University, NMFS, and NOAA's Pacific Marine Environmental Laboratory, CBNMS deployed a NOAA Noise Reference Station (NRS) to establish a baseline record of the soundscape of the sanctuary. The

equipment has been serviced every two years and is still recording. Analysis of the first two years of data shows that low frequency sound in the sanctuary is dominated by ships and baleen whales (Haver et al., 2020). This baseline data enables researchers and managers to understand the level of noise in the sanctuary, if ocean noise is a threat to sanctuary wildlife, and to measure effectiveness of any future management actions to reduce noise pollution. Other acoustic research in the sanctuary includes a NMFS project to deploy drifting acoustic buoys in partnership with sanctuary scientists. These buoys record sound at higher frequencies than the NRS and can be deployed beyond the geographic listening range of the NRS. Higher frequency recordings provide information about species in the sanctuary such as beaked whales, but also about human activities occurring in the sanctuary (e.g., small vessel use) that could cause acoustic impacts to wildlife. In addition to working to understand the sanctuary's soundscape, the sanctuary is engaged in regional, national, and international level partnerships that explore possible management efforts, particularly related to reducing shipping noise.

In addition, CBNMS has raised awareness to the public about the issue of ocean noise by creating videos, web stories, and in interviews with the media.

Ship Strikes

In response to the high-profile ship strikes to whales that occured in 2009, and the subsequent Advisory Council recommendations mentioned in the previous noise section, from 2010–2012 CBNMS worked with the U.S. Coast Guard, NOAA Fisheries, and the International Maritime Organization (IMO) to modify the San Francisco Traffic Separation Scheme (SF TSS), which includes the northern lane in CBNMS to improve safe navigation and reduce the co-occurrence of whales and ships transiting the sanctuary. As a result, the lanes were modified in 2014 from a funnel shape to straight lanes, and the northern lane through the sanctuary was lengthened and redirected. Beginning in 2010, CBNMS and GFNMS began to request that vessel traffic voluntarily slow down in the SF TSS. Since 2015, CBNMS and GFNMS have worked together to implement a consistent annual voluntary vessel speed reduction in the SF TSS from May 1 to November 15, during which the cooperation level is tracked and reported to the companies. As of 2021, the cooperation level with the voluntary request was 63%. In addition, CBNMS has partnered with GFNMS, CINMS, Bay Area Air Quality Management District, Air Pollution Districts of Santa Barbara and Ventura, EPA, California Marine Sanctuary Foundation, Greater Farallones Association, and the Volgenau Family Foundation to offer a monetary incentive program for ships to slow down in the TSS. Shipping companies register in advance and pledge to cooperate with the slow down request in exchange for funds. As of 2021, the cooperation level with the incentivized request was 60%. The population of ships engaged in the two programs (voluntary and incentivized) differs, leading to the different levels of cooperation. Beginning in May 2022, the voluntary slowdown extends through all of CBNMS and GFNMS and the end date was extended from November 15 to December 15 to further protect whales. Since 2019, staff from CBNMS and GFNMS began evaluating additional actions that could be taken to further reduce ship strike risk.

Protecting Blue Whales and Blue Skies Vessel Speed Reduction Incentive Program							
Program Year	2014	2016	2017	2018	2019	2020	2021
VSR Zone	Santa Barbara Channel Region		Santa Barbara Channel Region & San Francisco Bay Region			Southern California Region & San Francisco Bay Region	
# Companies	7	10	11	12	15	16	18
# Vessels	14	25	44	295	349	483	545
Slow-speed Distance (nautical miles)	2,700	5,000	12,630	46,026	99,019	181,306	179,530
Overall Fleet Cooperation	--	--	--	36%	55%	60%	64%
NOx Reductions (tons)	12.4	25.6	84	266	536	748	650
Regional GHG Reductions (metric tons)	535	1,005	2,630	8,668	17,026	24,258	22,201
Ocean Noise Reduction (Decibels (dB) / transit)	--	--	--	--	SoCal: 6 (Gold & Sapphire award tiers only)	SoCal: 4 (All award tiers)	SoCal: 5 (All award tiers)
Ship Strike Risk Reduction *	--	--	--	--	--	35%	50%
* Note: This represents the proportional decreases in risk from participating vessels and not absolute estimates of mortality avoided.							

Figure R.1. Results of the incentivized vessel speed reduction program. Image credit: Protecting Blue Whales and Blue Skies Program

Information from sanctuary science projects has been incorporated in the process to reduce ship strikes to whales. ACCESS data on the distribution and abundance of whales and prey were used to identify habitat use hotspots (Rockwood et al., 2020a). This information was then used to identify where whales are most at risk to ship strikes and what management efforts might be most effective in reducing the risk of ship strikes (Rockwood et al., 2020b). Modeling analysis indicates that ship strike risk was reduced by 9–13% depending on species and year during May, June, July, and September in 2016–2017 as a result of speed reductions (Rockwood et al., 2020b). The Noise Reference Station analysis provided new information about whale presence during times of the year when visual surveys were lacking, and this information was used in considerations of the timing and duration of the annual voluntary vessel speed reduction (Haver et al., 2020).

CBNMS has also sought to raise awareness about the risk of ship strikes to whales through web sites and media outreach.

Spills and Discharges

CBNMS regulations prohibit the discharge of material or matter into the sanctuary to protect the sanctuary from pollution. When the sanctuary was expanded in 2015, the regulation was applied to the new area following a review of the impacts to living resources, fisheries, and military. There are exemptions for discharge from lawful fishing, and for USCG exempt activities including training. In 2018 CBNMS and GFNMS completed an environmental assessment of the USCG discharge exemption and concluded that although there may be impacts to water quality the impacts would not be significant.

CBNMS staff members have worked with enforcement partners, including NOAA Office of Law Enforcement and USCG, to ensure that those charged with enforcing sanctuary regulations are familiar with them and keep up to date on any issues. This includes ensuring working pump-out facilities, and training boarding officers, wardens, and rangers. CBNMS works closely with these enforcement partners when any issues arise. As a result of regulations and enforcement, in 2021, NOAA settled a lawsuit against a cruise ship company for illegally discharging material into the sanctuary.

Vessel Response Conclusion
CBNMS has responded to the impacts of vessels on sanctuary habitats and living resources by increasing our understanding of ocean noise, reducing the risk of ship strikes to whales, and enforcing prohibitions on vessel spills and discharges. The status and trends section of this report identifies several areas where vessel impacts are a concern and factored into the ratings. Continued tracking of vessel use and analysis of trends, enforcement efforts, and passive acoustic monitoring is still needed. Management actions have reduced the risk to whales to some extent, but not to conservation targets, and cooperation with voluntary programs has leveled off. Further understanding of ship strike risk and possible management actions is needed.

Marine Debris
Sanctuary regulations prohibit discharge of marine debris into the sanctuary (see spills and discharges above), however, marine debris can enter the sanctuary through the loss of fishing gear, boating equipment, and research equipment. Also, litter from land outside the sanctuary or vessels, and materials in wastewater, including microfibers, can enter the sanctuary. The sanctuary staff record observations of marine debris during ACCESS and benthic surveys (see Figures Appendix X.10.8,, Appendix X.10.9, Appencis X.10.10). These records have led to targeted removals of lost fishing gear, including crab pots at the surface and nets on the seafloor, to reduce entanglement and ghost fishing. Sanctuary staff help to support and coordinate with other agencies and responders on entanglement, strandings, and necropsies. Outreach efforts by CBNMS staff aim to raise awareness about the impacts of marine debris on albatross that feed in the sanctuary. Programs with school groups, curriculum and exhibits have focused on actions students can take at schools and on local beaches to keep marine debris out of the watershed.

Marine Debris Response Conclusion
CBNMS has worked to reduce the impacts of marine debris in the sanctuary by recording the locations of marine debris, supports programs to reduce wildlife impacts from marine debris, and raises awareness about the issue. In the status and trends section of this report marine debris was noted to have impacts on water quality, habitat, and living resources. Continued monitoring to assess long term trends and more information about microplastics were identified as needs.

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Appendix C: Consultation with Experts, Documenting Confidence, and Document Review

The process for preparing condition reports involves a combination of accepted techniques for collecting and interpreting information gathered from subject matter experts. The approach varies somewhat from sanctuary to sanctuary in order to accommodate different styles for working with partners. CBNMS's approach was closely related to the Delphi Method, a technique designed to organize group communication among a panel of geographically dispersed experts by using questionnaires, ultimately facilitating the formation of a group judgment. This method can be applied when it is necessary for decision makers to combine the testimony of a group of experts, whether in the form of facts, informed opinion, or both, into a single useful statement. The Delphi Method requires experts to respond to questions with a limited number of choices to arrive at the best-supported answers. Feedback to the experts allows them to refine their views, gradually moving the group toward the most agreeable judgment.

In order to assess the standardized state of the resources questions and ecosystem services that are addressed in condition reports (see Appendices A and B), throughout the condition report process, ONMS selected and consulted outside experts familiar with water quality, habitat, living resources, maritime heritage resources, and socioeconomics in the sanctuary. A list of experts who have participated in the CBNMS condition report process is available in the Acknowledgements section of this report.

First, a series of virtual workshops were held from March–April and June, 2021 to discuss and evaluate the series of questions about each resource and ecosystem service: human activities, water quality, habitat, living resources, and ecosystem services (commercial harvest, consumptive recreation, non-consumptive recreation, science, education, heritage, and sense of place). During the virtual workshops, experts were introduced to the questions and ecosystem services, relevant indicators were presented, and experts were provided with time series datasets ONMS had collected from experts prior to the workshop. Attendees were then asked to review the datasets, identify data gaps or misrepresentations, and suggest any additional datasets that may be relevant. Once all datasets were reviewed, experts were asked to provide status and trend recommendations and supporting arguments. In order to ensure consistency with the Delphi Method, a critical role of the facilitator was to minimize dominance of the discussion by a single individual or opinion (which often leads to "follow the leader" tendencies in group meetings) and to encourage the expression of honest differences of opinion. To facilitate this, at most workshops experts were asked to enter their recommended ratings and trends in an online poll, after which the poll results were viewed and discussed among the group. As discussions progressed, the group converged on an opinion for each rating that most accurately described the resource or ecosystem service condition. After an appropriate amount of time, the facilitator asked whether the group could agree on a rating for the question or ecosystem service, as defined by specific language linked to each rating (see Appendices A and B). If an agreement was reached, the result was recorded and the group moved on to consider the trend in the same

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manner. If agreement was not reached, the facilitator recorded the vote of individuals for each rating category and that information helped to inform the confidence scoring process.

After assigning status ratings and trends, experts were asked to assign a level of confidence for each value by: (1) characterizing the sources of information they used to make judgments; and (2) their agreement with the selected status and trend ratings. The evidence and agreement ratings were then combined to determine the overall confidence ratings, as described in the three steps outlined below.

Step 1: Rate Evidence

Consider three categories of evidence typically used to make status or trend ratings: (1) data, (2) published information, and (3) personal experience.

Limited	Medium	Robust
Limited data or published information, and little or no substantive personal experience.	Data available, some peer reviewed published information, or direct personal experience.	Considerable data, extensive record of publication, or extensive personal experience.

Step 2: Rate Agreement

Rate agreement among those participating in determining the status and trend rating, or if possible, within the broader scientific community. Levels of agreement can be characterized as "low," "medium," or "high."

Step 3: Rate Confidence

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Using the matrix below, combine ratings for both evidence and agreement to identify a level of confidence. Levels of confidence can be characterized as "very low," "low," "medium," "high," or "very high."

Agreement →			
	"Medium" High agreement Limited evidence	"High" High agreement Medium evidence	"Very High" High agreement Robust evidence
	"Low" Medium agreement Limited evidence	"Medium" Medium agreement Medium evidence	"High" Medium agreement Robust evidence
	"Very Low" Low agreement Limited evidence	"Low" Low agreement Medium evidence	"Medium" Low agreement Robust evidence

Evidence (type, amount, quality, consistency) →

An initial draft of the report, written by ONMS, summarized information, expert opinions, and levels of confidence expressed by the experts. Comments, data, and citations received from the experts were included, as appropriate, in text supporting the ratings and compiled in three appendices. This initial draft was made available to contributing experts and data providers, which allowed them to review the content and determine if the report accurately reflected their input, identify information gaps, provide comments, or suggest revisions to the ratings and text.

Following the expert review, the document was sent to representatives of partner agencies for a second review. These representatives were asked to review the technical merits of resource ratings and accompanying text, as well as to point out any omissions or factual errors. Upon receiving reviewer comments, ONMS revised the text and ratings as appropriate.

In August 2022, a draft final report was sent to ____regional experts for a required external peer review. External peer review became a requirement when the White House Office of Management and Budget (OMB) issued a Final Information Quality Bulletin for Peer Review (OMB Bulletin) that established peer review standards to enhance the quality and credibility of the federal government's scientific information (OMB, 2004). Along with other information, these standards apply to "influential scientific information," which is information that can reasonably be determined to have a "clear and substantial impact on important public policies or private sector decisions" (OMB, 2004, p. 11). Condition reports are considered influential scientific information and are subject to the review requirements of both the Information Quality Act and the OMB Bulletin guidelines; therefore, every condition report is reviewed by a minimum of three individuals who are considered to be experts in their field, were not involved in the development of the report, and are not ONMS employees. Comments and recommendations of the peer reviewers were considered and incorporated, as appropriate, into the final text of this report. Furthermore, OMB Bulletin guidelines require that reviewer comments, names, and affiliations be posted on the agency website, http://www.cio.noaa.gov/. Reviewer comments, however, are not attributed to specific individuals. Comments by the external peer reviewers are posted at the same time as the formatted final document.

In all steps of the review process, experts were asked to review the technical merits of resource ratings and accompanying text, as well as to point out any omissions or factual errors; however, the interpretation, ratings, and text in the condition report are the responsibility of, and receive final approval by, ONMS. To emphasize this important point, authorship of the report is attributed to ONMS; subject matter experts are not authors, though their efforts and affiliations are acknowledged in the report.

Cordell Bank National Marine Sanctuary
Confidence Ratings from March–April and June, 2021 Virtual Expert Workshops

Table App___.2. A summary of confidence levels for CBNMS condition report ratings.

Question	Virtual Workshop Date	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
Human Activities/Water Quality	June 29	Status: Good/Fair	Medium	High	High
		Trend: Not Changing	Medium	Medium	Medium
Human Activities/Habitat	June 29	Status: Fair	Robust	High	Very High
		Trend: Improving	Robust	High	Very High
Human Activities/Living Resources[1]	June 29	Status: Fair	Robust	High	Very High
		Trend: Undetermined	Robust	Medium	High
	N/A	Status: Good	N/A	N/A	N/A

Commented [11]: Footnote #18

[1] Experts assigned a trend rating of undetermined at the workshop. However, following the workshop, a new trend "mixed" was introduced to the condition report rating scheme as a result of discussions with experts. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the combination of trends from available data.

Human Activities/Maritime Heritage Resources[2]		Trend: Undetermined	N/A	N/A	N/A
Water Quality/Eutrophication	March 24	Status: Good	Limited	High	Medium
		Trend: Not Changing	Limited	High	Medium
Water Quality/Risk to Human Health	March 24	Status: Good/Fair	Medium	High	High
		Trend: Worsening	Limited	Medium	Low
Water Quality/Climate Change	March 26	Status: Fair	Robust	Medium	High
		Trend: Worsening	Limited	Medium	Low
Water Quality/Other Stressors	March 26	Status: Good/Fair	Limited	High	Medium
		Trend: Undetermined	Limited	High	Medium

Commented [12]: Footnote #19

[2] A workshop was not convened for the question that asks, What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing? Archaeological experts with the ONMS Maritime Heritage Program and CBNMS internally evaluated this question. These subject experts have been monitoring existing archaeological sites along the west coast since the 1980s.

Habitat/Integrity[3]	March 29	Status: Fair	Medium	Medium	Medium
		Trend: Undetermined	Limited	High	Medium
Habitat/Contaminants	March 29	Status: Undetermined	Limited	High	Medium
		Trend: Undetermined	Limited	High	Medium
Living Resources/Keystone and Foundation Species	March 31	Status: Good/Fair	Medium	High	High
		Trend: Undetermined	Medium	High	High
Living Resources/Other Focal Species[4]	March 31	Status: Fair	Medium	High	High
		Trend: Undetermined	Medium	Medium	Medium

Commented [13]: Footnote #20

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[3] Experts assigned a trend rating of undetermined at the workshop. However, following the workshop, a new trend "mixed" was introduced to the condition report rating scheme as a result of discussions with experts. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the combination of trends from available data.

[4] Experts assigned a trend rating of undetermined at the workshop. However, following the workshop, a new trend "mixed" was introduced to the condition report rating scheme as a result of discussions with experts. ONMS staff determined that this new rating was more appropriate to apply to this question, based on the combination of trends

Living Resources/Non-indigenous Species	April 7	Status: Good	Limited	High	Medium
		Trend: Undetermined	Limited	Low	Low
Living Resources/Biodiversity	April 7	Status: Good/Fair	Medium	High	High
		Trend: Not Changing	Medium	High	High
Maritime Heritage Resources/Integrity[5]	N/A	Status: Undetermined	N/A	N/A	N/A
		Trend: Worsening	N/A	N/A	N/A

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Ecosystem Services	Virtual Workshop Date	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)

from available data. Because of this new trend, the confidence score was also adjusted to high in order to reflect a higher level of expert agreement.

[5] A workshop was not convened for the question that asks, What is the condition of known maritime heritage resources and how is it changing? Archaeological experts with the ONMS Maritime Heritage Program and CBNMS internally evaluated this question. These subject experts have been monitoring existing archaeological sites along the west coast since the 1980s.

Commercial Harvest[6]	June 30	Status: N/A	N/A	N/A	N/A
		Trend: N/A	N/A	N/A	N/A
Consumptive Recreation[7]	June 30	Status: N/A	N/A	N/A	N/A
		Trend: N/A	N/A	N/A	N/A
Non-Consumptive Recreation	May 21	Status: Good/Fair	Robust	High	Very High
		Trend: Worsening	Robust	High	Very High
Science	May 26	Status: Fair	Medium	High	High
		Trend: Improving	Medium	Medium	Medium
Education	May 27	Status: Good/Fair	Robust	High	Very High
		Trend: Improving	Robust	Medium	High
Heritage	May 26	Status: Fair	Medium	Medium	Medium

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[6] Because of a limited number of experts providing input, staff rated this service after the workshop.
[7] Because of a limited number of experts providing input, staff rated this service after the workshop.

		Trend: Improving	Limited	Medium	Medium
Sense of Place	May 27	Status: Good/Fair	Medium	Medium	Medium
		Trend: Improving	Medium	High	High

This is the post-peer review version of the CBNMS Condition Report. It is now locked and a new copy has been created for copy edits

Appendix D: Comparing the 2009 Cordell Bank National Marine Sanctuary condition report to the 2009–2021 Cordell Bank National Marine Sanctuary condition report

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2009 (left) and 2009–2021 (right) status, trend and confidence ratings for the human activities questions. The 2009 Condition Report ratings reflect the sanctuary prior to its expansion in 2015.

2009 Condition Report Questions		2009 Rating	2009–2021 Condition Report Questions		2009–2021 Condition Report Rating			
					Status	Confidence (Status)	Trend	Confidence (Trend)
N/A	N/A	N/A	1	Influential Drivers	Not rated			
4	Human activities and water quality	?	2	Human activities and water quality	Good/Fair	High	—	Medium
8	Human activities and habitat	▲	3	Human activities and habitat	Fair	Very high	▲	Very high
14	Human activities and living resources	▲	4	Human activities and living resources	Fair	Very high	▲▼	High
17	Human activities and maritime archaeological resources	?	5	Human activities and maritime heritage resources	Fair		?	
2	Eutrophic Condition	—	6	Eutrophic Condition	Good	Medium	—	Medium
3	Human Health Risks	—	7	Human Health Risks	Good/Fair	High	▼	Low
1	Multiple Stressors (including climate)	?	8	Climate Drivers	Fair	High	▼	Low
			9	Other Stressors	Good/Fair	Medium	?	Medium
5	Habitat abundance/distribution	?	10	Integrity of major habitats	Fair	Medium	▲▼	Medium

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6	Condition of biologically structured habitat	?						
7	Contaminants	?	11	Contaminants	Undetermined	Medium	?	Medium
12	Status of key species	▲	12	Keystone & foundation species	Good/Fair	High	?	High
13	Condition/health of key species	—	13	Other focal species	Fair	High	▲▼	High
11	Non-indigenous species	?	14	Non-indigenous species	Good	Medium	?	Low
9	Biodiversity	▲	15	Biodiversity	Good/Fair	High	—	High
15	Maritime archaeological resource integrity	?	16	Maritime heritage resource integrity	?		▼	