Office of National Marine Sanctuarie
National Oceanic and Atmospheric Administration

Olympic Coast national marine sanctuary

Olympic Coast

Condition Report

2008–2019

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Cover photo: Cape Flattery is the northwesternmost point in the continental United States and is known for its iconic, rugged coastline and deep, narrow coves. Photo: Jenny Waddell/NOAA

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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 areas 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.

Olympic Coast National Marine Sanctuary

Olympic Coast National Marine Sanctuary (OCNMS) includes 3,188 square miles of marine waters off the rugged Olympic Peninsula in northwest Washington state. The sanctuary covers much of the continental shelf and several major submarine canyons. By virtue of its enacting legislation, and ongoing refinement of case-specific conservation measures, the sanctuary protects a productive upwelling zone that is a seasonal host or home to marine mammals and seabirds. Along its shores are thriving kelp and intertidal communities, teeming with fishes and other sea life. In the darkness of the seafloor, scattered communities of deep-sea coral and sponges form habitats for fish and other important marine wildlife.

In addition to important ecological resources, the sanctuary has a rich cultural and historical legacy. The vibrant contemporary communities of the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation have forged inseparable ties to the ocean environment, maintaining traditions of the past while navigating the challenges of the present and future. Also, over 200 shipwrecks have been reported within OCNMS and are evidence of the extensive use of the area for fishing, transport of goods to support inland Washington, and transport of logging products from local markets.

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, drivers 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, and 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 are generally based on observed changes in status since the prior condition report, unless otherwise specified.

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 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, during the preparation of each condition report. Additional details about how the condition report process has evolved over time are below.

DPSER Framework

In 2019, ONMS began restructuring sanctuary condition reports based on a model that describes the interactions between driving societal forces (Drivers), 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), which prompts targeted management responses intended to prevent, reduce, or mitigate undesirable changes (see Figure FCR.1).

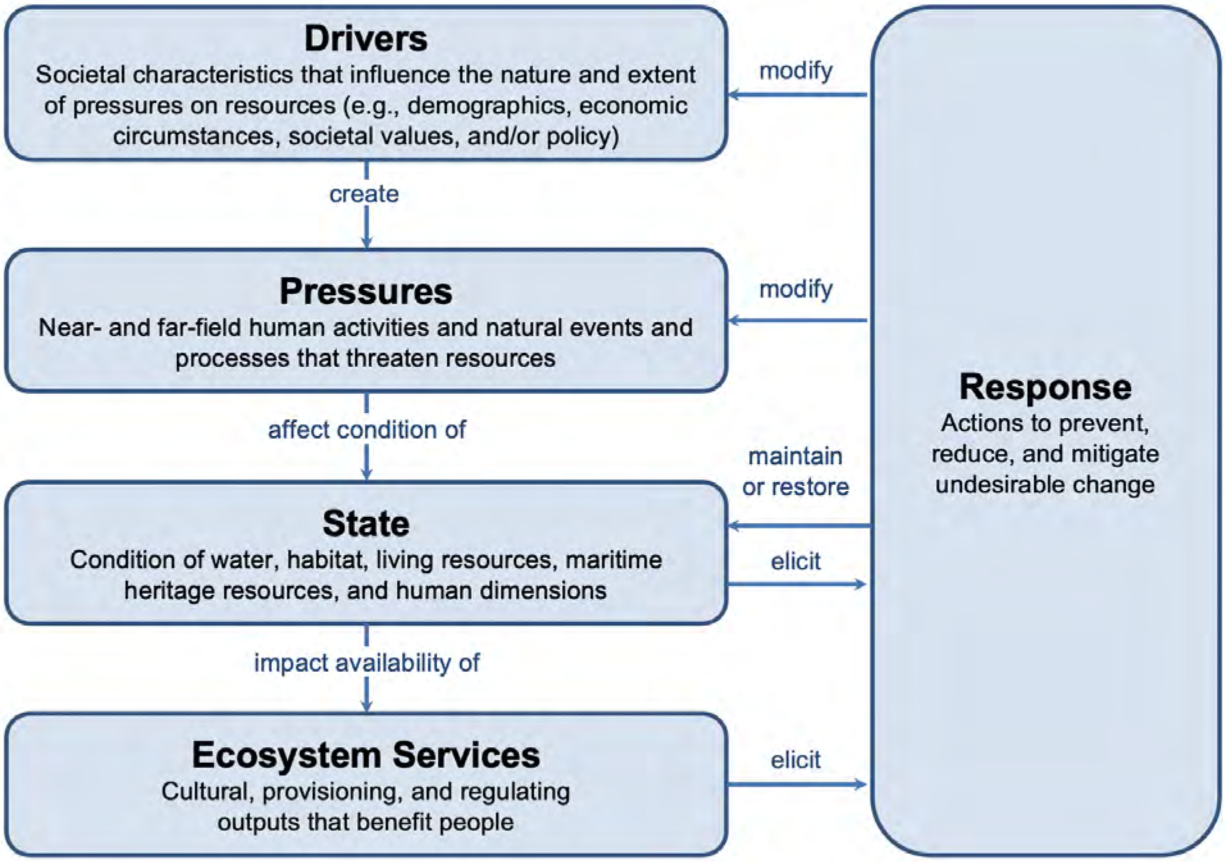


Figure FCR.1. This diagram of the DPSER framework illustrates the functional connections between compartments and the targets of management responses designed to modify drivers, pressures, and resource conditions. Image: NOAA

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 OCNMS was released in 2008 (Office of National Marine Sanctuaries [ONMS], 2008); 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 2008–2019, 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 OCNMS management plan. The management plan helps guide future work and resource allocation decisions at OCNMS 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 2022, building on the 2011 management plan, which contains a number of actions to address issues and concerns (OCNMS, 2011). 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 2008–2019, 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).

Executive Summary

The remote and rugged Olympic Coast of Washington state is a place of stunning beauty, where Indigenous peoples have long recognized the reciprocal relationship between humans and the environment during thousands of years of continuous residence. Olympic Coast National Marine Sanctuary (OCNMS) was established in 1994 and includes 3,188 square miles of marine waters off the rugged Olympic Peninsula in northwest Washington state. The sanctuary covers much of the continental shelf and several major submarine canyons, with upwelling that supports locally abundant marine life and supports seasonal populations of marine mammals and seabirds. Along its shores are thriving kelp and intertidal communities, teeming with fishes and other sea life. In the darkness of the seafloor, scattered communities of deep-sea coral and sponges form habitats for fish and other marine wildlife.

OCNMS was established in 1994 and includes 3,188 square miles of marine waters off the Olympic Peninsula in northwest Washington state. Image: NOAA

In addition to important ecological resources, the Olympic Coast has a rich cultural and historical legacy. The sanctuary is located within the boundaries of the legally defined usual and accustomed (U&A) fishing areas of four coastal tribes with reserved treaty rights. U&A fishing areas were acknowledged by the United States via treaties with the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation in 1855 and 1856, long before OCNMS was designated. The vibrant contemporary communities of these tribes, known as the Coastal Treaty Tribes, have forged inseparable ties to the ocean environment, maintaining traditions of the past while navigating the challenges of the present and future.

There are over 200 shipwrecks reported within OCNMS, which provide evidence of the extensive use of the area for fishing, transport of goods to support inland Washington, and transport of logging products from local markets.

The purpose of this condition report is to use the best available information to assess the status and trends of various components of the sanctuary's ecosystem, as well as the maritime heritage resources within the sanctuary. The report is structured around a management-logic model called the DPSER model, which stands for Drivers-Pressure-State-Ecosystem Services-Response. This model enables the sanctuary to comprehensively document the many factors that affect management responses, including the influence of societal drivers on the levels of pressures on resources, the effects of those stressors on the condition of resources, and the effects of changing conditions on the services they provide to society.

The first condition report for OCNMS was released in 2008. This is the second comprehensive update of the status and trends of sanctuary resources, covering the broad categories of water quality, habitat, living resources, and maritime heritage resources. This report also includes the status and trends of ecosystem services—the ways humans derive benefits from different ecosystem attributes that they care about for their lives and livelihoods. Ecosystem services evaluated in this report include consumptive and non-consumptive recreation, science, education, heritage, sense of place, commercial and subsistence harvest, and ornamentals.

The report documents the condition of sanctuary resources and ecosystem services between 2008 and 2019, unless otherwise noted. Throughout the report's development, sanctuary staff worked with numerous partners to identify and compile information, including traditional knowledge. To that end, we attempted to improve on the first condition report and better integrate Indigenous voices and perspectives, and in doing so, represent both traditional and modern-day aspects of the reciprocal relationship between humans and the ocean, as well as the existence of continued and contemporary rights, management responsibilities, and tribal jurisdictions and authorities.

The report also identifies gaps in current monitoring efforts, as well as factors that may require monitoring and potential remediation through management actions in the coming years. The ratings and conclusions in this report generally represent the shared perspective of sanctuary managers and subject matter experts on prior changes in resource status, and will inform future management, primarily through the management plan review process, to address significant challenges stemming from pressures like increasing coastal visitation and ocean commerce. Some of the greatest yet least manageable challenges may relate to climate change, which most agree is increasing the frequency and intensity of marine heatwaves, harmful algal blooms, hypoxic events, and ocean acidification. This may be particularly troublesome for Indigenous communities, who rely heavily on a healthy ocean to exercise place-based rights as co-managers of resources in OCNMS.

Quinault canoe *Os-chuck-a-bick* navigating off the Olympic Coast during the 2009 Paddle to Suquamish Tribal Canoe Journey. Photo: NOAA

Drivers and Pressures

Human Activities and Stressors

The pressures on OCNMS resources associated with human activities are diverse, operate at varying scales, and differ significantly in their impact. Operating throughout the sanctuary and potentially causing the greatest impacts are accelerating changes in ocean conditions, marine debris, non-indigenous species invasions, and noise. At intermediate scales, or more prominent in specific areas, are maritime transportation, whale entanglement, military activities, and contaminants. At even more limited scales are offshore aquaculture, submarine cables, increased visitation, and research activities. An emerging issue that may need to be addressed is offshore energy installations. Fishing also occurs throughout the sanctuary by tribal and non-tribal fishers. While fishing may be viewed as one pressure within the sanctuary, fishing is a treaty right of the Coastal Treaty Tribes as well as an ecosystem service, contributing to the wellbeing, livelihoods, and food security of tribal and non-tribal coastal communities.

Sunset at Second Beach. Photo: Matt McIntosh/NOAA

The societal drivers behind these pressures are not something OCNMS can manage, as they are primarily influenced by global, regional, and local demand for goods and services. Still, it is helpful to understand the connections between drivers and pressures in order to prioritize management actions. Drivers include economic factors, such as income and spending; 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 drivers influence pressures on resources by changing human preferences and, consequently, the levels of activities needed to meet the demand for resources and services.

Visitors on the beach. Photo: Matt McIntosh/NOAA

Several human activities in or around OCNMS have the potential to adversely affect water quality and other sanctuary resources, but currently, they occur only on very localized, short-term scales. These include oil spills, discharges of vessel sewage, and releases from at-sea seafood processing ships. Among the greatest risks are large spills from accidents among the many vessels that traverse the sanctuary. The human activities judged to be the most directly impactful to sanctuary habitats were bottom trawling and various forms of debris on the seafloor, including abandoned or lost fishing gear, sunken vessels, and ocean dumping. However, most are localized, and trawling activity has decreased over the reporting period. Recent spikes in the number of whale entanglements may be related to heatwave-induced habitat compression, which forces whales and their prey closer to shore, where most fishing utilizing traps, like Dungeness crab fishing, occurs. Otherwise, impacts to living resources from human activities have either declined during the assessment period (e.g., a reduction in the number of overfished species) or remained at lower levels than earlier periods (trawling and, presumably, gear impacts). These improvements reflect changes in fisheries management that have reduced the number of overfished species, a significant achievement. The effects of trawls on shipwrecks began decades before OCNMS was designated, and has probably declined, particularly over the last decade, as trawling has decreased within OCNMS. Significantly, however, once damaged by human activities, the archaeological value of such resources cannot be restored.

Deep-sea coral (*Paragorgia* spp.) photographed during a September 2020 research cruise on the exploration vessel *Nautilus*. Photo: Ocean Exploration Trust/NOAA

Wreck of the Russian steamship *Lamut* in 1944. Image: Robert Schwemmer Maritime Library

State of Resources

Water Quality

OCNMS is located within the northern California Current Ecosystem, a highly productive coastal ecosystem fueled by seasonal upwelling of cold, nutrient-rich water that supports the marine food web. During the assessment period for this condition report (2008–2019), the coastal ocean within OCNMS experienced profound changes associated with global climate change, particularly with respect to unusual ocean conditions that included marine heatwaves, worsening ocean acidification, seasonal low oxygen events, and toxic harmful algal blooms. Independently, each of these changes can cause detrimental impacts to the marine ecosystem, and when operating together, they may produce additive or synergistic impacts.

Particularly noteworthy, the California Current Ecosystem experienced exceptional climate variability that affected OCNMS over the last ten years, including an unprecedented North Pacific marine heatwave between 2014 and 2016, coupled with a robust El Niño event in 2015–2016 that was followed by a flux of cool, coastal waters and intense storms in the winter of 2016–2017. By the end of 2018, minimal flux of cold, nutrient-rich subarctic water from the North Pacific Gyre caused below-average productivity in OCNMS and the California Current Ecosystem in general. In the summer and fall of 2019, another major marine heatwave affected approximately 8.5 million km^2 of the Northeast Pacific over a period of 239 days, but dissipated by late January 2020.

Hypoxic, or low-oxygen, conditions can result in fish kills where dead animals, like this wolf eel, wash up onto Quinault Indian Nation beaches. Photo: Joe Schumacker/Quinault Indian Nation

Habitat

Six major habitat types are present in OCNMS: rocky shores, kelp forest, sandy beach, sandy seafloor, deep seafloor, and pelagic. The sanctuary's remote location and shorelines, buffered by the Olympic National Park and tribal reservations, offer protection from coastal development and other direct anthropogenic disturbances to habitats. Therefore, overall, the sanctuary's habitats are relatively undisturbed and in good condition, with stable or improving trends. However, the dominant habitat, the pelagic zone, is an exception, as it is experiencing worsening trends due to climate impacts like marine heatwaves, ocean acidification, and seasonal hypoxic events. Also of importance, although kelp habitats within OCNMS remain stable, there is uncertainty about their future given that kelp forests are sensitive to changing ocean conditions, such as increasing ocean temperatures, declines in sea stars, and increasing sea urchin abundance.

Intertidal algae flourish near Kydikabbit Point on the Makah Reservation. Photo: Jenny Waddell/NOAA

Living Resources

OCNMS is a productive marine ecosystem with stable or increasing populations of keystone (giant and bull kelp, purple sea urchins, northern sea otters) and foundation species (phytoplankton, copepods, northern anchovy, and Pacific hake). However, declines and increases in populations of some of these species are likely to have changed community structure and ecosystem function. One of the most notable population declines has been in the abundance of sea stars, specifically purple and sunflower sea stars, which declined due to sea star wasting diseases spanning the years 2013–2020.

With the exception of Southern Resident killer whales, the populations of all marine mammal species that use OCNMS have remained stable or increased since 2008. The recovery of Southern Resident killer whales is a concern because they face several threats, including environmental contaminants, low prey abundance, sound pollution, and vessel disturbance; the species is in danger of extinction.

Some groundfish stocks were overfished pre-2008; however, successful collaboration between Coastal Treaty Tribes, West Coast states, the Pacific Fishery Management Council, NOAA Fisheries, and fishers resulted in the successful rebuilding of stocks of canary rockfish, bocaccio, darkblotched rockfish, and Pacific Ocean perch. Unfortunately, some runs of Pacific salmon and steelhead face a range of threats. These fish are critically important species for subsistence, recreational, and cultural purposes in Washington. Some salmon and steelhead stocks in the Pacific Northwest have declining numbers or are listed under the Endangered Species Act, while other salmon runs are stable or increasing. In 2015 and 2016, fishery disasters were declared for ocean salmon that resulted in millions of dollars in lost income for local communities.

Rockfish in OCNMS. Photo: Kate Thompson/NOAA

In 2017, the invasive European green crab gained a foothold on the Olympic Coast and has since spread rapidly. Furthermore, a major tsunami in Japan in 2011 washed tons of marine debris onto Olympic Coast beaches, along with hundreds of non-indigenous marine species.

Invasive European green crab trapped on the Makah Reservation. Photo: Washington Sea Grant

Impacts from these ecosystem fluctuations have created unprecedented challenges for coastal communities. Both economic security and cultural practices are threatened by closures of recreational, commercial, and tribal shellfish harvests due to unsafe neurotoxins, fisheries disasters (including some within the valuable Dungeness crab fishery), and declining stocks of commercially and culturally important runs of salmon and steelhead.

Maritime Heritage Resources

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. Cultural resources can also include natural resources. The majority of existing information about maritime heritage resources at OCNMS describes shipwreck resources, and even then, there are only partial data on these resources. There are 197 reported vessel losses in the sanctuary; nine have been located, and seven have been assessed.

There is a desire to assess additional classes of resources that are highly valued by Indigenous communities, including paleo-landscapes, ancient canoe runs, and traditional canoe routes, some possibly unchanged since contact with Euro-American explorers and traders. These routes are still used by Olympic Coast tribes as part of annual Tribal Canoe Journeys.

The Quinault Indian Nation hosted the Tribal Canoe Journey in 2013. Photo: Larry Workman

State of Ecosystem Services

Ecosystem services include the tangible and intangible benefits people derive from a place. Nine types are discussed in this report:

- Consumptive Recreation: Activities that result in removal or harm to natural or cultural resources include fishing and razor clam harvesting, neither of which OCNMS manages. Fishing has remained stable or increased for most species, with some significant achievements by federal, state, and tribal co-managers in rebuilding some rockfish populations. However, some important or iconic salmon stocks remain depressed, with harvest at a fraction of what it was in the 1970s–1980s.
- Non-Consumptive Recreation: The stable or increasing popularity of shore-based activities, like wildlife viewing, sightseeing, and water-based sports, has some concerned about their sustainability. This is due to uncertainty about the effects of increasing use on resources and the quality of recreational experiences at some locations.
- Science: Though decades of significant research has occurred in OCNMS, persistent information gaps point to the need for enhanced capacity and infrastructure. But new and growing regional partnerships are expanding the breadth of science in the sanctuary, particularly regarding ocean acidification, deep-sea exploration, kelp forest surveys, and ocean sound. Furthermore, increasing use of traditional knowledge of the four Coastal Treaty Tribes significantly enhances the collective understanding of the Olympic Coast.

Surfers at Second Beach walking at sunset. Photo: Matt McIntosh/NOAA

Field work being conducted off R/V *Tatoosh* during wildfire season. Photo: Kathy Hough/NOAA

Family inspecting intertidal species. Photo: Matt McIntosh/NOAA

- Education: Services that provide intellectual enrichment are considered acceptable and improving, based largely on the many successful and broad-ranging education and outreach programs offered by OCNMS.
- Heritage: There continues to be a strong recognition of the benefits of Olympic Coast resources to the region's historic and heritage value, and cultural practices of coastal communities, particularly the Coastal Treaty Tribes.
- Sense of Place: The Olympic Coast has been inhabited by the four Coastal Treaty Tribes for thousands of years and non-Indigenous people for about two hundred years. Subsequent arrivals by a diversity of inhabitants and visitors defies a collective description of sense of place. Nevertheless, the many special designations within the region reflect the Olympic Coast's reputation for unfathomable natural beauty and power, with unmatched biodiversity and heritage, the latter owing to vibrant tribal communities; many have shared aspects of their cultural heritage through public visitor centers and ceremonies.
- Commercial Harvest: High productivity of the region is the key factor supporting commercial fisheries and the communities and economies that depend on them. Most targeted fish stocks were stable or increasing, although some were in decline. Other stocks exhibited unprecedented high variability, attributable to changing ocean conditions. This variability is showcased by both high catches and fishery disasters, which could force some to leave the fishery. The effects on tribal communities could be particularly devastating, given their dependence on these resources for food and cultural practices, as well as income.

Cape Flattery is the northwesternmost point in the continental United States and is known for its iconic, rugged coastline and deep, narrow coves. Photo: Jenny Waddell/NOAA

Quinault Pride Seafood employees process salmon in Taholah, Washington on Quinault Indian Nation lands. This tribal business ships seafood products in response to orders placed on their website. Photo: Matt McIntosh/NOAA

- Subsistence Harvest: The non-commercial harvesting of food and utilitarian products has always been a common practice of the Coastal Treaty Tribes. Some stocks, such as blueback sockeye salmon from the Quinault River, have been limited or unavailable in recent years, and others may have declined (hard shell clams and octopus). Recent fishery disaster declarations impact food security and highlight the vulnerability of species and communities in this region to changing conditions. Fortunately, trends for some important species, including Pacific halibut and gray whales, have increased in OCNMS, and others, like razor clams, have remained stable.
- Ornamentals: These resources continue to be collected from OCNMS for decorative, aesthetic, and ceremonial purposes, but shifts in distribution and abundance have occurred for some species in recent years, and the status of some is unknown.

A tribal member from the Quinault Indian Nation harvests large, healthy razor clams from a reservation beach closed to the public. Photo: David Ruck/NOAA

Fish on a stick, salmon being cooked during the Makah Days celebration. Photo: Karlyn Langjahr

Response

This report describes a variety of issues and human activities occurring within and beyond OCNMS that warrant attention, tracking, study, and, in some cases, specific management actions. Addressing any of these issues requires participation by and coordination with a variety of agencies and organizations. OCNMS is fortunate to be able to work with many entities that contribute to managing human activities and addressing marine conservation issues. Central to that collaborative approach are the Olympic Coast Intergovernmental Policy Council (IPC) and the OCNMS Advisory Council.

The IPC was formed in 2007 to provide an effective and efficient forum for communication, exchange of information, and policy recommendations regarding the management of marine resources and activities within the boundaries of OCNMS. The IPC is a forum where sovereigns with regulatory jurisdiction over marine resources and activities within the boundaries of OCNMS meet to enhance their communication, policy coordination, and resource management strategies. Membership includes the Hoh Tribe, Makah Tribe, Quileute Tribe, Quinault Indian Nation, and the state of Washington.

The OCNMS Advisory Council was established immediately after the sanctuary's 1994 designation, under the authority of the National Marine Sanctuaries Act. 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. The advisory council includes governmental (tribal, state, local, and federal agencies) and non-governmental (education, conservation, research, fishing, tourism, industry, marine resources committee, citizen at large) seats.

In addition to these groups, OCNMS also consults on a government-to-government basis with the Coastal Treaty Tribes individually.

Following the completion of the 2008 OCNMS condition report, a new management plan and changes to OCNMS regulations were drafted. These management actions included the drafting of 20 action plans and new regulations prohibiting cruise ship discharge. Other significant responses include investigations into changing ocean conditions, such as a report, *Climate Change and the Olympic Coast National Marine Sanctuary: Interpreting Potential Futures* (Miller et al., 2013), and the designation of OCNMS as a sentinel site for ocean acidification.

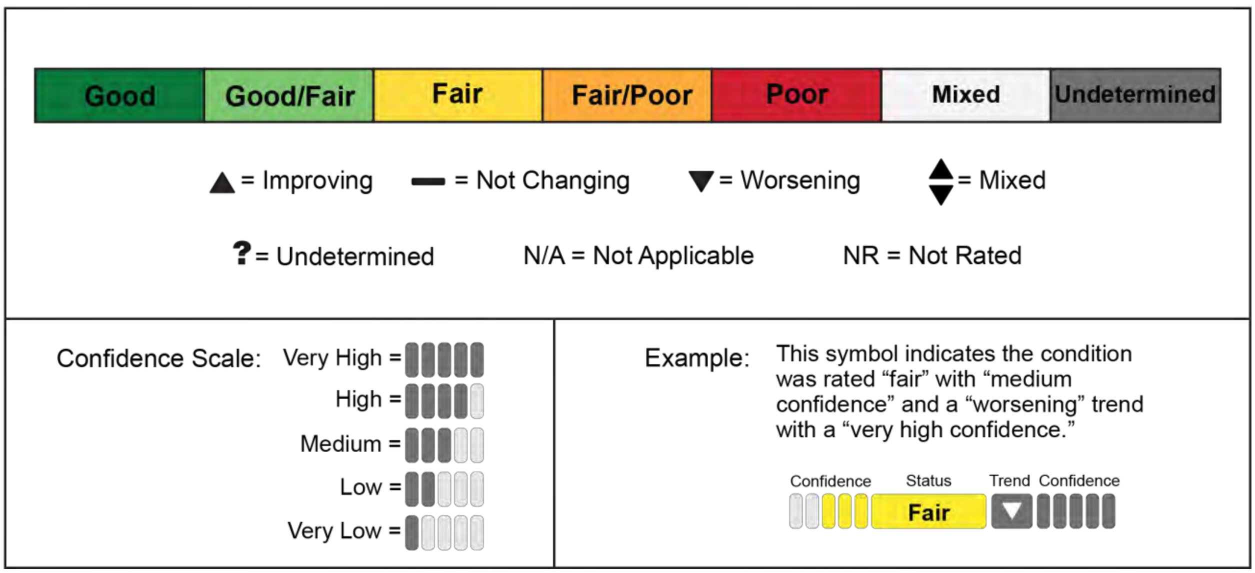
Conclusion

This condition report provides the public with an overview of the condition and trends of resources and ecosystem services in OCNMS. It is intended to inform individuals who may be interested in providing recommendations to OCNMS during the revision of its management plan. The information in the report will also be used to inform various management efforts, including a climate vulnerability assessment for the sanctuary, immediately followed by the development of the new management plan. That plan will guide future work and resource allocation decisions at OCNMS by describing strategies and activities designed to address priority issues, fill information gaps identified here, and advance core sanctuary programs. The update to the sanctuary management plan will begin in 2022, building on the 2011 management plan, and will involve significant tribal and agency consultation, public input, and environmental compliance work, and, depending on the complexity of actions proposed, may take one to three years to complete.

Olympic Coast National Marine Sanctuary
Summary of Resource Conditions

The various resource status and trend evaluations presented in this report are summarized below. Each question used to rate the condition and trends sanctuary resources is listed, followed by:

1) A set of rating symbols that display key information. The first symbol includes a color and term to indicate status. The next symbol indicates trend. A shaded scale adjacent to both symbols indicates confidence (see key for example and definitions).
2) The status description, which is a statement that best characterizes resource status and corresponds to the assigned color rating and definition as described in Appendix A. The status description statements are customized for all possible ratings for each question.
3) The rationale is a short statement or list of criteria used to justify the rating.



Drivers/Pressures

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

Not rated

Rationale: ONMS and OCNMS staff decided not to rate the status and trend of influential human drivers at OCNMS. 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. For the most part, drivers are not manageable, at least not under the authority of the National Marine Sanctuaries Act, 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.

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

Status Description: Some potentially harmful activities exist, but they have not been shown to degrade water quality to a degree that raises substantial concern.

Rationale: Several human activities have the potential to adversely influence water quality, but generally do not seem to be doing so within OCNMS waters, except on very localized, short-term scales. Activities of concern include oil spills from vessels, vessel discharges from sewage and exhaust gas cleaning systems, and at-sea seafood processing.

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

Status Description: Selected activities have caused measurable resource impacts, but effects are localized and episodic, rather than widespread or persistent.

Rationale: There have been shifts in the location of trawl impacts and improved management of bottom-contact gear. Activities of potential concern to benthic habitats include use of bottom-contact fishing gear; abandoned, lost, or derelict crab pots; lost vessels; and ocean dumping.

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

Status Description: Some potentially harmful activities exist, but they have not been shown to degrade living resource quality to a degree that raises significant concern.

Rationale: Despite recent spikes in the number of whale entanglements, impacts from human activities overall either declined during the assessment period (e.g., a reduction in the number of overfished species) or remained at lower levels than earlier periods (trawling, and, presumably, gear impacts).

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

Status Description: Selected activities have caused measurable impacts to maritime heritage resources, but effects are localized and episodic rather than widespread or persistent.

Rationale: Cumulative damage to shipwrecks from bottom-trawl fishing gear began when trawl gear was first introduced, decades before OCNMS was designated. The level of trawl activity has been relatively steady since 2008, but is reduced compared to historic levels. Additional, but limited, bottom disturbance exists from ocean dumping, lost vessels, and research activities.

Water Quality

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

Status Description: Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.

Rationale: High primary productivity naturally occurs seasonally in OCNMS due to upwelling during the spring and summer. Human contributions to eutrophication (primarily via seasonal inputs of nutrients from the Salish Sea and Columbia River) appeared to be negligible compared to natural cycles controlled by upwelling.

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

Status Description: Water quality problems have caused measurable human impacts, but effects are localized and episodic rather than widespread or persistent.

Rationale: Harmful algal blooms occur naturally in OCNMS, and biotoxins are periodically detected in shellfish, sometimes resulting in trophic transfer of biotoxins to predators like marine mammals and seabirds. However, impacts on human health have been minimized due to effective seasonal monitoring and measures, like beach closures.

Question 8: Have recent, accelerated changes in climate altered water conditions, and how are they changing?

Status Description: Climate-related changes have caused severe degradation in some but not all attributes of ecological integrity.

Rationale: Since 2008, concerning climate-related changes have been documented for several critical ocean indicators, including dissolved oxygen, aragonite saturation, pH, and marine heatwaves, all of which produce detrimental effects on ecosystems.

Question 9: Are other stressors, individually or in combination, affecting water quality, and how are they changing?

Status Description: Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.

Rationale: Persistent organic pollutants were present in some forage fish and gray whales, but below effects levels. Microplastics are likely present, based on data from Oregon. The worsening trend determination was based on global trends in these stressors.

Habitat Resources

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

Status Description: Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.

Rationale: Since 2008, the ecological integrity of major habitat types has been mixed. There was little evidence of major degradation in kelp forests and rocky coasts, but the dominant habitat, the pelagic zone, has been degraded by marine heatwaves, ocean acidification, and hypoxic events, and measurable declines in these indicators drove the ratings for this question. Data on the integrity of other habitat types in the sanctuary are lacking.

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

Status Description: Contaminants have not been documented, or do not appear to have the potential to negatively affect ecological integrity.

Rationale: Contaminant concentrations are considered to be generally low in the sanctuary, and there is no evidence to suggest contaminant concentrations are increasing; however, most data and published information preceded the assessment period.

Living Resources

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

Status Description: The status of keystone or foundation species suggests measurable, but not severe, degradation in some attributes of ecological integrity.

Rationale: Since 2008, populations of some keystone (e.g., purple and sunflower sea stars) and foundation species (e.g., California mussels) have declined while populations of other keystone (e.g., kelp, sea otters) and foundation species (e.g., anchovies, pacific hake) are stable or increasing.

Question 13: What is the status of other focal species and how is it changing?

Status Description: Selected focal species are at reduced levels, but recovery is possible.

Rationale: Since 2008, some populations of focal species (e.g., razor clams, groundfish) have remained stable or have increased while others (e.g., Dungeness crab, chinook salmon, steelhead) and state and/or federal species of concern (e.g., eulachon, Southern Resident killer whale, humpback whale, fin whale, marbled murrelet, tufted puffin) have declined or have remained critically endangered.

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

Status Description: Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.

Rationale: Non-indigenous species (e.g., *Sargassum muticum* and *Caulacanthus okamurae*) have existed at low abundances in OCNMS for decades; however, a greater number of non-indigenous species have been identified as a concern in or adjacent to OCNMS boundaries in the last 10 years. These include the European green crab, 289 non-indigenous species introduced to the U.S. West Coast by the 2011 tsunami, and farmed Atlantic salmon that escape from net pens in Puget Sound.

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

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: Some keystone and foundation species experienced significant declines after 2013, which may have altered biodiversity and community structure and function. A worsening trend was determined based on changes to keystone and foundation species and declining diversity metrics over the last several years for groundfish; however, variable results for some other groups suggest that more comprehensive biodiversity assessments are needed.

Maritime Heritage Resources

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

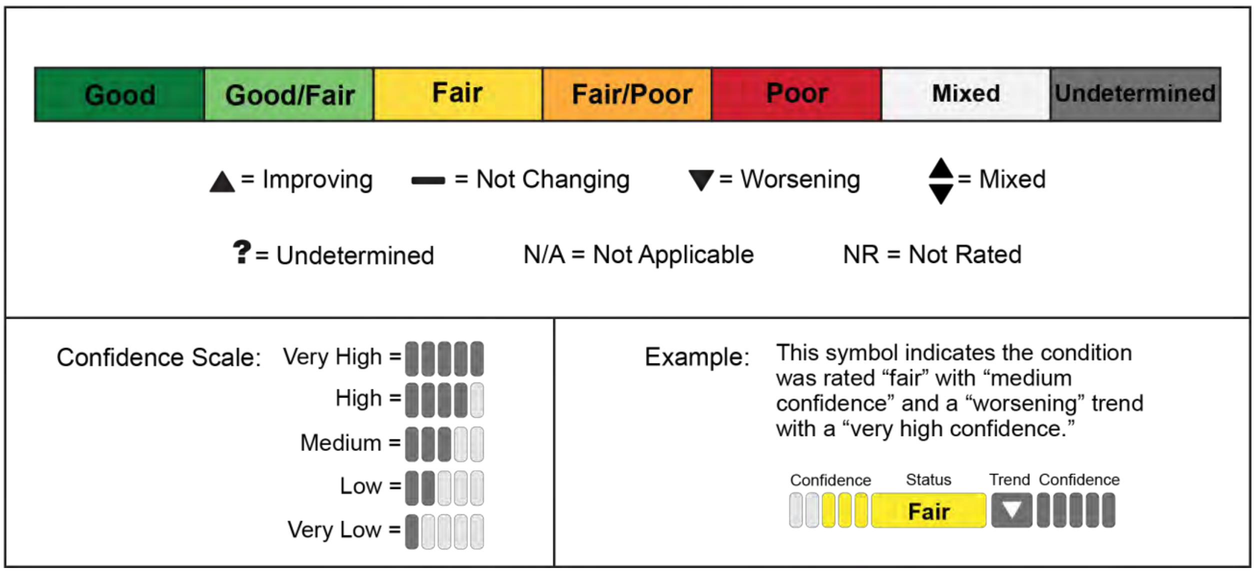
Status Description: Selected maritime heritage resources exhibit indications of natural or human disturbance, but there appears to have been little or no reduction in aesthetic, cultural, historical, archaeological, scientific, or educational value.

Rationale: Shipwrecks in the nearshore, and to a lesser extent shipwrecks in deeper water, are degrading, primarily due to natural processes. Traditional canoe routes are actively being used during the annual Tribal Canoe Journeys.

Olympic Coast National Marine Sanctuary
Summary of Ecosystem Services

The various resource ecosystem service evaluations presented in this report are summarized below. Each ecosystem service is listed, followed by:

1) A set of rating symbols that display key information. The first symbol includes a color and term to indicate status, the next symbol indicates trend, and a shaded scale adjacent to both symbols indicates confidence (see key for example and definitions).
2) The status description, which is a statement that best characterizes status and corresponds to the assigned color rating and definition as described in Appendix B.
3) The rationale, a short statement, or list of criteria used to justify the rating.



Cultural (Non-Material Benefits)

Consumptive Recreation

Status Description: Ability to provide ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Consumptive recreation includes recreational activities that result in the removal of or damage to natural and cultural resources. In OCNMS, this activity is primarily recreational fishing and razor clam harvesting, activities that the sanctuary does not manage. The number of charter boat angler trips had no clear upward or downward trend from 1998–2019, the number of private boat angler trips has increased during the same time period, and the number of razor clam licenses increased from 2011 to 2019. Though the quantity of some fished species kept by charter boats has increased or remained stable, some important or iconic salmon stocks have remained depressed and have yet to recover to provide the desired level of recreational fishing opportunities in the sanctuary.

Non-Consumptive Recreation

Status Description: Ability to provide ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Various measures of visitation have remained stable or increased from 2008 to 2018. Visitors and residents to the OCNMS area report engaging in a variety of non-consumptive recreational activities, including shore-based activities, wildlife viewing, sightseeing, and water-based sports. However, the popularity of recreational activities in OCNMS has led to substantial concerns regarding the region's ability to support increased visitor use, which was a key factor in determining the fair rating. The undetermined trend was driven by uncertainty regarding the effects of increased use on the condition of sanctuary resources and the quality of non-consumptive recreation at some sanctuary locations.

Science

Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: The fair rating was driven by the fact that several critical science needs are not being met due to insufficient resource allocation. Limitations exist with regard to OCNMS capacity, staffing, resources, and infrastructure, including limited staff capacity in several areas; aging research vessels (R/V *Tatoosh*); and limited internet, lab space, and academic institutions on the coast to conduct all of the science activities required. However, research partnerships, collaboration, and coordination are improving, which is increasing the breadth of science conducted within OCNMS. New research programs have been initiated; these include the establishment of an ocean acidification sentinel site, kelp forest surveys, deep sea exploration, and ocean sound monitoring. Established activities, including oceanographic moorings, habitat mapping and seafloor characterization, and intertidal surveys, have continued throughout the study period. Furthermore, the extensive traditional ecological knowledge of the four Coastal Treaty Tribes significantly enhances our shared understanding of the Olympic Coast.

Education

Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.

Rationale: Key indicators used to determine the status and trend of the education ecosystem service were willingness to pay for educational programs, funding for educational programs, the number of people receiving formal and informal education, the quality of the educational experience, the number of volunteers working with OCNMS, and the number and types of educational programs offered. Studies focusing on similar California-based Ocean Guardian School programs show that parents have a willingness to pay for hands-on ocean conservation and stewardship programs. The number of Twitter and Facebook followers (those who like the social media page) of OCNMS has increased over the past few years. Driven by sanctuary, tribal, and partner education programs, educational activities focused on OCNMS and related ocean science and stewardship have increased in quality over time and contributed to the public's awareness of OCNMS, enhancing ocean literacy.

Heritage

Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.

Rationale: The existence, and in some cases resurgence, of traditional cultural practices reflecting heritage contributed to the good/fair rating for this ecosystem service. These practices include exercising treaty rights, revitalizing tribal languages, subsistence harvest, potlatches, canoe journeys, the publication of several books about tribal histories and culture, and interpretive programs that help to restore and preserve heritage. However, some key heritage practices are compromised due to declines, closures, or shifts in resources (e.g., harvest of blueback salmon and other cultural keystone species). Cultural practices such as harvesting and sharing of knowledge (e.g., how and when to harvest) through the practice of harvesting are not as robust as they have been, indicating that improvements could be made.

Sense of Place

Not rated: This ecosystem service was not assigned a status or trend rating (or accompanying confidence scores). The workshop participants determined that a context-specific narrative was more appropriate to discuss sense of place, particularly due to its many unquantifiable aspects.

Rationale: The Olympic Coast is a unique place that four Coastal Treaty Tribes, who have reserved treaty rights to the resources and area, have inhabited since time immemorial. Additionally, there are non-Indigenous inhabitants with a rich history since their ancestors' arrival hundreds of years ago. Further, there are newer members of the community and many visitors to the area from around the world. Given the diversity of inhabitants and timeframes, rating sense of place for the sanctuary is not only difficult, but unsuitable for collectively describing these perspectives. There was high agreement among workshop participants that a context-specific narrative was better suited to examine the breadth of this service.

Provisioning (Material Benefits)

Commercial Harvest

Not rated

Rationale: Workshop participants opted to not rate this service due to complexity and dynamics among the human and natural factors affecting commercial fisheries, and because OCNMS does not manage fisheries. Throughout the study period (2008–2019), variability has been showcased by both high catches and fishery disasters. Although management seeks to reduce variability within this ecosystem service, changing ocean conditions and weather are key contributors to the variability of annual harvests.

Subsistence Harvest

Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Over the study period, razor clam subsistence harvest has remained relatively stable, while other species, such as the prized blueback sockeye salmon from the Quinault River, have been limited or entirely unavailable in recent years. Further, several participants across tribal communities have expressed concern about having enough species through the year to meet their needs and desires. Additionally, hard shell clams and octopus, which were gathered traditionally by the Coastal Treaty Tribes, are reported to be less available.

Ornamentals

Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.

Rationale: A wide variety of marine resources have been, and continue to be, collected from OCNMS for decorative, aesthetic, and ceremonial purposes. However, shifts in distribution and abundance have occurred for some ornamental species from 2008 to 2018. Data gaps are present regarding the status and trends of a number of ornamental species.

Sanctuary Setting

Overview

OCNMS is one of 15 national marine sanctuaries and two marine national monuments comprising a national system of ocean and Great Lakes areas selected for their ecological, recreational, historical, cultural, and aesthetic values. Designated in 1994, the sanctuary's mission is to protect the Olympic Coast's natural and cultural resources through responsible stewardship, to conduct and apply research to preserve the area's ecological integrity and maritime heritage, and to promote understanding through public outreach and education.

OCNMS is one of North America's most productive marine regions, supporting some of the highest biodiversity on the West Coast. Located adjacent to relatively pristine temperate rainforests in northwest Washington state, the lands and waters of the western Olympic Peninsula have sustained and hosted some of the earliest human populations in North America, whose descendants remain on the coast today. OCNMS spans 3,188 square miles of marine waters off the rugged Olympic Peninsula and extends seaward approximately 25 to 45 miles (Figure SS.1). The sanctuary borders an undeveloped coastline, including Olympic National Park's coastal strip, as well as the Washington Maritime National Wildlife Refuge (NWR) Complex. Furthermore, the sanctuary is located within the boundaries of the adjudicated usual and accustomed (U&A) fishing areas of four Native American tribes with treaty rights to ocean resources (Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation). While OCNMS was established in 1994, tribal U&A fishing areas were acknowledged by the United States through treaties with the coastal tribes in 1855 and 1856. The sanctuary also overlaps with Washington state waters that extend 3 nautical miles offshore. Superimposed on a nutrient-rich upwelling zone with high primary productivity and composed of a multitude of marine habitats, the sanctuary is home to numerous marine mammals and seabirds, diverse populations of kelp and other macroalgae, and speciose fish and invertebrate communities. Here we provide a history of this region as well as the important physical, geological, biological, and archeological features that make the sanctuary unique.

Figure SS.1. Map of Olympic Coast National Marine Sanctuary in relation to adjacent coastal counties and communities, tribal reservations for the four Coastal Treaty Tribes (Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation), and boundaries of Olympic National Park and three National Wildlife Refuges. Coastal ports along this wilderness coastline are limited to Neah Bay and La Push, which are both on tribal reservations, and Westport. Locations on the map are mentioned throughout this report. Image: Tony Reyer/NOAA

Original Peoples

The Olympic Coast has sustained human communities for at least 4,000–8,000 years, and possibly much longer. Native American villages were located along the coast, at protected harbors and at river mouths, where people practiced ocean- and river-dependent hunting, gathering, fishing, sealing, and whaling activities. There are four federally recognized tribes adjacent to the sanctuary—Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation (hereinafter referred to as the Coastal Treaty Tribes)—with treaty-reserved rights off reservation, including U&A fishing areas that extend 30–40 nautical miles offshore. There are three distinct language groups on the Olympic Coast: Quinault (Coast Salish), Quileute and Hoh (Chimakum), and Makah (Wakashan). Each of the Coastal Treaty Tribes are sovereign governments, with their own cultures, histories, languages, place names, ceremonies, and practices (Figure SS.2).

Figure SS.2. Makah welcoming figures carved of cedar greet visitors to Neah Bay, Washington. Photo: Makah Tribe

Coastal Treaty Tribes of the Outer Coast of Washington

Quinault Indian Nation – The Quinault Indian Nation consists of the Quinault and Queets tribes and descendants of five other coastal tribes. Quinault are Coast Salish. The Quinault Indian Reservation, located in the southwest corner of the Olympic Peninsula, includes 23 miles of Pacific coastline and covers 208,150 acres of forested land. The Quinault are a party to the Treaty of Olympia.

Hoh Indian Tribe – The Hoh call themselves Chalá·at: People of the Hoh River. The Hoh reservation is located 28 miles south of Forks at the mouth of the Hoh River. The Hoh are a place-based society, dependent on resources from the Hoh River watershed and the Pacific Ocean. The reservation has about 1 mile of beachfront between the mouth of the Hoh River and nearby Ruby Beach, and is surrounded by Olympic National Park. The Hoh speak a dialect of Chimakum distinct to the tribe. The Hoh are a party to the Treaty of Olympia.

Quileute Indian Tribe – Surrounded on three sides by Olympic National Park, the Quileute Reservation is located on 2,100 acres along the Pacific Ocean on the south banks of the Quillayute River and includes the Village of La Push. Traditionally, most of the Quileute lived inland and visited La Push seasonally to fish. The Quileute speak Chimakum. The Quileute are a party to the Treaty of Olympia.

Makah Indian Tribe – Qʷidiččaʔa·tx̌ is the Makah Tribe's name for themselves in their language, meaning "the people who live by the rocks and seagulls." Located in the northwesternmost corner of the contiguous U.S., the Makah Reservation consists of 30,000 acres, is bounded by the Pacific Ocean and the Strait of Juan de Fuca, and includes the town of Neah Bay. Over 1,000 acres of the land bordering the Pacific Ocean have been reserved as a wilderness area. The Makah are part of the Nootkan branch of the Wakashan culture, which includes two other First Nations in British Columbia, Canada. The Makah are a party to the Treaty of Neah Bay.

Artifacts from one prehistoric site, the Ozette Indian Village Archeological Site[1] near Cape Alava, provide a window into the daily life of the Makah culture immediately before European contact. Tools made from natural materials developed from their intimate relationship with natural resources, complex artwork, and rich oral traditions demonstrate the sophistication of these Native American societies.

Recent research on earlier Makah sites confirms maritime-adapted cultural practices of offshore fishing and whaling dating at least 1,500 years before present and occurring 40–100 miles offshore (Renker, 2018). Native peoples lived as part of and modified their environment to ensure ready access to resources for current and future generations, as well as for commerce and trade. Burning prairies for camas, berries, and ferns to grow; tending clam gardens to ensure bountiful shellfish; and designing fish traps to readily access fish resources were commonplace. Native peoples also utilized new information and technology to enhance their success. For example, when federal Indian agents attempted to turn Makah into farmers, the Makah instead used tines from the pitchforks to make fish hooks.

Traditional Knowledge (TK),[2] as defined in Van Pelt et al. (2017), is "a cumulative body of scientific knowledge, passed through cultural transmission, that evolves adaptively through time as a result of Indigenous peoples living in and observing the local environment for many generations; it is a form of adaptive management." TK is a robust and dynamic knowledge system that is based on observations and experiences over thousands of years and should be considered peer-reviewed in western science standards (Chang et al., 2018). "Respecting and embracing [I]ndigenous knowledge as important science benefits all of us" (Greene, 2018). Sharing TK should be based on free, prior, and informed consent with ownership and intellectual property rights belonging to the tribal communities or knowledge holders. The Coastal Treaty Tribes have lived on the Olympic Coast for thousands of years, and each has cultivated a body of knowledge on ecosystem processes, timing, location of important habitats and species, and a variety of other topics over generations (Chang et al., 2018; Shannon et al., 2016).

The four Coastal Treaty Tribes are independent sovereign nations, with the inherent right to self-governance and decision making on issues that affect their own people, lands, and resources. In the mid-1800s, Isaac Stevens, governor and Superintendent of Indian Affairs of Washington Territory, was authorized to conduct treaty negotiations with tribes on behalf of the United States government. Through the treaties, many tribes ceded title to hundreds of thousands of acres of land for the settlement of the Washington Territory by non-Indian settlers and reserved rights to resources. In return, treaty tribes were to receive reservation homelands for their exclusive use and were promised assistance from the United States. The 1855 Treaty of

[1] Ozette Indian Village Archeological Site was added to the National Register of Historic Places in 1974 following an 11-year excavation. The Makah Cultural and Research Center houses the 55,000 artifacts recovered.

[2] Traditional Knowledge, Traditional Ecological Knowledge, Indigenous Knowledge, and numerous variations of these terms will be referred to as Traditional Knowledge (TK) here.

Neah Bay with the Makah Indian Tribe and the 1856 Treaty of Olympia with the Hoh Indian Tribe, Quileute Indian Tribe, and Quinault Indian Nation reserved the rights of those coastal tribes to continue to fish, hunt, and gather resources off reservation at their usual and accustomed places to maintain their lifestyles and economies. It is important to emphasize that these rights were reserved by the tribes, not rights given to the tribes. The treaties continue to govern the relationships between the federal government and individual tribal governments today.

The Treaty of Olympia, also referred to as the Quinault River Treaty, continued Governor Isaac Stevens policy of consolidating tribes, often requiring tribes to move far from their homeland to a reservation to be occupied by several unrelated tribes. The Treaty of Olympia resulted in the establishment of the Quinault Reservation in the Quinault homeland but required several tribes, including the Quileute and Hoh, to move there, although few did. Reservations for the Quileute and Hoh tribes were established by executive orders in 1889 and 1893, respectively.

The Coastal Treaty Tribes ceded lands for the formal reservation of certain inherent rights as well as some monies and a "tract or tracts of land sufficient for their wants" and other services, including education and healthcare. The treaties were a grant of rights from the tribes and a reservation of rights not granted. Of these rights reserved, the "right of taking fish[3] at all usual and accustomed grounds and stations"[4,5] in perpetuity was vital to each of the Coastal Treaty Tribes. The marine ecosystem and its associated natural resources form an essential foundation for the economies and cultures of the Coastal Treaty Tribes. They view the continued ability to harvest and utilize water, plants, mammals, fish, and other resources of this region as critical to the protection of their treaty rights and the continuity of their distinct societies and cultures.

In the 1970s, treaty tribes in the state of Washington sought to access their treaty resources and uphold their treaty rights through legal action in federal court. The outcome of this arduous legal path re-established these treaties as the supreme law of the land and culminated in the seminal case of *United States v. Washington*, written by Judge George Boldt and often referred to as the "Boldt decision."[6] In arriving at the decision upholding the treaty rights, Judge Boldt traced the history of the fishing tribes of the state of Washington to the time of treaty signing.

The Boldt decision upheld tribal treaty rights to 50% of the harvestable salmon that are available in tribal U&A fishing areas. Subsequent court cases, including the 1994 Rafeedie decision, upheld the tribes' treaty-reserved rights to half of all of the harvestable fish and shellfish. These decisions also recognized Washington treaty tribes as co-managers of fishery resources with the state of Washington, empowering tribes to develop infrastructure and capacity to manage treaty resources. Each tribal government regulates the fishing activities of its members within its respective U&A fishing areas in accordance with tribal law and approved fisheries management plans. Each tribe also maintains its own fisheries management and enforcement staff, enters into management agreements, and engages in a wide variety of research for resource protection

[3] The Treaty of Neah Bay has unique language reserving Makah's right to "whaling and sealing" in addition to fish.
[4] Treaty of Neah Bay, U.S.-Makah Tribe, January 31, 1855, 12 Stat. 939.
[5] Treaty of Olympia, U.S.-Quinault Indian Nation-Hoh Tribe-Quileute Tribe, July 1, 1855 and January 25, 1856, 12 Stat. 971.
[6] United States v. Washington, 384 F. Supp. 312 (1974), aff'd 520 F.2d 676 (1975).

and stewardship. Federal regulations further recognize the sovereign status and co-manager role of treaty tribes over shared fishery resources.

Today, the Coastal Treaty Tribes carry their heritage forward, balancing the very modern needs of their communities with long tradition. Tribes exercise their treaty rights, hold potlatches and ceremonies (e.g., first salmon ceremony), and celebrate their cultures through songs, dances, names, language, and more.

In 2007, in recognition that the Hoh, Makah, and Quileute tribes; the Quinault Indian Nation; and the state of Washington are managers of the fisheries resources and their habitats within OCNMS, the Intergovernmental Policy Council (IPC) was formed. The first of its kind within the national marine sanctuary system, the IPC provides a regional forum for resource managers to exchange information, coordinate policies, and develop recommendations for resource management within the sanctuary. However, this forum does not supplant the federal trust responsibility or direct government-to-government relationships between the sanctuary and individual tribal governments.

European Exploration and Settlement

Native peoples exchanged resources and employed a local currency system prior to European settlement. Extensive trade routes via waterways were established by Indigenous peoples, who followed the coast to the Columbia River, into Puget Sound, and up to Alaska. Trade of whale oil, furs, halibut, salmon, and other resources was prevalent among the Coastal Treaty Tribes.

The first recorded European contact with the coastal tribes involved the Spanish explorers Bruno Heceta and Don Juan Francisco de la Bodega y Quadra in 1775. In 1778, the English explorer Captain James Cook sailed the coast and in 1788 he was followed by fellow Englishman John Meares. Although the Spanish built the first European settlement near Neah Bay in 1792, it was abandoned after only five months when Spain came under the threat of war from Great Britain.

Much of the early contact between European and Indigenous peoples was associated with the early maritime fur trade. Furs were the key to opening the northwest coast to European trade in the late 1700s, especially the profitable fur seal and sea otter pelts that were obtained from coastal tribes. European fur sealers established a fur sealing station in Victoria, British Columbia in 1837, hunting animals along the coast of Vancouver Island and purchasing pelts from local tribes. Stimulated by the high price paid by non-tribal sealers for skins, tribes spent considerable time hunting seals using canoes and spears during the mid and late 1800s. Using sailing craft, non-tribal fur sealers operated out of Vancouver Island and Seattle and hunted fur seals as far south as Mexico. Fur seals were hunted into the 20th century, but hunting ceased as the populations were driven to very low levels and the governments of Canada and the U.S. interceded.

At the start of the 19th century, there were conflicting claims in the Pacific Northwest. However, it is important to remember that these lands were not unclaimed. While European powers maneuvered to exert claims and influence, Indigenous peoples went about their own lives, interacting with traders on their own terms. Ultimately, the United Kingdom and United States compromised in the 1846 Treaty of Oregon, adopting the 49th parallel, which already marked the U.S.-Canada border east of the Rockies, as the international boundary in the mainland Pacific Northwest.

The sea otter trade was central to economic and political development in the Pacific Northwest. The international fur trade transitioned the lower-impact local exchange into worldwide consumer exploitation. Several tribes engaged in the commercial sea otter trade as the dense fur made sea otter pelts, referred to as "soft gold," extremely valuable to fur traders (Hughes, 2018). Commercial trade ultimately led to overexploitation, and by the early 1900s, hunters had completely extirpated sea otters from Washington waters.

Migration along the Oregon Trail funneled many settlers to the northwest. Settlements grew around Puget Sound as lumber became a money making industry. The California Gold Rush of 1849 attracted thousands of miners to California and sparked demand for Puget Sound timber. As commerce intensified in and out of the Puget Sound, the government erected lighthouses at critical nearshore shoals to improve navigation. After Washington became a territory in 1853, the pressure from American settlers moving into the area led to the placement of the tribes onto reservations.

Over time, the economic focus shifted from the fur trade to settlement and commercial fishing, with increasing numbers of vessels plying the outer coast and inland waters of Washington Territory. Fishing became an important economic activity of European and other immigrants to the Pacific Northwest soon after they settled along the U.S. Pacific Coast, within Puget Sound, and in British Columbia, Canada. There can be little doubt that the development of commercial fisheries by settlers began with the harvest of salmon, most likely in central California and along the Columbia River. It is known that the Hudson's Bay Company began to export salted salmon to Hawaiʻi in the 1820s. By 1877, a salmon cannery was operating in Puget Sound. However, it is not clear when the first settlers moved their salmon fishing operations into the Strait of Juan de Fuca and, eventually, into Pacific Ocean waters off and to the south of Cape Flattery. It is likely that a major early source of salmon to Puget Sound canneries involved purchase of fish caught by local tribes who had been involved in trading salmon for centuries.

Three commercial fisheries appear to have started in the waters offshore of Cape Flattery prior to the end of the 1800s. These included the salmon troll fishery as well as the halibut and sablefish (blackcod) handline and longline fisheries. Canneries were established along the Columbia River and outer coast, with three salmon canneries in Aberdeen by 1890. Over time, the introduction of modern fishing methods and the types of boats employed in the Pacific Northwest was strongly influenced by immigrants from Norway and other Scandinavian countries, in addition to fishermen from Yugoslavia, Portugal, and Italy.

Through the latter part of the 1800s, pioneers moved into the Olympic Peninsula to farm, fish, and cut timber. Like many tribes, most early settlers chose to settle along the coast. In 1851, Port Townsend became the first permanent American settlement on the peninsula, providing a gateway for further settlements to the west. Port Angeles, with its harbor, lighthouse, military reservation, customs house, and strategic location on the Strait of Juan de Fuca, was designated as a town site in 1862 and the nation's second national city. Farther west, the town of Forks had

European settlers as early as the 1860s. People were originally drawn to Forks by gold prospects, and for a short period by oil prospects, but timber became the mainstay of the economy.

Although the area attracted logging, farming, and fishing interests, in the southern portion of the peninsula, the timber industry clearcut large swaths of land. Deep ports in Grays Harbor allowed this region to become a center of timber production, driving timber barons to Hoquiam and Aberdeen. The first mills were established in 1882, and by 1890, Aberdeen had four mills. This changed the landscape of the peninsula forever. Frederick Weyerhaeuser purchased 900,000 acres of western Washington timber in 1900 and by 1903 he held 26% of all private timberlands in Washington. In 1910, Weyerhaeuser began milling and manufacturing, building mills in Everett, Longview, Aberdeen, Raymond, and elsewhere. Railroad expansions and the arrival of large corporations transformed the timber industry in Washington, becoming the largest employer in the state and establishing Washington as the leading U.S. producer of timber until the late 1930s.

National park and wilderness designations on the Olympic Peninsula reduced the available timber harvest. Olympic National Park was established in 1938 and the coastal strip of the park was added in 1953, together encompassing nearly a million acres of mountain, forest, and coastline designated as wilderness. The adjacent Olympic National Forest was designated in 1897 as the Olympic Forest Reserve and now contains 88,265 acres (15% of the total national forest acreage) of designated wilderness.

Throughout the period of European settlement on the western Olympic Peninsula, the link between the land and the ocean has shaped history. All coastal trade vessels working between California and Puget Sound, as well as vessels visiting the region for trans-Pacific trade, traversed the area that is now the sanctuary. The lumber trade on the Pacific Coast was a long-lived and significant aspect of maritime trade along the coast. Beginning in the 1850s with the establishment of sawmills on Puget Sound, larger vessels, many of them veterans of the California Gold Rush, commenced the trade. Early canneries, logging operations, and hotels reflected not just the economic opportunities offered by coastal resources, but the hardships imposed by the Olympic Coast's remoteness, such as lack of or limited road infrastructure. Coast-wide trade linked the productive Olympic Peninsula with Seattle and markets in California, Hawaiʻi, Australia, and beyond. The deep ports and rail access in Grays Harbor was instrumental to the development of the timber and fishing industries on the coast. In addition, the completion of railroad links across the Continental Divide in both Canada and the United States made the ports of Vancouver, Seattle, Everett, Tacoma, Grays Harbor, and Victoria important sources of grain, timber, gold, and other resources for the world's economy. The Northern Pacific Railroad, constructed in 1892, was the first rail line to serve the Grays Harbor region. Due to its isolated geography, it took decades for rail lines to be built to boost the economic development of the northern Olympic Peninsula; lines between Port Angeles and Port Townsend were not constructed until 1915.

Today, commerce on the Olympic Coast depends largely on commercial and recreational fishing, logging, and tourism. In the 1990s, the local timber industry was impacted by reduced harvests driven by environmental protections under the Endangered Species Act (ESA) in addition to automation of the lumber industry and diminishing old-growth forests, and the local economy has struggled since. Fishing continues to be an important commercial, ceremonial, subsistence, and recreational venture for coastal communities like Neah Bay and La Push. Fisheries have improved in recent years, with several rockfish stocks rebuilt and no longer considered overfished or depleted. The recovery of these fish stocks was a result of extensive efforts by fisheries management entities (federal, state, and tribal co-managers) through the Pacific Fisheries Management Council (more information on these efforts is provided in the Response section). However, for some fisheries, harvest is still a fraction of what it was in the 1970s and 1980s.

Coastal communities continue to respond to a changing economy by developing innovative enterprises such as value-added wood product manufacturing (local manufacturing rather than export of raw timber) and accommodating the growth of tourism to diversify the economic base, while remaining reliant on natural resources.

Military History

The United States military has had a presence on the Olympic Coast since the 1850s. In 1851, George Davidson of the U.S. Coast Survey undertook detailed charting of Washington's coast, first focusing at the mouth of the Columbia River for critical navigation and commerce and then the northern coast. Following the coast survey, Davidson recommended Tatoosh Island for construction of a lighthouse. This recommendation was prior to the 1855 Treaty of Neah Bay negotiation. A lighthouse was built on Tatoosh Island in 1857 and operated by the United States Coast Guard (USCG) and Navy for over one hundred years. During World War II, a radio intercept station was operated on Tatoosh Island until the end of the war when long range navigation equipment was installed. The lighthouse and long-range navigation equipment were automated in 1976, and in 2008, a separate LED pole was erected, eliminating the need for USCG personnel on Tatoosh Island.

However, the Makah Tribe never agreed to cede its offshore islands as described within the written treaty document and continued to assert their claim until they successfully negotiated for return of Tatoosh and Waadah Islands under the Indian Claims Act in 1984. Since 1999, the Makah Tribe has been working with USCG and the Department of Defense under the Native American Lands Environmental Mitigation Program to conduct remediation at numerous sites on reservation, including Waadah and Tatoosh Island, by conducting soil cleanup, removal of dilapidated buildings and underground storage tanks, and other activities.

Following the attack on Pearl Harbor in 1941, the U.S. military mobilized defenses to the west coast. During this time, the Olympic Peninsula was considered one of the most threatened and vulnerable locations of the contiguous U.S. (Evans, 1983). During World War II, the military referred to the Olympic Coast as the Northwest Sea Frontier and mobilized the U.S. Army, Navy, and Coast Guard to the region. This included construction of forts at the entrance to Puget Sound and fixed gun installations planned for Cape Flattery. The USCG was transferred to the command of the Navy in 1941 and established the Coast Lookout System. The purpose of the Coast Lookout System was to "prevent communication between persons on shore and the enemy; to observe the actions of any enemy vessels in coastal waters and to transmit such information to naval or army commands; and finally, to report attempts of enemy landing to army and naval commands and to assist in preventing such action" (Evans, 1983). During this time, the strip of coastline that is now Olympic National Park was occupied by the USCG. The USCG took over the army camp at Lake Ozette, creating the Ozette Lake Coast Guard Station. USCG activity included ten beach patrol outposts and three lookout towers positioned at Cape Alava, Eagle Point, and the mouth of Starbuck Creek. Beach patrol stations included La Push and Kalaloch. Beach patrolling activities ended in 1944.

In 1944, the Quillayute Naval Auxiliary Air Station opened southwest of Quillayute. The same year, the Navy was granted the use of a number of rocks within the Washington Maritime NWR Complex for bombing and strafing activities. The main island used was Sea Lion Rock. The U.S. Fish and Wildlife Service later determined that this practice was not compatible with the purposes of the refuge, and in 1993, Navy use of the area was rescinded by the Secretary of the Interior.

The U.S. Army leased reservation land from the Makah Tribe to construct a coastal battery in 1942. However, guns were never installed and the lease was terminated in 1945, with all lands except 10 acres on Bahokus Peak reverting to the Makah. The Air Force also had a presence on the outer coast, with the Makah Air Force Station built in 1951, prompted by the Korean War. This was a surveillance radar station and was established as the 758th Aircraft Control and Warning Squadron[7] on Bohokus Peak in 1950. The base closed in 1988; the lands leased for the Air Force station and housing reverted to the land owners, primarily the Makah Tribe, and now serve as the Makah Tribal Council Center. However, there is still radar at the site operated by the Federal Aviation Administration as part of the Joint Surveillance System.

The Navy has utilized the airspace of the Olympic Peninsula for over 70 years. The Navy continues to exercise military readiness in the air and water of the Olympic Coast as part of their Northwest Testing and Training Study Area and Naval Undersea Warfare Center Division Keyport Range Complex. The Navy's mission is to maintain, train, and equip combat-ready naval forces capable of winning wars, deterring aggression, and maintaining freedom of the seas (10 U.S.C. § 8062). The Naval Undersea Warfare Center Division Keyport Range Complex includes the Quinault Range Site, which is located off the coast in Jefferson and Grays Harbor counties, and includes one mile of shoreline at Pacific Beach. The Quinault Range Site provides key oceanographic features, depth, and logistics proximity for select at-sea testing events, including access to shore, that cannot be conducted elsewhere within the Northwest Testing and Training Offshore Area.

Geology

OCNMS is located within a region known for dynamic plate tectonics that have shaped marine and terrestrial habitats and continue to affect the sanctuary in a geologic context. Earthquakes, tsunamis, and massive glaciers have shaped the landscape over time, isolating the Olympic Mountains to produce endemic species, carving submarine canyons and coastlines, and depositing boulders and other glacial moraines on the adjacent continental shelf. Efforts to better understand the region's geologic past continue to inform contemporary research efforts, including seismic testing of active submarine faults associated with a 700-mile subduction zone offshore; understanding differential vertical shifting of land on the Olympic Peninsula relative to

[7] Later the 758th Radar Squadron.

sea level; mapping for hazard planning and modeling; and development of tsunami inundation maps and alert systems for residents and visitors to the region's coastal areas.

The Olympic Coast is subject to tectonic forces caused by the combined movements of the large Pacific and North American Plates and the smaller Juan de Fuca Plate. The Juan de Fuca Plate and the Pacific Plate are spreading away from each other at a divergent plate boundary offshore, with the Juan de Fuca plate being pressed toward and beneath the North American Plate. The area encompassing this activity is known as the Cascadia Subduction Zone (Figure SS.3). These forces have produced a chain of volcanoes within the uplifted Cascade Range. The geologic activity in the area off the Olympic Coast gives rise to potential hazards such as earthquakes and associated submarine landslides, tsunamis, and volcanic eruptions.

Figure SS.3. Location of the Cascadia Subduction Zone. Image: Mustafa Lazkani/Federal Emergency Management Agency

Due to geological forces, the northern portion of the Olympic Peninsula is experiencing vertical land movement (uplift), which results in low relative sea level rise compared to the southern portion of the sanctuary, where relative sea level rise is more pronounced. Plate tectonics, and to a lesser extent isostatic rebound of land following glacial melt, are the driving forces in this vertical land movement.

The Cascadia Subduction Zone is capable of generating a magnitude 9 or higher earthquake and resulting tsunami. Such a large magnitude earthquake could significantly impact remote communities on the Washington coast within a few minutes and affect major cities throughout Puget Sound soon after. Places like Neah Bay that are currently experiencing vertical uplift are at risk of significant subsidence following an earthquake, and may experience slumps and drops of up to 2 meters (6 feet).

The sanctuary seafloor is a rich and varied component of the marine ecosystem (Figure SS.4). The glacial landscape that has been submerged for the last 10,000 years contains deeply eroded canyons, rocky shorelines, and scattered boulders, along with glacial ridges and vast, uninterrupted sand and mud plains. A continental shelf reaches 13–64 kilometers (8–40 miles) out from Washington's coast and provides a relatively shallow (200 meters or 660 feet in depth or less) coastal environment within the sanctuary. Unconsolidated, soft-bottom sediments comprise the majority of habitat in the sanctuary. Several submarine canyons cut into the continental shelf along the western boundary of the sanctuary, and the Strait of Juan de Fuca flows into the trough of the Juan de Fuca Canyon in the northern portion of the sanctuary. Submarine canyons act as channels for coastal sediment to reach the deep seafloor; enhance upwelling by providing deep, cold, nutrient-rich water to the surface; and are habitats with high biodiversity. In the northern portion of the sanctuary, sediments on the shelf are largely glacial deposits from the Ice Age, and the shelf slope is steep and jagged. Modern sediments are carried west through the Strait of Juan de Fuca, north from the Columbia and Chehalis rivers, and oceanward from the prominent coastal rivers of Quinault, Queets, Hoh, and Quillayute. These materials are generally transported northward by year-round bottom currents and winter storms, and eventually accumulate on the shelf. Some of the sanctuary seafloor has been mapped, however, various methods have been used, resulting in disparate resolution and detail. Thus, a full understanding of habitat distribution, as defined by sediment type and bathymetry (depth of seafloor), remains elusive (Battista et al., 2017). Fortunately, in recent years, the sanctuary and partners have prioritized, and are working to fill gaps in, mapping of the sanctuary.

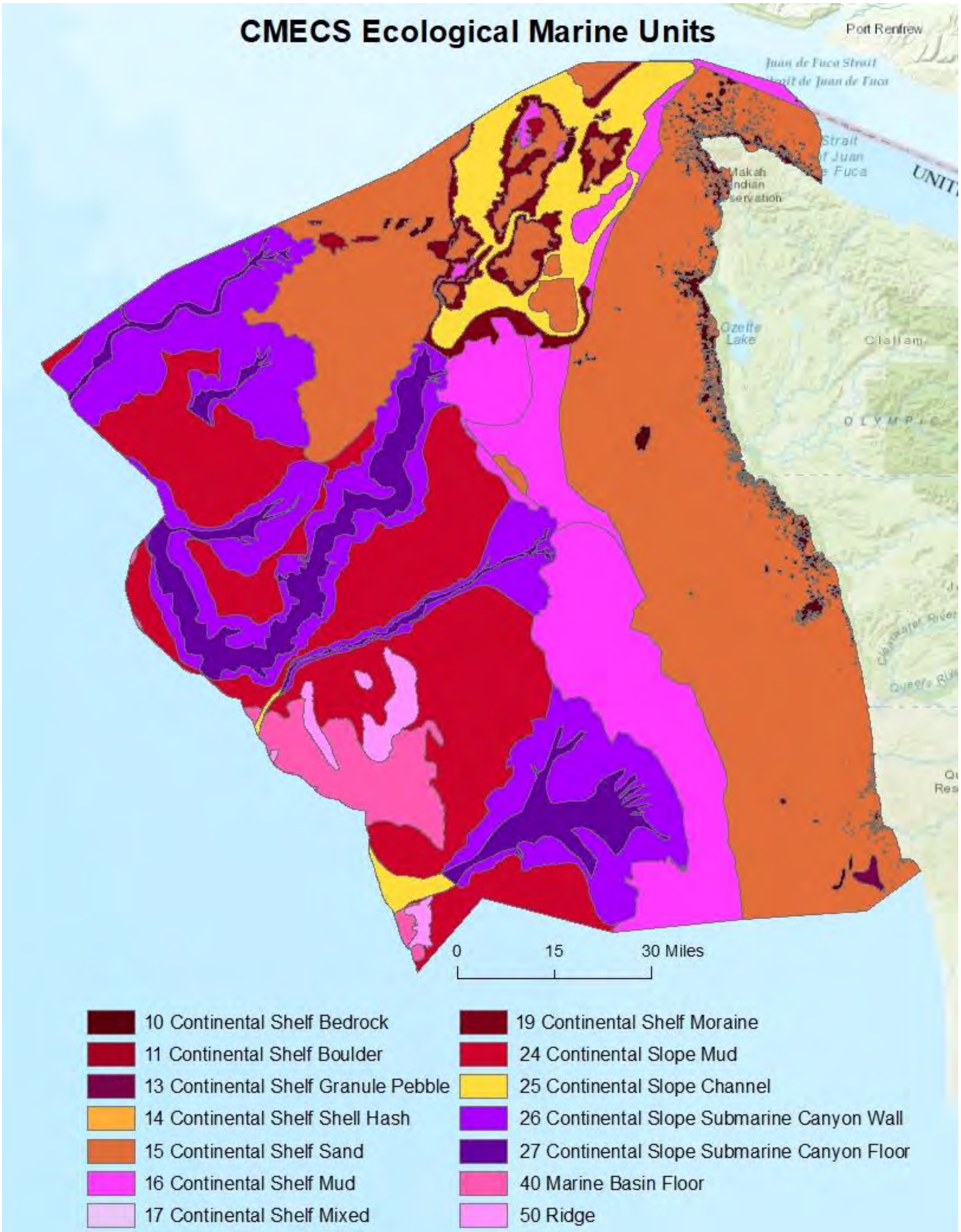


Figure SS.4. Map of ecological marine units as defined in the habitat framework developed by the IPC. Source: Northwest Indian Fisheries Commission

Broad beaches with various grain sizes (e.g., sand, gravel, cobble), dunes, and ridges dominate the Washington coastline from Cape Disappointment, on the north side of the Columbia River mouth, to the Hoh River. Wave action has eroded the shoreline through time and has formed steep cliffs at various places along the coast, and forested hills and sloping terraces are found near river mouths. Between Point Grenville and Cape Flattery, rocky cliffs can rise abruptly 15 to 90 meters (50 to 300 feet) above a wave-cut platform that is underwater except during extreme low tides. This wave-cut platform can be almost three kilometers (2 miles) wide in some places. Small islands, sea stacks, and rocks dot the platform's surface.

Oceanography

The Washington outer coast is known for its rough seas and large waves. Extreme wave heights up to 15 meters (49 feet) have been recorded on and beyond the continental shelf (Ruggiero et al., 2013). Winter storms travel across the fetch of the Pacific Ocean and the energy is magnified as they encounter the shallower continental shelf, where their force pounds the coast with gathered intensity. Storm intensity and wave height have increased over the past 50 years (Ruggiero et al., 2013).

Surface winds generated by atmospheric pressure systems are the main force driving ocean surface circulation off the Pacific Northwest and produce two distinct 'seasons' that are tightly associated with regional productivity and energy flow. Spring and summer winds generally blow from the north and push surface waters southward and offshore, resulting in nearshore upwelling of cold, nutrient-rich water to the surface. This influx of nutrients enhances plankton communities that support the region's productive fisheries. Downwelling tends to occur in the fall and winter months, when the winds generally blow from the south, forcing surface water into the subsurface. Other physical features also play a role in these dynamics, including shelf platform width, river plumes, submarine canyons, banks, coastal promontories, and offshore eddies. These geographic features influence the retention, magnitude, and timing of nutrient delivery to plankton and may explain why primary productivity is higher along the Washington coast than the Oregon coast (Hickey & Banas, 2003, 2008).

On a regional scale, the California Current transports cold, subarctic water southward from British Columbia along the Washington coast to Baja California, directly influencing the local distribution of marine organisms. The California Current generally occurs from the continental shelf break to a distance of about 1,000 kilometers from shore and rides above the narrower California Undercurrent, which flows northward and is implicated in the transport of larvae and other plankton. The California Current and Undercurrent are strongest in the summer, while the seasonal, nearshore Davidson Current flows northward during winter months, transporting the Columbia River plume along the Washington coast. Another local feature, the Juan de Fuca Eddy, which is approximately 50 kilometers in diameter and located offshore of the mouth of the Strait of Juan de Fuca, persists in summertime and entrains nutrient-rich, cold water in a counterclockwise circulation pattern.

Oceanic and atmospheric events across the Pacific basin influence the waters off the Olympic Coast. For example, the El Niño Southern Oscillation (ENSO) is primarily driven by sea surface temperature (SST) in the Equatorial Pacific Ocean, but is a major source of interannual climate variability in the Pacific Northwest, with events lasting 6 to 18 months. El Niño periods generally produce lower chlorophyll and higher SST, while La Niña years produce high chlorophyll and low SST. During an El Niño phase, storms have also created erosion hotspots (Ruggiero et al., 2013). Similarly, the Pacific Decadal Oscillation (PDO) is a dominant driver of climate variability in the Pacific Northwest, where warm or cool phases can each last 20 to 30 years. Warm PDO phases correlate with diminished upwelling along the California Current. Positive PDO phases result in warm temperatures and higher sea level (Miller et al., 2013). The phase of ENSO and PDO may also reinforce or weaken the climatic effect of each phenomenon. Climatic cycles such as these are natural events and are often associated with strong fluctuations in weather patterns and biological resources.

Habitat

OCNMS contains a broad diversity of habitats including rocky shores, sand and gravel beaches, kelp forests, sea stacks and islands, open ocean or pelagic habitats, a broad continental shelf, deep-sea habitats, and submarine canyons. Along the shoreline, tide pools are nestled amid boulders and rocky outcrops that provide both temporary and permanent homes for an abundance of marine plants and animals. Rocky shores of the Olympic Coast have among the highest biodiversity of marine invertebrates and macroalgae of all eastern Pacific coastal sites from Central America to Alaska (Schoch et al., 2006). Nestled between these rocky headlands are numerous pocket beaches that host a unique array of intertidal algae, invertebrates, and fishes. While beach sediments in the north may be composed of pebbles and cobbles as well as sand, near the southern portion of the sanctuary, sandy beaches are more prevalent. The pelagic zone includes all water column habitat from near the seafloor to the surface. Currents, upwelling, and other physical oceanographic drivers influence this dynamic zone, at times generating high primary productivity.

Kelp forests include floating kelp canopies as well as submerged kelp beds. Floating kelp forests form dense stands in nearshore waters, with individual plants anchored to the seafloor and reaching more than 20 meters in height. The structure of this living habitat alters the physical forces (waves and currents) in the nearshore area and creates a protective environment for fish and invertebrates, from holdfast bases on the seafloor to canopies at the surface. Kelp forests occur primarily along the northern coast of the sanctuary. There are 21 species of kelp found in the sanctuary, with another two species likely (Mumford, 2014). Sea otters often form rafts of animals that may rest in and near kelp canopies, while many species of fish, including the more vulnerable younger age classes, utilize this protective habitat.

Pinnacles (sea stacks) and islands along the coast provide havens and resting sites for pinnipeds and thousands of nesting seabirds. High-relief submerged topographic features, such as rock piles, often serve as fish aggregation areas and settlement habitats for sessile invertebrates, concentrating biodiversity in relatively small areas.

A majority of the sanctuary lies over the continental shelf, extending from the shoreline to the shelf break near the 200-meter depth contour. The shelf is composed primarily of soft sediment and glacial deposits of cobble, gravel, and boulders, punctuated by rock outcrops, and it is inhabited by creatures such as flatfish, rockfish, octopuses, crabs, brittle stars, and sea pens that have evolved to flourish in the darkness, cold, and pressure of the seafloor. Sanctuary boundaries extend beyond the edge of the continental shelf and include portions of Nitinat, Juan de Fuca, Quileute, and Quinault submarine canyons. Quinault Canyon is the deepest, descending to 1,420 meters (4,660 feet) at its deepest point within the sanctuary. Many creatures, such as corals, sponges, crinoids, rockfish, and shrimp, inhabit these areas of physical extremes.

Hundreds of new methane seeps were also recently identified within OCNMS (Figure SS.5). These fascinating habitats are only beginning to be understood in terms of their contributions to ocean chemistry and biodiversity, their role as essential fish habitat, and their possible biopharmaceutical applications. Many of the seeps recently identified are adjacent to submarine canyons, which are dynamic areas of the seafloor. Massive submarine landslides can shape the steep side walls, and canyon bottoms collect sediment deposited from above. Canyons also serve as conduits for dense, cold, nutrient-rich seawater that is upwelled and pulled toward shore, fueling productivity at the base of the food web.

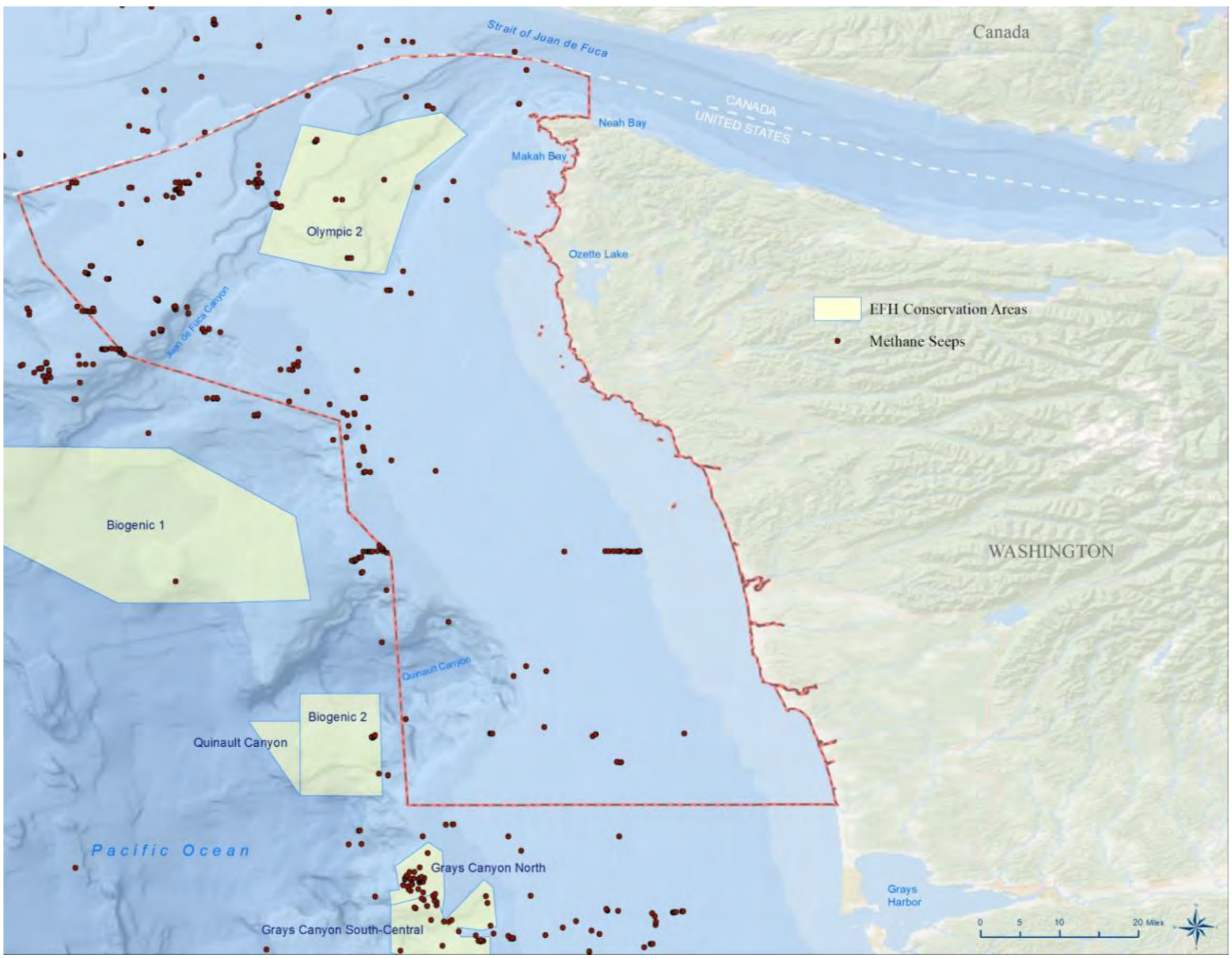


Figure SS.5. Locations of known methane seeps in and adjacent to OCNMS. Source: Andrew Thurber/OSU and NOAA; Image: NOAA

Scientists have also documented deep-sea coral and sponge reefs in the sanctuary. Unlike better-known shallow-water tropical corals, deep-sea corals live on continental shelves, slopes, canyons, and seamounts in waters ranging from 50 m to over 2,000 m in depth. Deep-sea corals lack the symbiotic algae (zooxanthellae) found in most shallow reef-building tropical corals, so unlike their shallow water relatives that rely heavily on photosynthesis to produce food, deep-sea corals take in plankton and organic matter for their energy needs. Many deep-sea corals are also extremely long-lived and slow growing animals, which makes their populations particularly vulnerable to physical disturbance. The branching and upright growth structure of these organisms serves as biogenic habitat for other invertebrates and fish (Whitmire & Clarke, 2007). Habitat-forming corals and sponges can provide shelter, attachment sites, and food sources for animals living in deep sea environments.

Living Resources

The high primary productivity, strong coastal upwelling, and diverse seafloor (including submarine canyons) of OCNMS supports a variety of marine life, including more than 300 species of fish, more than 100 species of seabirds and shorebirds, 29 species of marine mammals, and a growing list of invertebrates and marine algae.

Of the 29 species of marine mammals sighted in OCNMS, eight species are listed under the ESA. Two species are frequent foragers in OCNMS: the humpback whale and the Southern Resident killer whale. Gray whales, which were removed from the endangered species list in 1994 and, as of 2016, number ~27,000, travel through OCNMS on their annual migrations between breeding and calving grounds off the Baja Peninsula and summer feeding grounds in the northern Pacific. Harbor and elephant seals and Steller and California sea lions aggregate along the shore and haul out on land at many locations along the coast throughout the year. In 1969 and 1970, 59 sea otters were translocated from Amchitka Island, Alaska to the Olympic Coast, where they gradually reestablished a breeding population; the 2019 census identified a minimum of 2,785 sea otters on the Washington outer coast (Jeffries et al., 2019).

Three sea turtle species (leatherback, loggerhead, and green) also occur infrequently within OCNMS; the leatherback sea turtle is the most likely to occur. All three species are listed under the ESA. Sea turtles use the sanctuary for foraging but breed in tropical habitats.

Seabirds are the most conspicuous members of the offshore fauna of the Olympic Coast. Sea stacks and islands provide critical nesting habitat for 19 species of marine birds and marine-associated raptors and shorebirds, including seven alcid species (e.g., murres, puffins, murrelets), three cormorant species, four gull and tern species, two storm petrel species, two raptors, and one shorebird (the black oystercatcher). Marbled murrelets are listed as threatened under the ESA. Productive offshore waters attract large feeding aggregations of marine birds that breed in other regions of the world but travel great distances to forage in productive sanctuary waters during the summer upwelling season. The sooty shearwater, for example, breeds along the coasts of New Zealand and Chile in the austral summer and congregates along the Pacific coast in its non-breeding season. Blackfooted and Laysan albatross travel far from their breeding grounds in Hawaiʻi and Japan to forage in the eastern Pacific. Nearer to shore, sand and gravel beaches furnish foraging areas for shorebirds, crows, gulls, and a host of other birds and mammals, including black bears. The coastline forms an important migratory pathway for millions of birds that pass through each year, guiding waterfowl, cranes, shorebirds, and raptors toward northern breeding areas during the spring and southward as winter approaches.

Sanctuary waters are inhabited by diverse and abundant fish and invertebrate populations. Commercially important fish and shellfish include at least 30 species of rockfish and 16 species of flatfish (including Pacific halibut), Pacific herring and other forage fishes, Pacific cod, Pacific whiting, lingcod, sablefish, Dungeness crab, razor clams, and several species of shrimp. Five species of Pacific salmon (Chinook, sockeye, pink, chum, and coho) occur along the outer coast of Washington and breed in the Olympic Peninsula's rivers and streams. Three additional salmonid species found in freshwater systems (sea-run cutthroat trout, bull trout, and steelhead) spend portions of their lives in nearshore marine waters. Olympic Coast populations of Lake Ozette sockeye and bull trout were designated as threatened species under the ESA in 1999. Nearshore habitats of the sanctuary are important for salmon that spawn in adjacent streams. OCNMS also encompasses the migration corridor of both juvenile and adult salmonids from California, Oregon, British Columbia, Puget Sound, and rivers in Washington, including the Columbia River and its tributaries. Numerous populations of these salmonids are ESA listed. Forage fish such as Pacific herring, surf smelt, and eulachon feed in nearshore and pelagic waters of OCNMS and are important components in the food web. Sharks, albacore tuna, sardines, mackerel, anchovies, and other migratory species are also found in OCNMS seasonally.

Intertidal habitats challenge inhabitants with exposure, desiccation, extreme temperatures, and salinity and oxygen fluctuations, along with powerful physical forces such as sand scouring and wave action. Invertebrate communities in rocky intertidal zones are some of the richest on the West Coast and include a wide diversity of sea stars, sea urchins, mussels, barnacles, nudibranchs, chitons, and polychaetes. Macroalgae or seaweeds are also extremely diverse in the region; one estimate suggests 120 species occur within the sanctuary rocky intertidal zone (Dethier, 1988), although another indicates more than 180 species are likely present (T. Mumford, personal communication, August 31, 2020). Shi Shi beach, for example, exhibits high diversity of intertidal seaweeds (T. Mumford, personal communication, August 31, 2020). Sandy intertidal areas host sand-dwelling invertebrates and several notable fish species including starry flounder, staghorn sculpin, Pacific sand lance, sand sole, surfperches, and sanddabs. Surf smelt spawn at high tide on sand-gravel beaches where surf action bathes and aerates the eggs. Rocky intertidal habitats hold another roster of residents, including tidepool sculpins, gunnels, eelpouts, pricklebacks, cockcombs, and warbonnets. Intertidal areas transition to sandy habitat that supports large populations of Pacific razor clams in the southern reaches of OCNMS.

In the deeper waters of OCNMS, investigations have found stunning colonies of brightly colored, cold-water corals and sponges (Figure SS.6). These unique assemblages include soft coral species from multiple families (e.g., gorgonians, *Primnoa pacifica*), stony corals (e.g., *Lophelia* spp.and *Desmophyllum* spp.), and at least 40 species of sponges, including some that are believed to be new species (Brancato et al., 2007; Waddell et al., 2019; Thurber et al., 2021). The sanctuary is working to better explore and characterize deep sea communities and their distribution through research cruises and remotely operated vehicle (ROV) surveys, modeling efforts, environmental DNA sampling, specimen collection, and taxonomic validation of new species.

Figure SS.6. A mature colony of the deep-sea coral *Primnoa pacifica*, encountered in central Juan de Fuca Canyon during an ROV dive in OCNMS in September 2019. Photo: Marine Applied Research & Exploration/NOAA

Maritime Heritage Resources

OCNMS is within a significant and unique maritime cultural landscape in the United States. The Olympic Coast is characterized by its broad continental shelf, which would have appeared as a topographically homogeneous coastal plain during the last glacial maximum, approximately 19,000 years before present. Due to shifts in sea level, many prehistoric archeological sites may be submerged or found further upland. In 2013, the Bureau of Ocean Energy Management published an inventory of coastal and submerged archaeological sites (ICF International et al., 2013) and assessed the relative sensitivity of cultural resources identified along the Pacific coast. These resources include archaeological resources, built environment resources, and culturally significant properties. The modern shoreline of the Olympic Peninsula contains dozens of late prehistoric archaeological sites that are rich in materials documenting the character of the maritime environment and the use of this environment by the region’s native peoples. Nearshore coastal forests adjacent to OCNMS contain mid-Holocene shorelines and older prehistoric archaeological sites. These older sites are rich in materials documenting the character of maritime paleo-environments, the history of environmental change, and the record of use of these environments by the region’s native peoples.

The earliest dated archaeological site on the Washington Coast occurs adjacent to OCNMS on the Makah Indian Reservation, establishing human presence for at least the last 6,000 years. Although complex geological and climatic factors have changed the shoreline due to tectonic uplift and global sea level rise, it is evident that humans have occupied the coastal zone and adapted to changing habitats over time. The recent investigation of paleo-shoreline sites on the Makah reservation revealed high sea-stand village sites inland near Ozette and the Tsoo-Yess (Sooes) and Wa'atch river valleys, ranging from 7–14 meters above current sea level and kilometers from the current ocean shore (Wessen, 2003; Wessen & Huelsbeck, 2015). These sites indicate complex interactions with marine resources of the period and yield important clues to large-scale ocean and climate regimes, marine wildlife and fish populations, habitat distribution, and cultural patterns of marine resource use. Late prehistoric cultural patterns are particularly well documented. The Makah Cultural and Research Center in Neah Bay houses an extraordinary collection of artifacts from the Ozette Indian Village Archaeological Site, which was partially buried by a mudslide nearly 500 years ago and excavated in the 1970s. Ozette Indian Village Archeological Site is listed on the National Register for Historic Places. Excavated items are used for research as well as displayed in the Makah Museum, highlighting the tools and activities of prehistoric Makah people, including whaling, seal hunting, and a variety of fishing gear.

Other tangible records of prehistoric human occupation include petroglyphs—both above the intertidal zone and within it—and canoe runs (channels cleared of boulders to facilitate landing of dugout watercraft). Research and preservation of coastal native languages, traditional cultural properties, and traditional practices of song, dance, and activities like whaling also enhance awareness of the region's rich ocean-dependent heritage among native and non-native peoples. The canoe culture, as celebrated in the annual "Tribal Canoe Journeys," is a transfer of knowledge and understanding of coastal culture to new generations.

Maritime resources for native peoples are not exclusive to tangible resources. Locations, language, and activities are linked to the marine environment and are the foundation for the Olympic Coast's maritime heritage. For example, traditional places and activities (fishing, whaling, sealing), plant knowledge, and prehistoric navigational aids contribute to the unique character of this region.

Shipwrecks serve as another tangible maritime heritage resource. OCNMS lies at the international border with Canada, at the entrance to a major inland maritime highway and the Inside Passage to Alaska, and also serves as the gateway to several historically significant and active ports. The combination of fierce weather, isolated and rocky shores, and thriving ship commerce have, on many occasions, made the Olympic Coast a graveyard for tribal and non-tribal ships and their crews. While there are few recorded shipwrecks prior to the mid-19th century and no verified wrecks during the 18th century, the number of vessel losses increased significantly as Puget Sound developed into an economic center and as Victoria, the provincial capital of British Columbia, developed on the north side of the Strait of Juan de Fuca in the 19th century. The 19th-century lumber trade, in particular, greatly expanded vessel traffic—for example, more than 600 vessels entered and cleared Puget Sound past Cape Flattery in 1886. Ship losses were predominantly weather-related and included founderings, collisions, and groundings. Many ships simply disappeared; their last known location recorded by the lighthouse keeper at Tatoosh Island. As of July 2015, more than 197 shipwrecks have been reported in the vicinity of the Olympic Coast, yet only a few have been investigated using modern survey techniques (OCNMS, 2018). Currently, 69 shipwrecks have been identified with confirmed, specific or general locations within and adjacent to OCNMS; nine of the wrecks have been located and confirmed (Figure SS.7).

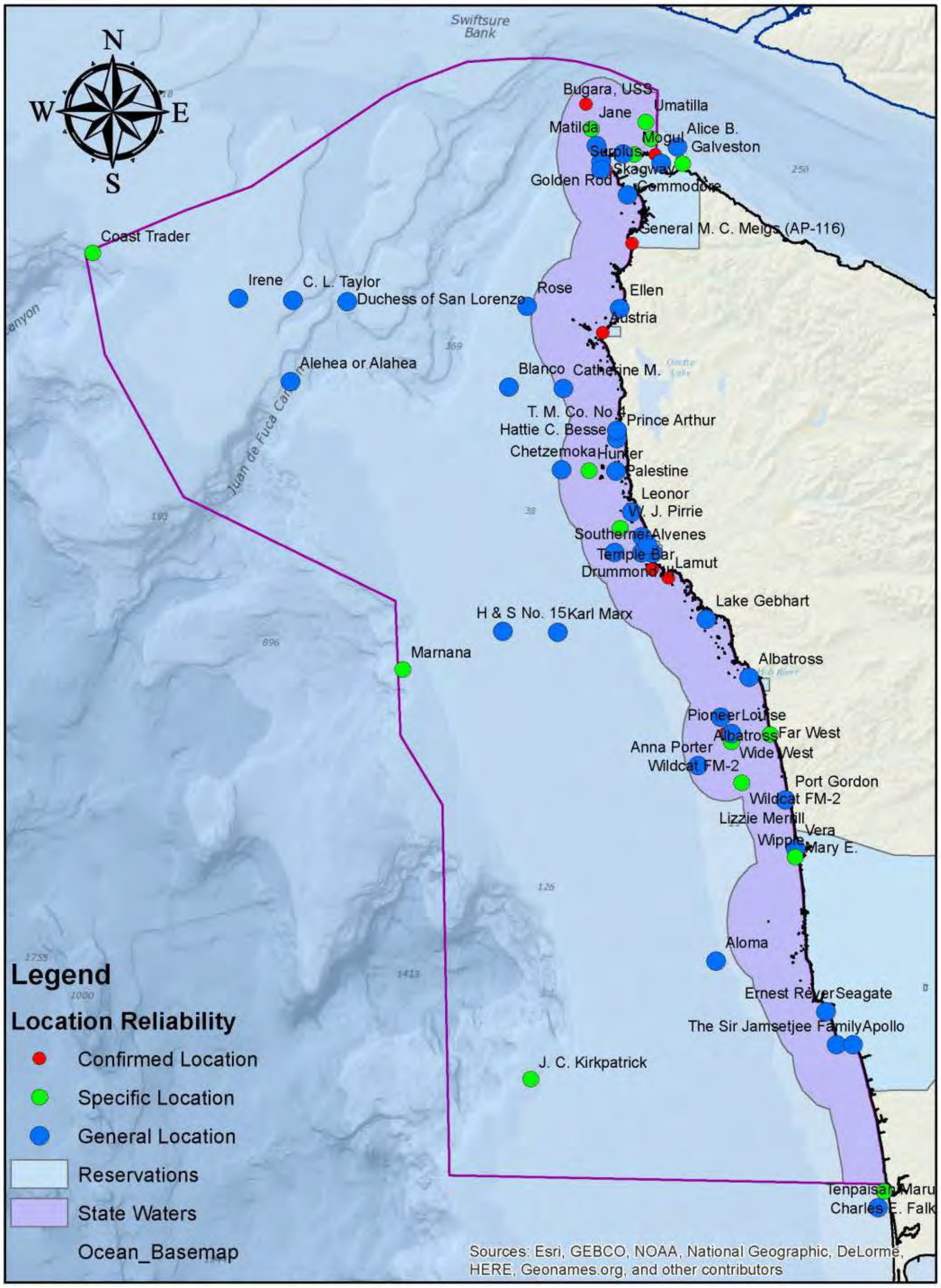


Figure SS.7. Locations of confirmed, specific, and general locations of shipwrecks in OCNMS as of July 2015. Source: Washington State Department of Archaeology and Historic Preservation; Esri, GEBCO, NOAA, National Geographic, DeLarme, HERE, Geonames.org, and other contributors

Figure SS.8. The SS *Coast Trader* serves as an artificial reef to many species, including lingcod (pictured). Photo: Hale, 2016

The SS *Coast Trader* was surveyed by the E/V *Nautilus* in 2016. The SS *Coast Trader* was built in 1920 and operated as a merchant ship during World War II before sinking in 1942 from a torpedo strike by a Japanese Imperial Navy submarine. The SS *Coast Trader* was observed acting as an artificial reef, with lingcod, yelloweye, and other fish using the shipwreck (Figure SS.8). Additionally, several trawl nets were caught on the shipwreck over time.

The USS *Bugara* (SS-331) was a U.S. Navy submarine that served in World War II, the Korean War, and the Vietnam War before being decommissioned in 1970 (OCNMS, 2017a). The USS *Bugara* sank in 1971 near Cape Flattery, Washington while under tow to serve as a target vessel. The E/V *Nautilus* surveyed the USS *Bugara* in 2017 (Delgado et al., 2018a).

Historic structures on land, while technically outside of OCNMS boundaries, are important tangible fragments of the past and provide insight into past human interactions with the ocean. These include middens, village sites, historic lighthouses at Tatoosh and Destruction islands, lifesaving station remnants at Waadah Island and La Push, wartime defense sites at Cape Flattery and Anderson Point, and sites of coastal patrol cabins scattered along the Olympic Coast. Homesteads, resorts, graves, and memorials also reflect a human dimension to the coast now largely reclaimed by time, the forest, or the sea.

Jurisdictional Authorities

Under the authority of the National Marine Sanctuaries Act (NMSA) of 1972, as amended, 16 U.S.C. §§ 1431 et seq., and its implementing regulations, ONMS works:

1) "to identify and designate as national marine sanctuaries areas of the marine environment which are of special national significance and to manage these areas as the National Marine Sanctuary System;
2) to provide authority for comprehensive and coordinated conservation and management of these marine areas, and activities affecting them, in a manner which complements existing regulatory authorities;
3) to maintain the natural biological communities in the national marine sanctuaries, and to protect, and, where appropriate, restore and enhance natural habitats, populations, and ecological processes;
4) to enhance public awareness, understanding, appreciation, and wise and sustainable use of the marine environment, and the natural, historical, cultural, and archeological resources of the National Marine Sanctuary System;
5) to support, promote, and coordinate scientific research on, and long-term monitoring of, the resources of these marine areas;
6) to facilitate to the extent compatible with the primary objective of resource protection, all public and private uses of the resources of these marine areas not prohibited pursuant to other authorities;
7) to develop and implement coordinated plans for the protection and management of these areas with appropriate federal agencies, state and local governments, Native American tribes and organizations, international organizations, and other public and private interests concerned with the continuing health and resilience of these marine areas;
8) to create models of, and incentives for, ways to conserve and manage these areas, including the application of innovative management techniques; and
9) to cooperate with global programs encouraging conservation of marine resources." (16 U.S.C. §1431(b)).

There are multiple overlapping jurisdictions on the Olympic Coast (Figure SS.9). OCNMS works in coordination with multiple authorities and aims to facilitate compatible uses to the extent practicable. Under regulations (15 CFR §922.152), the following activities, with some exceptions, are prohibited within OCNMS:

- Exploring for, developing, or producing oil, gas, or minerals within the sanctuary.
- Discharging or depositing, from within the boundary of the sanctuary, any material or other matter.
- Moving, removing, or injuring, or attempting to move, remove, or injure, a sanctuary historical resource.
- Drilling into, dredging, or otherwise altering the seabed of the sanctuary.
- Taking any marine mammal, sea turtle, or seabird in or above the sanctuary.
- Disturbing marine mammals or seabirds by flying motorized aircraft at less than 2,000 feet over the waters within one nautical mile of the Flattery Rocks, Quillayute Needles, or

Copalis National Wildlife Refuges or within one nautical mile seaward from the coastal boundary of the sanctuary, except for activities related to tribal timber operations conducted on reservation lands, or to transport persons or supplies to or from reservation lands as authorized by a governing body of an Indian tribe. Failure to maintain a minimum altitude of 2,000 feet above ground level over any such waters is presumed to disturb marine mammals or seabirds.
- Possessing within the sanctuary (regardless of where taken, moved or removed from) any historical resource, or any marine mammal, sea turtle, or seabird taken in violation of the Marine Mammal Protection Act, ESA, or Migratory Bird Treaty Act.
- Interfering with, obstructing, delaying, or preventing an investigation, search, seizure, or disposition of seized property in connection with enforcement of the NMSA or any regulation or permit issued under the NMSA.
- The Department of Defense is prohibited from conducting bombing activities within the sanctuary.

OCNMS spans 3,188 square miles (8,257 square kilometers) of marine waters off Washington state's rugged Olympic Peninsula. Extending seaward approximately 25 to 45 miles (40 to 72 kilometers), the sanctuary covers much of the continental shelf and the heads of three major submarine canyons, in places reaching depths of over 4,500 feet (1,400 meters). The shoreward boundary of the sanctuary is the mean lower low water line when adjacent to tribal reservations and state and county lands. When adjacent to federally managed lands, the coastal boundary extends to the mean higher high water line. The coastal boundary cuts across the mouths of all rivers and streams.

The sanctuary borders an undeveloped coastline, enhancing protection provided by the 56-mile-long (90-kilometer) wilderness of Olympic National Park's coastal strip, as well as more than 600 offshore islands and emergent rocks that extend 100 miles (161 kilometers) along the coast within the Washington Maritime NWR Complex, established in 1907, which includes Flattery Rocks NWR, Quillayute Needles NWR, and Copalis NWR and is managed by the U.S. Fish and Wildlife Service (USFWS).

The sanctuary is located within the boundaries of the legally defined U&A fishing areas of the Coastal Treaty Tribes. While the sanctuary boundary was established in 1994, the U&A fishing areas were acknowledged by the United States via treaties with the Coastal Treaty Tribes in 1855 and 1856. Tribal U&A fishing areas extend 30–40 nautical miles offshore and tribal commercial, ceremonial, and subsistence fisheries occur throughout. OCNMS does not manage fisheries; fisheries resources are managed in coordination by federal, state, and tribal co-managers. Tribal governments also manage the land, resources, and people on their respective reservations. Several tribes, including the Makah Tribe and Quinault Indian Nation, are treated as states by the Environmental Protection Agency (EPA) and manage water quality on reservations, issue permits, and perform other activities under the Clean Water Act.

The National Environmental Protection Act requires federal agencies to prepare an environmental impact statement for major federal actions that would significantly affect the environment. NOAA's National Marine Fisheries Service (also referred to as NOAA Fisheries) manages fisheries from 3–200 nautical miles through fishery management plans prepared by the Pacific Fisheries Management Council under the Magnuson-Stevens Fishery Conservation and Management Act of 1976. NOAA Fisheries and USFWS manage marine mammals under the Marine Mammal Protection Act and threatened and endangered species under the ESA. USFWS also implements the Migratory Bird Treaty Act. The U.S. Coast Guard is the lead federal agency in managing vessel traffic, oil and other hazardous spills, navigation, maritime safety, search and rescue, and federal enforcement (Clean Water Act, fisheries, sanctuary regulations, etc.). Military activities in the area of the sanctuary consist of subsurface, offshore surface, and aerial operations by the U.S. Navy. The U.S. Army Corps of Engineers manages dredging activities as well as jetty maintenance. The EPA manages ocean dumping, vessel scuttling, air and water quality, and pollution activities, including permitting point source pollution into navigable waters of the U.S. or ocean waters, such as the National Pollution Discharge Elimination System program. Agencies must also comply with the National Historic Preservation Act to protect cultural and archeological resources; Section 106 requires agencies to consider potential impacts of their actions, which includes the review of permit applications for projects that may include disturbance of the seabed where archaeological remains may lie. Section 110 requires agencies to actively search for archaeological resources and to assess them for their significance and eligibility for inclusion in the National Register of Historic Places.

State and local authorities apply within state waters (0–3 nautical miles from shore). However, under the Coastal Zone Management Act, the federal consistency clause allows state agencies to review federal actions that will affect the state's coastal resources and to ensure consistency with the Coastal Zone Management Program's approved enforceable policies. State agencies and local governments implement the State Environmental Protection Act, in which they review proposed actions to identify environmental impacts. The Ocean Resources Management Act outlines state policies and regulations on the planning and permitting of ocean uses on the outer Washington coast.

The Washington State Department of Ecology is charged with implementing portions of the Clean Water Act as delegated by the EPA, including Section 401 certification to ensure a project will comply with state water quality standards as well as National Pollution Discharge Elimination System construction stormwater permits. The Department of Ecology is also the state lead in implementing the approved Coastal Zone Management Program, which is approved by NOAA under the Coastal Zone Management Act. The Washington Department of Natural Resources administers leases, easements, and rights-of-entry to authorize use of the seabed of Washington's marine waters under Aquatic Use Authorizations. The Washington Department of Fish and Wildlife manages state commercial and recreational fisheries, finfish aquaculture, and hydraulic projects in state waters.

OCNMS is adjacent to Clallam, Jefferson, and Grays Harbor counties. Local governments (county or city) implement several authorizations and permits relevant to the ocean. Under the Shoreline Management Act, counties and cities develop Shoreline Master Programs to protect shoreline resources and public access while allowing for water-dependent uses out to 3 nautical miles. The Shoreline Master Plans are approved by the state as part of their Coastal Zone Management Program. Local governments also implement the Growth Management Act and floodplain management.

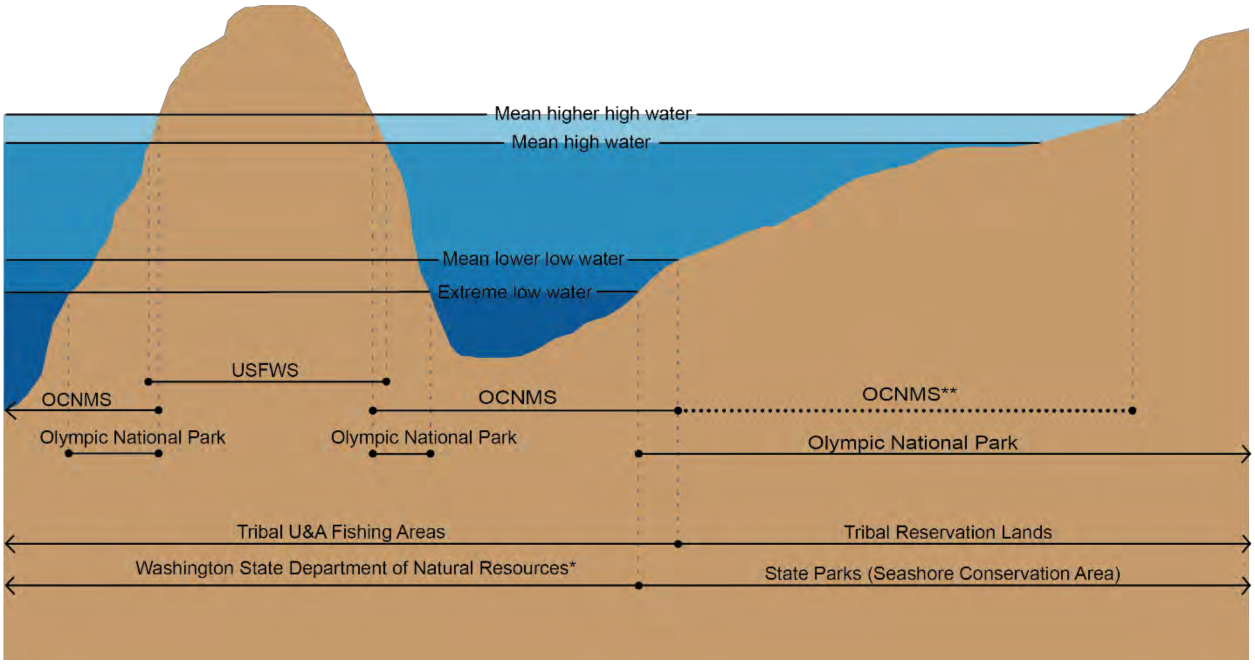


Figure SS.9. Jurisdictional authorities of the Olympic Coast overlaid on a cross-section that illustrates bathymetry from shore (right) to sea (left). Image: D. McLaughlin/NOAA (modified from Antrim/NOAA)

*Washington state ownership and jurisdiction extends out to three nautical miles from shore. The Washington Department of Natural Resources manages the majority of state-owned tidelands in the Strait of Juan de Fuca, Puget Sound, Willapa Bay, Grays Harbor, and along the Columbia River. The state owns around 30% of tidelands, and the rest are privately owned.

**OCNMS jurisdiction extends shoreward to mean higher high water when adjacent to ONP and to mean lower low water when adjacent to tribal reservations, state, and county-owned lands.

Drivers

For purposes of condition reports drivers are defined as societal values, policies, and socioeconomic factors that influence different human uses of the ecosystem. Drivers can influence the condition, or state, of the environment, creating both negative results, considered pressures, as well as positive results that benefit the environment. Drivers can result in pressures that affect the condition, or state, of the environment. They help us understand the forces behind pressures and are the ultimate cause of anthropogenic changes in ecosystems. Further, drivers may be local, regional, national, or global in scale. Because the majority of influential drivers originate and operate at large geographic scales, this section necessarily begins with a broad focus on drivers, followed by a much more locally focused discussion of pressures that directly affect sanctuary water, habitat, living resources, and maritime heritage resources. Trends in drivers and pressures support the assessment of these resources and can aid in forecasting the direction and influence of future pressures.

Pressures may be affected by one or more drivers, which often affect multiple pressures. The most influential drivers of pressures at OCNMS are shown in Table D.1 and are also integrated in discussions of each pressure. Table D.1 shows the relationships between drivers and pressures.

Table D.1. Drivers and their relationship to pressures that affect OCNMS resources. For each row, the bullets indicate the range of influence of drivers across pressures. For each column, the bullets indicate drivers affecting 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**	**Changing Ocean Conditions**	**Noise**	**Large Vessel Traffic**	**Petroleum & Other Chemical Spills**	**Vessel Discharges**	**Exhaust Gas Cleaning Discharges**	**Cables & Pipelines**	**Fishing**	**Military Activity & Use**	**Marine Debris**	**Non-indigenous/ Invasive Species**	**Research Activities**	**Aquaculture**	**Visitation**
Tribal Treaty Rights and Gov't Relationships	N, R, L	•	•	•	•	•		•	•	•	•	•	•	•	•
Traditional Management	L								•					•	•
Population	G, N, R, L	•	•	•	•	•	•	•	•		•	•	•	•	•
Per-capita Income	G, N, R, L	•	•	•	•	•	•	•	•		•	•		•	•
GDP	G, N, R, L	•	•	•	•	•	•	•	•		•	•		•	•
Fuel Prices	G, N, R, L	•	•			•			•		•				•
Demand for Seafood	G, N, R, L	•	•	•		•			•		•	•		•	•
Regulatory Exemptions	N, L		•	•	•	•				•					
Demand for Energy	G, N, R, L		•	•	•			•							
Societal Values/ Conservation Ethic	N, R, L	•							•		•	•	•	•	•
Environmental Activism	R, L	•	•	•	•	•	•		•	•	•	•	•	•	•
Ocean Policy	N, R, L	•	•	•	•	•	•	•	•		•	•		•	•

		PRESSURES													
Drivers	**Scale**	**Changing Ocean Conditions**	**Noise**	**Large Vessel Traffic**	**Petroleum & Other Chemical Spills**	**Vessel Discharges**	**Exhaust Gas Cleaning Discharges**	**Cables & Pipelines**	**Fishing**	**Military Activity & Use**	**Marine Debris**	**Non-indigenous/ Invasive Species**	**Research Activities**	**Aquaculture**	**Visitation**
U.S. National Security	N		•	•		•				•			•		•
Technological Advancement	G, N, R, L		•	•	•		•	•	•		•	•		•	

Drivers operate at different, and sometimes multiple, scales ranging from local to international. Most affect demand for resources (e.g., food, infrastructure, access for recreation) and, thus, levels of activities (e.g., development, ship traffic, boating, pollution, noise) that alter resource conditions. Some, like the gross domestic product (GDP) of foreign countries, have global influence. Among other things, GDP affects global demand for seafood and the pressure of commercial fishing. Local drivers, on the other hand, are those that originate from and influence the OCNMS "local economy" (sometimes called the "study area" or "sanctuary economy") (Figure D.1). This area is identified by looking at commuter work flows in the counties adjacent to the sanctuary to determine the spatial footprint of localized socioeconomic contributions stemming from the use of sanctuary resources. These contributions include income, jobs, and economic output, all of which respond to changes in resource conditions that are influenced by changing pressures. Although the population centers within these counties are not on the outer coast, these counties contain the highest concentration of people who depend on the sanctuary and its resources for their livelihoods.

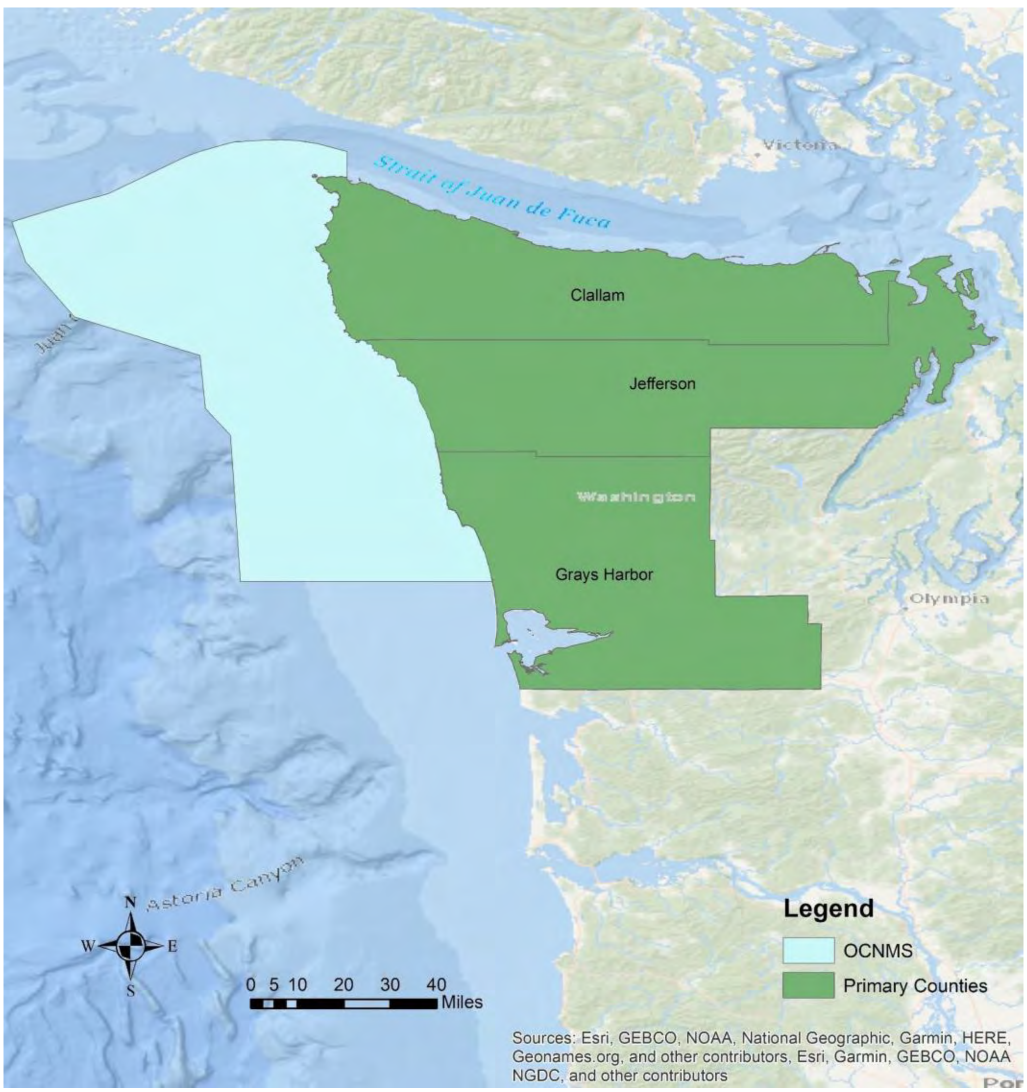


Figure D.1. Map of OCNMS and the study area, which includes counties with populations that are likely to have the greatest economic dependence on sanctuary resources. Image: NOAA

Some drivers influence the supply of or access to resources. These stem mostly from management and policy actions, whether local, state, tribal, national, or international, and may increase or decrease the pressures on resources. Some, such as relationships established and dictated through treaties, create cooperative management approaches that can preempt pressures (e.g., cooperative fisheries management, preparation of oil spill response plans). Importantly, these drivers also exemplify a concept frequently expressed by Indigenous peoples, namely the reciprocal relationship between people and the environment. This originates from Indigenous peoples' sense of oneness with nature and emphasizes the mutual roles of both in supporting each other. Advocates of the modern conservation movement will recognize this as a foundational aspect of their efforts as well. In this way, both can be considered "positive" drivers.

Before discussing other drivers, it is important to consider NOAA and OCNMS mandates as institutional drivers. Starting with federal agencies' basic obligation of public service, each employee has an oath-bound responsibility to the United States government and its citizens to display loyalty to the Constitution, laws, and ethical principles (5 CFR § 2635.101). This includes fulfilling the responsibilities outlined in the NMSA (16 U.S.C. § 1431), which:

> "establishes areas of the marine environment [that] have special conservation, recreational, ecological, historical, cultural, archeological, scientific, educational, or esthetic qualities as national marine sanctuaries managed as the National Marine Sanctuary System will—(A) improve the conservation, understanding, management, and wise and sustainable use of marine resources; (B) enhance public awareness, understanding, and appreciation of the marine environment; and (C) maintain for future generations the habitat, and ecological services, of the natural assemblage of living resources that inhabit these areas."

This guiding language ensures that the sanctuary acts in a manner to improve conservation and management for generations to come. The fulfillment of the OCNMS designation, authorized by the NMSA and carried out as a public process, is a public trust. The designation (59 FR 24586) states:

> "The Act authorizes the issuance of such final regulations as are necessary and reasonable to implement the designation, including managing and protecting the conservation, recreational, ecological, historical, research, educational, and aesthetic resources and qualities of...Olympic Coast National Marine Sanctuary."

Tribal Treaty Rights and Government Relationships

The Treaties of Neah Bay and Olympia are the "supreme law of the land"[8] under the U.S. Constitution and, accordingly, the federal government has a federal trust responsibility to protect the treaty rights of signatory tribes. This legally enforceable fiduciary obligation protects tribal treaty rights, lands, assets, and resources. Several Supreme Court cases have used language affirming legal responsibilities, moral obligations, and the fulfillment of understandings and expectations that have arisen over the history of the relationship between the United States and treaty tribes.

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[8] Constitution of the United States, Art. VI, Clause 2.

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. To the extent consistent with federal law, NOAA implements its trust responsibility toward the Coastal Treaty Tribes and discharges its statutory mission under the NMSA to:

- Protect and conserve treaty trust resources;
- Protect the exercise of treaty rights by the Coastal Treaty Tribes;
- Support the development of and deference to tribal treaty resource management plans meeting the objectives of the NMSA; and
- Consult with the Coastal Treaty Tribes on a government-to-government basis when proposing an action that may affect treaty resources, tribal treaty rights, or resources of cultural or historical significance.

The Coastal Treaty Tribes have place-based rights in the ocean, with reserved rights to half of the harvestable marine species that transit through their U&A fishing areas. U&A fishing areas of the Coastal Treaty Tribes overlap with OCNMS, and the sanctuary is within a tribal U&A fishing area. The presence of treaty rights, and the federal government's responsibility to uphold those rights, are positive drivers that help maintain the condition of OCNMS. Those positive drivers include ensuring sustainable fish populations upon which to exercise treaty rights in perpetuity and protecting the coast from oil spills that would threaten those rights.

Collaborative research with the Coastal Treaty Tribes also benefits OCNMS by forming partnerships that help to secure competitive funds, extending the ability to monitor and conduct research in remote areas of the sanctuary, and incorporating the long history of traditional knowledge of coastal ecosystems carried by tribal members.

Traditional Management

Tribal and traditional knowledge enhances contemporary management through the robust knowledge each of the Coastal Treaty Tribes have developed in this region over thousands of years. Tribes also have a reciprocal relationship with nature, meaning that people benefit or receive services from nature and nature benefits or receives services from people. This is demonstrated in a variety of ways, through restoration and conservation efforts, in oral history and traditional knowledge, and in policy and management decisions.

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 (2020).

The U.S. population increased by 5.8% between 2010 and 2018. In Washington, the increase was greater, at 11.8%. Of the 7.5 million residents of Washington state, just over 182,000 (2.4%) live in the three-county OCNMS study area (Clallam, Jefferson, and Grays Harbor counties) (Table D.2). The population in the study area grew by only 4.7% from 2010 to 2018. Per capita income in the study area has also increased at a slower rate than in both the U.S. and

Washington. It increased by 34.3% in the United States, 45.3% in the state of Washington, and 33.2% in the study area from 2010 to 2018.

Table D.2. Population and real per capita income for study area, 2010–2018. Source: U.S. Census, 2020

Year	Per Capita Income	Population	Per Capita Income (% Change)	Population (% Change)
2010	$33,743	174,243	N/A	N/A
2011	$35,054	173,958	3.9%	-0.2%
2012	$36,586	173,330	4.4%	-0.4%
2013	$36,597	173,098	0.0%	-0.1%
2014	$38,905	173,399	6.3%	0.2%
2015	$40,075	174,580	3.0%	0.7%
2016	$41,276	176,748	3.0%	1.2%
2017	$43,032	179,456	4.3%	1.5%
2018	$44,938	182,367	4.4%	1.6%

The expected result of increases in both per capita income and population over the past decade is an increase in pressures on resources in OCNMS, created by higher demand for products and services. Activities required to meet the demand could include fishing, transportation, energy development and exploration, submarine cable installation, construction, land development, and visitation. These have direct impacts on resources, such as pollution, removal of fish, seafloor disturbance, marine mammal ship strikes, and underwater sound impacts on marine mammals and other species. Many of these activities also produce greenhouse gases, increase rates of runoff and pollution, and change the way land is used. An increase (or decrease) in pressures based on population increases may vary by county. Therefore, population change can have direct and indirect influences on threats ranging from beach closures to climate change.

In 2018, there were about 11,100 people living within ZIP codes adjacent to the Olympic Coast, mostly in small, rural, remote communities. Tribal reservations are the only communities situated on the coast, many of which are adjacent to the mouths of rivers. These communities have primarily natural-resource-dependent economies, relying on commercial fishing, timber harvest, and tourism. The figure below shows how population has changed from 2011 to 2018 by ZIP code on the outer coast.

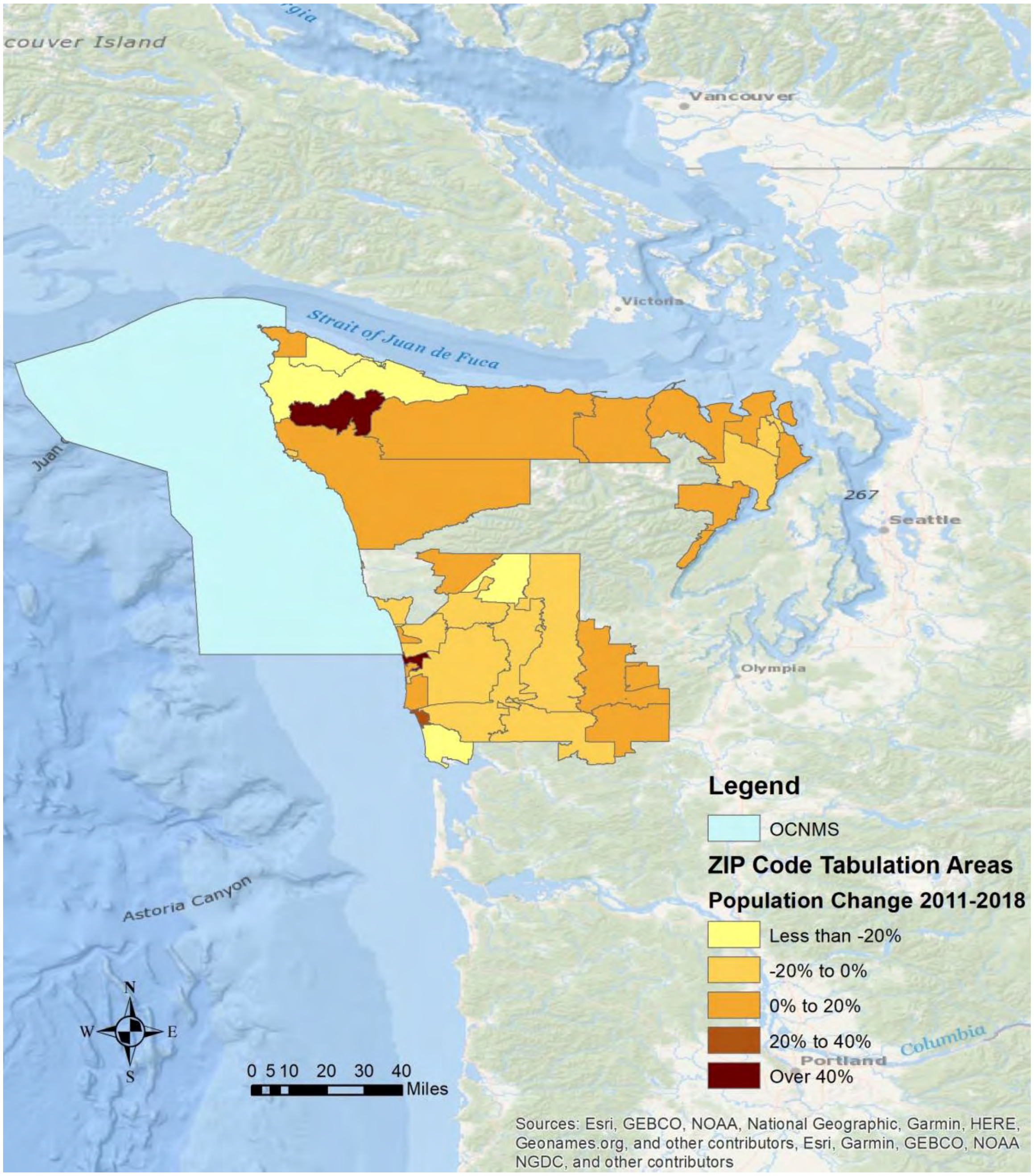

Figure D.2. Population change from 2011 to 2018 by ZIP code. Source: U.S. Census Bureau, 2020

Gross Domestic Product

Another high-level driver of pressures on natural resources, including those in OCNMS, is the GDP of trade partners that were the top importers of U.S./tribal seafood and other fishery products in 2018, namely Canada, the European Union, China, Japan, Switzerland, and South Korea (National Marine Fisheries Service, 2020). Changes in GDP in these countries directly affect demand for all goods. Furthermore, seafood is bought and sold in a global market such that changes to demand directly affect prices of species caught in OCNMS and, thus, affect fishing behavior in and around the sanctuary itself. GDP growth for each of these trading partners is shown in Figure D.2. With the exception of China, most countries' GDP growth remained stable from 2008 to 2018. Despite remaining stable (or decreasing in China), GDP growth for all countries has been positive since 2013, so it is likely that demand for OCNMS products continued to increase (Organisation for Economic Co-operation and Development [OECD], 2020; Figure D.3).

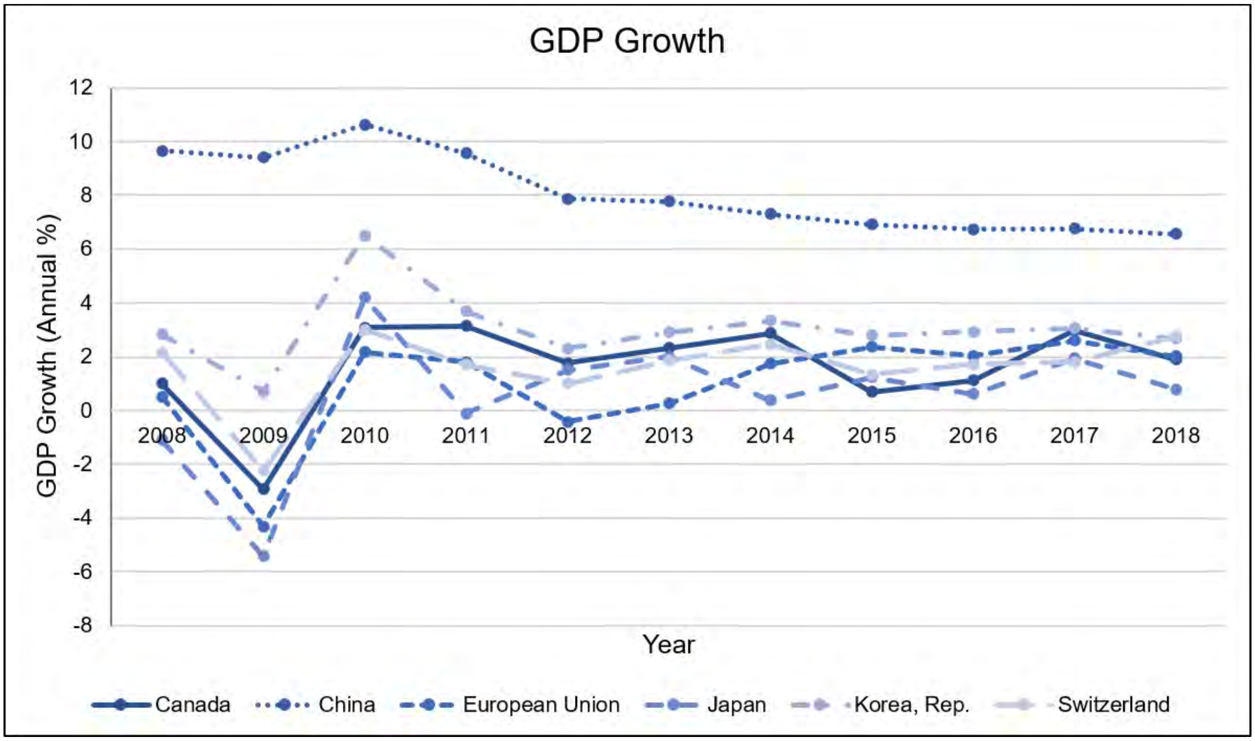

Figure D.3. GDP growth in top countries receiving U.S. seafood exports. Source: OECD, 2020

Fuel Prices

Fuel prices are an important, and often an immediate, driver of many ocean activities. Ocean users consider fuel prices in their decisions about whether to conduct activities like commercial fishing, to buy and register boats for ocean recreation, or to explore for offshore oil and gas (and in the longer term, install offshore renewable energy facilities). Gasoline prices varied from 2008 to 2018, but had no clear trend (Figure D.4). By the end of the study period, fuel prices were 5.3% below those of 2008, but Washington boat registrations during the period decreased by 7.5% (U.S. Energy Information Administration [EIA], 2020; National Marine Manufacturers Association [NMMA], 2019). The U.S. average price of retail diesel is also presented below and shows similar trends to retail gasoline, but at higher price points for each year. (Data on retail diesel prices were not available at the state level on the U.S. Energy Information Administration [EIA] website). This may be partly explained by higher fuel prices between 2011 and 2014, but there were likely other drivers that influenced the use of boats in the area. While fewer boat registrations would suggest that pressures from on-water use of motorized vessels may have decreased, state-wide registration data do not indicate spatial patterns of use. Regardless, considering data from registrations, it is likely that the pressures from on-water use of motorized vessels may be decreasing.

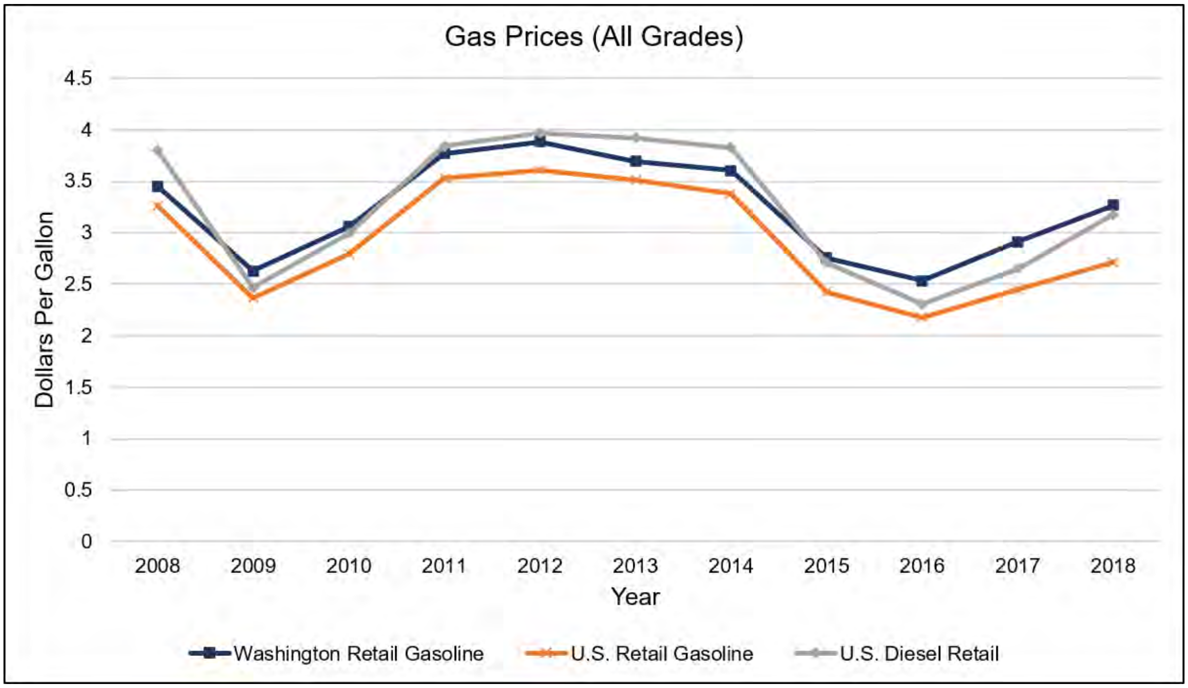

Figure D.4. Retail gasoline prices for Washington and the U.S., 2008–2018. Source: EIA, 2020

Demand for Seafood

As global and domestic demand for seafood grows, effective management of wild-caught fish and continued increases in the growth of aquaculture will be required (NOAA Fisheries, 2020a). Yet, while these approaches are needed to meet demand, they may also lead to increased pressures on resources and ecosystems. While this section considers global and national demand, local and regional markets are likely to be affected and face increased pressures to meet global and national demands. Further, as prices fluctuate locally, this may change the willingness of commercial fishermen to expend time and resources targeting specific species. For example, if the price of salmon increases while the price of black cod stays the same, more effort may be spent harvesting salmon. For more information on harvest revenue and landings of species within the Olympic Coast region, see the Commercial Harvest section of this report.

Global seafood production has quadrupled over the past fifty years, while the world population has more than doubled, and the average person now eats almost twice as much seafood as half a century ago (Ritchie & Roser, 2019; Food and Agriculture Organization of the United Nations, 2020). Although the global supply of wild-caught fish has been relatively steady for more than 20 years, the human population continues to grow, and the U.S. imports over 80% of seafood, about half of which is farmed seafood (NOAA Fisheries, 2020a). Aquaculture has been increasing in Washington state, and there are roughly 2,100 acres of Washington state-owned land under lease for aquaculture (primarily in tidelands; Washington Sea Grant, 2015; Washington State Department of Natural Resources, 2020a). Aquaculture in Washington state is dominated by shellfish and occurs in Puget Sound, Grays Harbor, and Willapa Bay. Washington state is the largest producer of farmed shellfish in the U.S., generating 25% of domestic production. Washington state has banned non-native fish net pen aquaculture within state waters following a failure of an Atlantic salmon net pen near Cypress Island in Puget

Sound, in which approximately 250,000 Atlantic salmon were released, with remaining facilities phasing out by 2025 (Wash. Rev. Code § Chapter 77.125). However, interest in aquaculture of native finfishes has increased in Puget Sound in response to this moratorium.

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 the sanctuary through water quality degradation, injury to sanctuary resources or habitats, or other impacts.

There are several sanctuary regulations for which federal agencies or other entities have exemptions. The Department of Defense, specifically the Navy, trained and tested in this region for decades prior to the designation of OCNMS. As such, some military operations are exempt from sanctuary regulations, including:

- Hull integrity tests and other deep-water tests;
- Live firing of guns, missiles, torpedoes, and chaff;
- Activities associated with the Quinault Range Site, including the in-water testing of non-explosive torpedoes; and
- Anti-submarine warfare operations.

As of September 2020, the proposal for a Department of Defense exemption for the Quinault Range Site on the Olympic Coast could also affect the designation of critical habitat for humpback whales and Southern Resident killer whales.

Other examples of regulatory exemptions for OCNMS include:

- Coastal Treaty Tribes exercising treaty-secured rights;
- Overflight requirements for tribal timber operations conducted on reservation lands or to transport persons or supplies to or from reservation lands as authorized by a governing body of an Indian tribe;
- Certain activities that may incidentally affect the submerged lands of the sanctuary, including:
    - Installation of navigation aids;
    - Lawful fishing operations;[9]
    - Vessel anchoring;
    - Harbor maintenance in the areas necessarily associated with the Quillayute River Navigation Project, including dredging of entrance channels and repair, replacement or rehabilitation of breakwaters and jetties, and related beach nourishment;

[9] Fisheries are regulated under the Magnuson-Stevens Fishery Conservation and Management Act and are not regulated by OCNMS or the NMSA.

- Construction, repair, replacement, or rehabilitation of boat launches, docks, or piers and associated breakwaters and jetties; and
- Beach nourishment projects related to harbor maintenance activities.

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. For example, the Trans Mountain Pipeline was oversubscribed by over one-third in early 2018 (Trans Mountain, 2018), meaning the pipeline capacity was insufficient to meet demand. A project to expand the pipeline is in development in response to requests from shippers to increase supply so that they may meet demand in new and growing markets. This is North America's only pipeline with West Coast access, and its expansion would increase shipping traffic along the coast and within the sanctuary. Specifically, oil-laden tanker traffic would increase seven-fold from one tanker a week to one a day, which would increase pressures on resources and the risk of an oil spill in the region.

Societal Values/Conservation Ethic

Information on societal values related to conservation can be obtained from various national or local opinion polls. Nationally, several are relevant to OCNMS pressures. First, a national poll focusing on how much people worry about climate change found that the percentage of people who "worried a great deal" increased from 37% to 44% from 2008 to 2019 (Figure D.5). Further, the percentages "worrying a great deal" in the last three years (2017–2019) have been the highest since the poll started in 1995 (Gallup, 2020).

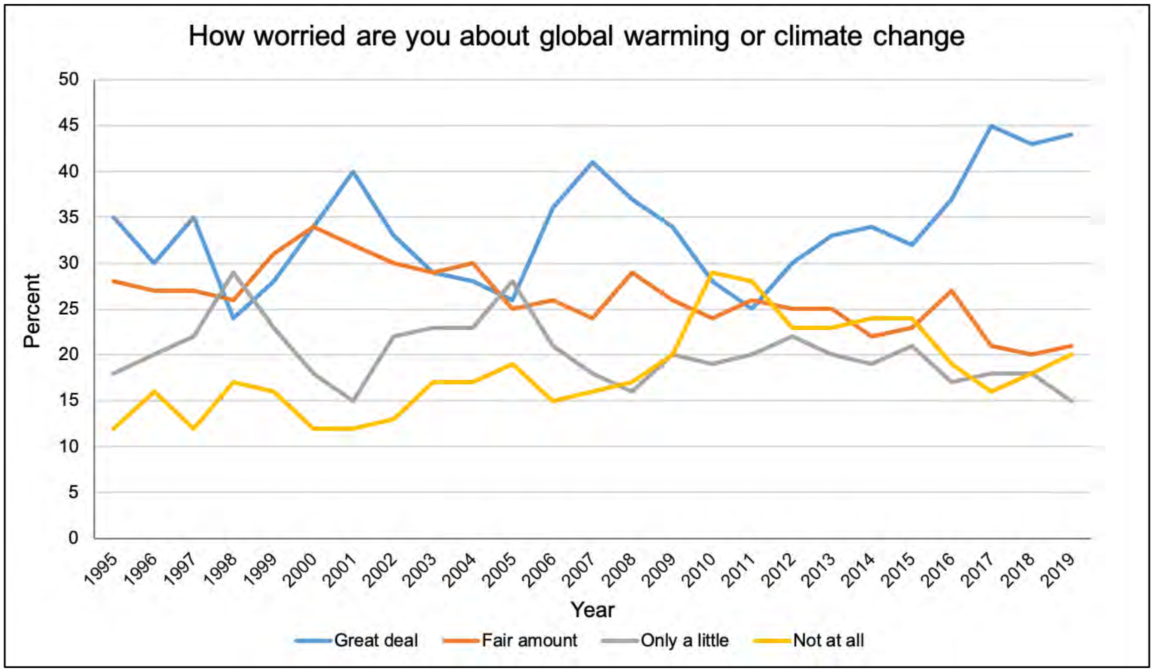

Figure D.5. Responses to the national opinion poll question "How worried are you about global warming or climate change?" from 1995–2019. Source: Gallup, 2020

Additionally, a national poll conducted by Pew since 2014 found that more Americans now oppose (51%) rather than favor (42%) allowing offshore oil and gas drilling in U.S. waters, most likely reflecting increasing awareness over links between fossil fuel consumption and climate change. This represents a 10 percentage point decline in those who favor expanded offshore drilling since 2014 (Jones, 2018).

According to a poll conducted annually in the state of Washington, between 2009 and 2018, no more than 7% of people considered the environment a top priority. In January of 2019, however, 15% of respondents considered the environment a priority, the highest since 2001. Likely reasons for the increase include growing impacts from wildfire smoke in Washington, a marine heatwave from 2013–2016, and the death of a killer whale calf—the first in years to be born to a pod of Southern Resident killer whales—shortly after its birth (Secaira, 2019). International attention on the threats to orca populations resulted from images of the mother whale carrying around the calf's body and pushing it to the surface for seventeen days over hundreds of miles (Buch, 2018).

Another study of Washington households provides a point estimate about attitudes and perceptions related to the sanctuary (Leeworthy et al., 2016). Specifically, survey respondents were willing to pay, on average, $152 annually to ensure that there is low impact of development, no offshore structures, and easy access to beaches and shores. This is a driver that helps to inform local attitudes toward pressures related to coastal and offshore development, such as energy development, and indicates there is support to maintain natural viewscapes void of development.

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.

Activism directly related to the changing conservation ethic discussed above resulted in several new programs forming on the outer Washington coast. In 2015, the Washington State Legislature created the Washington Coast Restoration and Resiliency Fund, allocating $10–15 million per biennium on coastal restoration projects and local economic development. The Surfrider Leadership Academy, focused on effective leadership development for coastal conservation on the Washington coast, also launched in 2015. Past participation included individuals from the Makah and Quileute tribes, Quinault Indian Nation, Pacific Coast Shellfish Growers Association, City of Ocean Shores, The Nature Conservancy, and more.

In the Heritage section of this report, other examples from the sanctuary's history are discussed in further detail, including a hike by Supreme Court Justice William O. Douglas of the Olympic Coast in 1958 to protest a proposed highway through the undisturbed old growth forest of the coast, and Washington Attorney General Bob Ferguson replicating his hike in protest of proposed offshore oil and gas exploration along the Olympic Coast 60 years later.

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 Hake/Whiting Joint Management Committee, 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.

Since 2010, the United States has had an ocean policy, first through Executive Order 13547 (2010) and later replaced with Executive Order 13840 (2018). While the primary focus differs between these policies, both emphasize improving cross-agency coordination on management of the ocean and its resources and access to data. Mapping the seafloor of our nation's waters is a priority under the current ocean policy to enhance navigation and development of the blue economy. Furthermore, in 2019, a Presidential Memorandum on "Ocean Mapping of the United States Exclusive Economic Zone (EEZ) and the Shoreline and Nearshore of Alaska" set forth a strategy for mapping, exploring, and characterizing the EEZ through enhanced collaboration.

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.

Washington state completed a marine spatial plan for the outer coast in 2018. The marine spatial plan covers the entire outer coast of Washington state to 700 fathoms (4,200 feet) depth and is focused on planning for potential new uses (e.g., marine renewable energy, offshore aquaculture, dredge disposal, mining, marine product harvesting) and maintaining existing sustainable uses (e.g., fishing, shellfish aquaculture, recreation, maritime shipping). The sanctuary was supportive of the marine spatial planning process, and the entire sanctuary was included in the study area.

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 bases via sea level rise, but also because melting of the polar ice caps can open new avenues for shipping and raise security concerns. The increasing intensity and frequency of natural disasters also increases demand for disaster relief, further threatening national security.

The Department of Defense has had a presence on the Olympic Coast for over one hundred years. The Navy tests and trains to ensure it meets its statutory mission (10 U.S.C. § 8062). U.S. military activities may affect pressures on sanctuary resources in OCNMS, including disturbance from noise and vessel traffic. This is discussed further in the Pressures section in the context of the Navy's Northwest Testing and Training study area.

Technological Advancement

Technological advancement may be viewed as either a positive and negative driver depending on the technology and what it promotes. For example, requirements for seafloor mapping may act as a positive driver by increasing knowledge and awareness of sensitive habitats and refining our understanding of species distributions. Significant efforts to increase seafloor mapping in OCNMS by NOAA ships *Fairweather* and *Rainier*, as well as the R/V *Nautilus* and R/V *Ocean Titan* have taken place in the past decade. On the other hand, seafloor mapping may also identify previously unknown deposits of oil and minerals, which could increase pressures to extract those resources. Advancements in fishing technology in the past have resulted in increased harvests while decreasing the effort needed to catch fish. Improvements in fishing gear technologies can also reduce bycatch of sensitive species. Advancements in autonomous vehicles have helped to estimate fish abundance to promote sustainable fishing while reducing the risks to human health and fish (NOAA Fisheries, 2020b).

Pressures on the Sanctuary

Human activities and natural processes both 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 OCNMS, including changing ocean conditions, ocean sound, maritime transportation, submarine cables, fishing, whale entanglement, military activities, marine debris, non-indigenous and invasive species, contaminants, research activities, offshore aquaculture, offshore energy, and increased visitation.

Changing Ocean Conditions

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 patterns. 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, occurence/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). However, 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.

Anthropogenic climate change is primarily caused by greenhouse gas emissions. Greenhouse gases (i.e., 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 (Intergovernmental Panel on Climate Change [IPCC], 2019).

As global temperatures rise, the ocean has absorbed over 90% of the excess heat, causing the average ocean temperature to increase worldwide (IPCC, 2019). In OCNMS, water temperatures are expected to increase 2°F (1.1°C) by 2050 (Mote & Salathé, 2010). Warmer sea surface temperatures may weaken circulation patterns that drive upwelling, resulting in lower productivity. Furthermore, copepod communities are impacted by increasing ocean temperatures, with lipid-poor, warm-water species becoming more prevalent than cold-water, lipid-rich species (McClatchie et al., 2016). Warmer ocean temperatures decrease oxygen and increase stratification (Miller et al., 2013; IPCC, 2019), weaken upwelling and productivity, and affect species composition and ranges. This is especially problematic given the placed-based boundaries of OCNMS and the treaty-reserved rights that each of the Coastal Treaty Tribes have to marine resources in their U&A fishing areas.

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 known as “the blob” led to water temperatures 1.8–7.2°F (1.0–4.0°C) above normal (Bond et al., 2015; Kintisch, 2015). These warm waters also fueled the largest harmful algal bloom (HAB) ever recorded in the Northeast Pacific, which produced toxins that killed whales, sea lions, and birds and led to the closure or delay of the Dungeness crab fishery (McCabe et al., 2016; Washington State Department of Ecology, 2018). As temperatures warm, such HABs may become more common, last longer, and be more toxic (McKibben et al., 2017). Furthermore, marine heatwaves may become more common in the future, lasting longer and becoming larger (IPCC, 2019). For instance, in 2019, another marine heatwave appeared in the Northeast Pacific, lasting until mid-January 2020 and becoming the second largest and longest event recorded in the northern Pacific Ocean (Figure P.1).

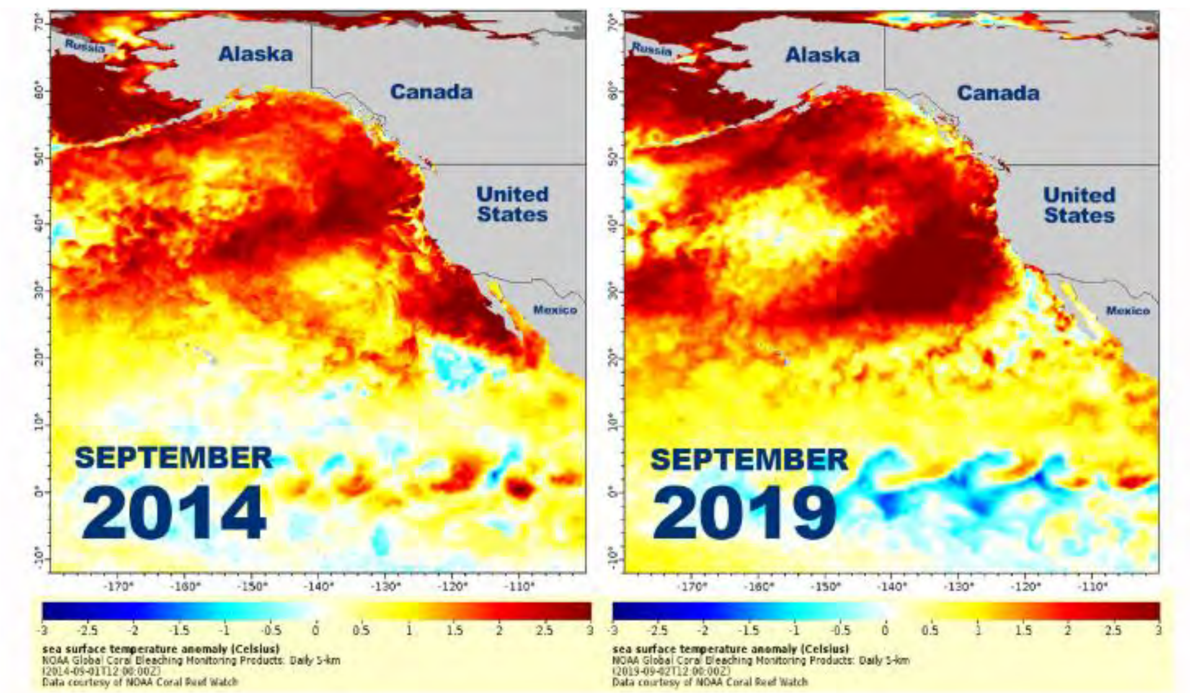

Figure P.1. Sea surface temperature anomaly (°C) along the Pacific coast of North America in September 2014 and September 2019. Several intense marine heatwaves have affected the Northeast Pacific in recent years. Source: NOAA Fisheries, 2019a

There are many kinds of HABs, caused by a variety of algal groups with different biotoxins. HABs of greatest concern in the Pacific Northwest are those that produce neurotoxins, such as saxitoxin, which is produced by dinoflagellates in the genus *Alexandrium* and causes paralytic shellfish poisoning (PSP), and domoic acid, which is produced by diatoms in the genus *Pseudo-nitzchia*. HABs impact commercial, recreational, and subsistence harvest, as well as outdoor recreation and visitation. Climate change is expected to increase the frequency of HABs because warmer sea surface temperatures increase metabolic rates of algae and other primary producers, fueling blooms (Miller et al., 2013; Trainer et al., 2020a). HABs are also influenced by upwelling, which increases nutrient transport to surface waters. In the late 1990s, HABs were identified as a concern on the Olympic Coast, resulting in significant investments by NOAA (i.e., Northwest Fisheries Science Center [NWFSC], National Centers for Coastal Ocean Science [NCCOS]), the State of Washington (i.e., Washington Department of Fish and Wildlife, Department of Health), the Integrated Ocean Observing System (IOOS) and Northwest Association of Networked Ocean Observing Systems (NANOOS), the Coastal Treaty Tribes, and other partners to effectively protect human health and coordinate through the Olympic Region Harmful Algal Bloom partnership.

About one-third of the carbon dioxide (CO_2) released into the atmosphere is absorbed by the ocean, causing a chemical reaction that leads to ocean waters becoming acidified (i.e., lower pH) (Chan et al., 2016; Eyre et al., 2018). Globally, ocean pH has become 30% lower since the beginning of the industrial revolution in the 1880s (Doney et al., 2009). The same chemical reaction also results in reduced availability of the carbonate ion. This makes the water increasingly corrosive for animals like oysters, crabs, pteropods, and deep-sea corals that use calcium carbonate to make and maintain shells and skeletons (U.S. Global Change Research Program [USGCRP], 2018; Davies & Guinotte, 2011; Miller et al., 2013; Barton et al., 2015; Jones et al., 2018a; Bednaršek et al., 2017, 2020). Increased CO_2 in seawater may also affect the development and behavior of finfish (Williams et al., 2019) and zooplankton (McLaskey et al., 2019). Furthermore, ocean acidification will affect marine food webs by impacting prey species (i.e., pteropods, zooplankton) that many important fishery species, such as salmon, herring, and mackerel, depend on (Chan et al., 2016). Within the Pacific Ocean, ocean acidification is projected to cause up to a 50% decrease in carbonate ion concentration of surface waters by 2100 (Feely et al., 2012). Recent studies of fossil foraminifera off the west coast of the U.S. indicate that rates of pH decline in this region may exceed global rates of decline by a factor of more than two (Osborne et al., 2019). Coastal upwelling is seasonally driven by alongshore winds, which push surface waters offshore via Ekman transport, allowing deep waters to rise to the surface. Upwelled water is cold, salty, and rich in nutrients, but is lower in oxygen and pH than surface waters. The waters over the continental shelf within OCNMS are especially susceptible to acidification because coastal upwelling brings waters high in CO_2 to the surface, where they mix with the atmospheric load (Miller et al., 2013; Jones et al., 2018a).

During the summer upwelling season, low concentrations of dissolved oxygen are a common feature in the subsurface waters of OCNMS. This results from high levels of primary production, which create an organic load that sinks and becomes respired, and strong and persistent stratification that impedes mixing with more oxygenated surface waters. Occasionally hypoxic waters shoal to occupy most of the water column. Hypoxia, defined as dissolved oxygen concentrations low enough to cause stress to aquatic animals (<2 mg/L), has been observed throughout the historical record of the past sixty years (Connolly et al., 2010). However, unusually severe hypoxia has been associated with mortality of fish, crabs, and other marine life off the coasts of Washington and Oregon in recent years. The California Current is expected to continue to experience substantial oxygen loss under future conditions. Under global climate change, hypoxic regions are expected to expand due to warming of the ocean surface and changing circulation patterns (IPCC, 2019; Howard et al., 2020). Furthermore, species will experience habitat compression, as suitable habitat will be constrained by hypoxia from below and warmer sea surface temperatures from above (Howard et al., 2020), which will disproportionately affect species with lower mobility. As water temperatures increase, ocean waters hold less oxygen, yet organisms require more oxygen to survive in warmer water.

Climate change is predicted to impact the coast of OCNMS through changes in sea level and storm intensity. Average sea level is rising worldwide (USGCRP, 2018). However, factors such as currents and changing land height from tectonic activity cause changes in relative sea level to vary by location. As a result, relative sea level is falling in the northern part and rising in the southern part of OCNMS (Miller et al., 2018). Furthermore, increasing storm intensity is contributing to coastal erosion along Olympic Coast beaches through increased wave height and larger storm surges (Miller et al., 2013).

A better understanding of regional ocean responses to global scale climatic changes is needed in order to improve interpretation of observable ecosystem fluctuations, such as changes in temperature, dissolved oxygen, and ocean chemistry. Forecast models that have been downscaled to the Washington-Oregon coast, such as those by Siedlecki et al. (2015), are providing some insights.

Ocean Sound

Sound pollution in the ocean has significantly increased in the past 50 years (Hildebrand, 2009). The primary source of low-frequency ocean sound is commercial shipping; however, military training activities, fishing activities, oil and gas exploration, sonar, airguns, and other active acoustic technologies used in research contribute to anthropogenic sound underwater. The acoustic environment or 'soundscape' within the sanctuary has been studied through passive acoustic monitoring (Figure P.2), and results indicate that there is a predictable presence of sensitive species that actively use low-, mid-, and high-frequency sound throughout this region (Debich et al., 2014, 2016; Hatch & Broughton, 2015). Understanding the soundscape is critical for the conservation of marine species, including marine mammals, fish, and invertebrates. Impulsive sound sources, such as pile driving, seismic surveys, and underwater explosives, can result in physical injury and mortality; however, chronic and continuous sound sources are also a concern due to the potential for impacts to species' fitness and decreases in survival and recovery of protected species (Gedamke et al., 2016a, 2016b). Anthropogenic sound is not uniformly distributed throughout the sanctuary; areas with higher sound include vessel traffic lanes.

Since the early 2000s, several ocean sound monitoring efforts have been sponsored in and around OCNMS by the U.S. Navy's Marine Species Monitoring program, which has maintained an active research portfolio to better understand underwater sound impacts on marine mammals. Past projects have yielded critical insights about sound impacts to animals. These projects include a decade (starting in 2004) of passive acoustic monitoring by Scripps Institution of Oceanography at deep and shallow sites in Quinault Canyon (Oleson et al., 2009; Wiggins et al., 2017); long-term (2014 to present) deployment of ecological acoustic recorders by NWFSC to detect Southern Resident killer whale movements on the Washington Coast (Emmons et al., 2019; Hanson et al., 2017; Hanson et al, 2018); and NWFSC's placement of an array of Vemco acoustic receivers in OCNMS and along the Washington Coast as part of the Salmon Ocean Behavior and Distribution project, which aims to elucidate movement patterns of tagged Chinook and other salmonids that make up the primary prey species favored by Southern Resident killer whales (Smith & Huff, 2020). The SanctSound program, a four-year sound monitoring program involving eight sites within the National Marine Sanctuary System, continues the collaboration between ONMS and the Navy. Recordings from four sites in OCNMS that will be monitored from 2018 to 2022 have already yielded important insights about the underwater sound environment in this region and enabled comparisons within and among sites across the sanctuary system, while building capacity and infrastructure to continue to monitor this dynamic and important variable.

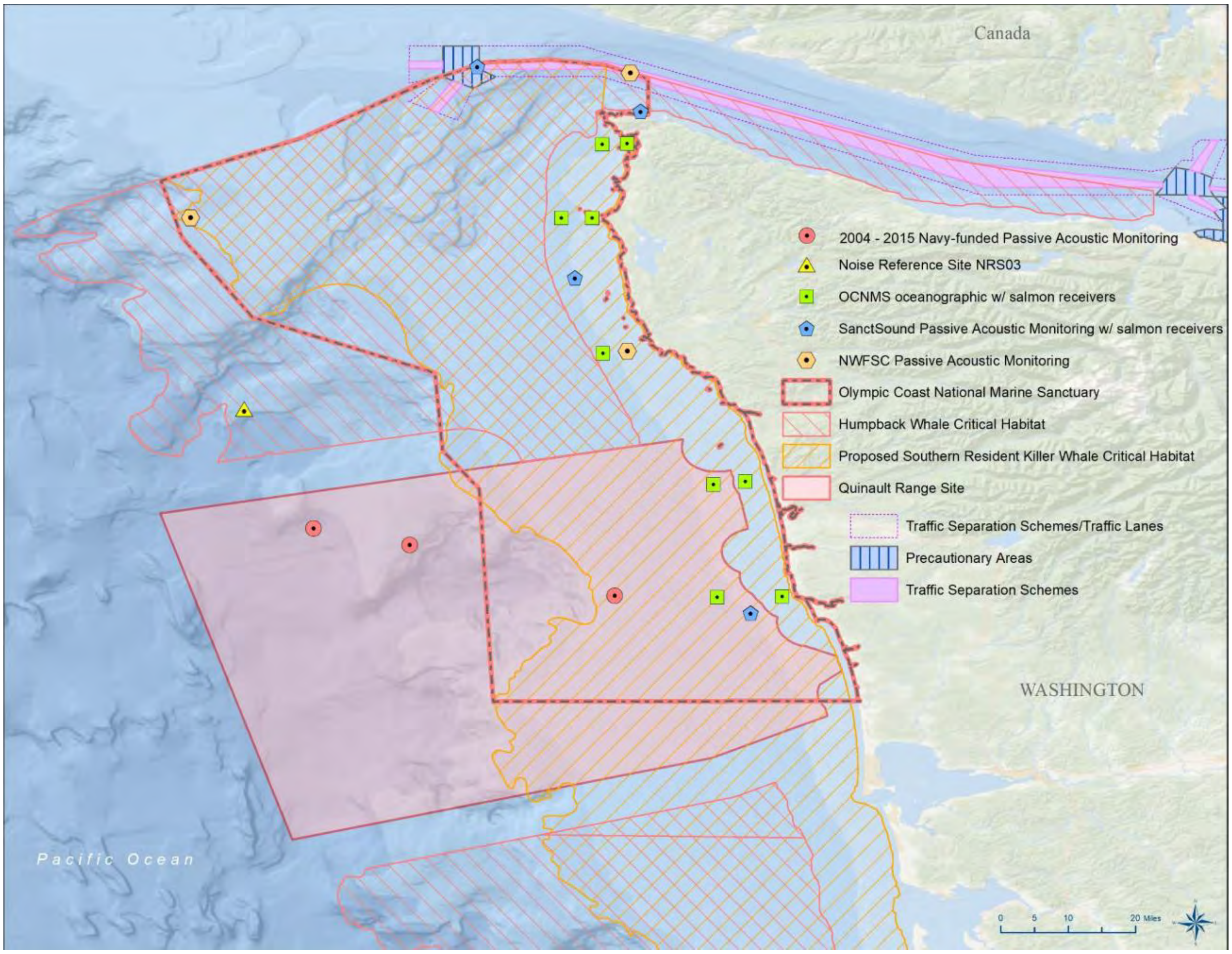

Figure P.2. Overlap between OCNMS, NOAA Fisheries' proposed critical habitat designation for Southern Resident killer whales, critical habitat for North Pacific humpback whales, and the Quinault Range Site within the U.S. Navy's Northwest Testing and Training (NWTT) Study Area. The locations of other important sound monitoring projects conducted in and around OCNMS are also identified. Image: NOAA

Underwater sound is known to impact marine mammals. Marine mammals may respond to sound in a variety of ways, including, but not limited to, altering their breathing rates, spending more time underwater, changing the depth or speed of their dives, shielding their young, changing their vocalization content and duration, and swimming away from the source of the sound (Richardson et al., 1995; Gedamke et al., 2016b). Sound pollution can be acute (intense sound events) or chronic (rising ambient sound) (Hatch & Broughton, 2015). Acute sound impacts may result in temporary or permanent hearing loss and disorientation, which could account for some ship strikes with marine mammals that are unaware of an approaching vessel. Sound impacts could also affect predation efficiency for marine mammals that use sound to forage. Critically endangered Southern Resident killer whales may be especially vulnerable to sound impacts limiting their ability to effectively forage for Chinook salmon and other prey. Factors limiting the recovery of Southern Resident killer whales include lack of prey, sound disturbance, and contaminant levels (i.e., polychlorinated biphenyls [PCBs]). Lacy et al. (2017)

projected that reducing acoustic disturbance by 50%, combined with increasing Chinook salmon by 15%, would meet Southern Resident killer whale recovery goals and have the same effect as increasing Chinook salmon by 30%, equivalent to their highest levels since the 1970s.

Fish also have the potential to be affected by sound in the water. Fish have two sensory systems that can detect sound in the water: the inner ear, which functions similarly to the inner ear in other vertebrates, and the lateral line, which consists of a series of receptors along the body of the fish (Popper & Schlt, 2008). The inner ears of fish are directly sensitive to acoustic particle motion, and direct inertial stimulation of fish otoliths from acoustic particle motion is the most common mode of hearing in fishes (Popper & Fay, 2010; Gedamke et al., 2016b). Impulsive sound sources, such as air guns for seismic exploration, were shown to cause extensive damage to sensory epithelia of fish ears (McCauley et al., 2003). Swim bladders also affect acoustic pressure sensitivity (both hearing and physical), making fishes with swim bladders more susceptible to physical injury from sound than those without (Gedamke et al., 2016b). Less is known about sound impacts to fish from lateral line receptors.

While sound impacts on invertebrates have not been extensively studied, we do know that some invertebrates (e.g., larval coral, squid, octopuses, and oysters) may use sound to inform their physical orientation in the environment, while others rely on sound for courtship, foraging, and protection from predators (Gedamke et al., 2016b). However, it is not clear if invertebrates are sensitive to acoustic pressure changes, nor how any impacts from this sensitivity might affect specific behaviors, population dynamics, or ecological interactions.

Maritime Transportation

As one of North America's major gateways to Pacific Rim trade, the Strait of Juan de Fuca is one of the busiest waterways in the world, with vessel traffic going to several busy ports in Washington state and Vancouver, British Columbia. Every year, approximately 8,300 deep-draft vessels transit the northern part of the sanctuary to enter and depart the Strait of Juan de Fuca (Washington Department of Ecology, 2019). Since the sanctuary was designated in 1994, there has been an ongoing effort to track vessel incidents in or in the vicinity of the sanctuary. Since 1998, the sanctuary has been using an automatic identification system (AIS) data-based vessel traffic monitoring program to monitor compliance with the Area to be Avoided (ATBA) provision, which was established to reduce the risk of oil spills on the remote Olympic Coast. There have been no major oil spills in this region since 1991. The ATBA may also play a role in reducing sound in the nearshore environment of the sanctuary. (More information on ATBA compliance is available in the Response Section).

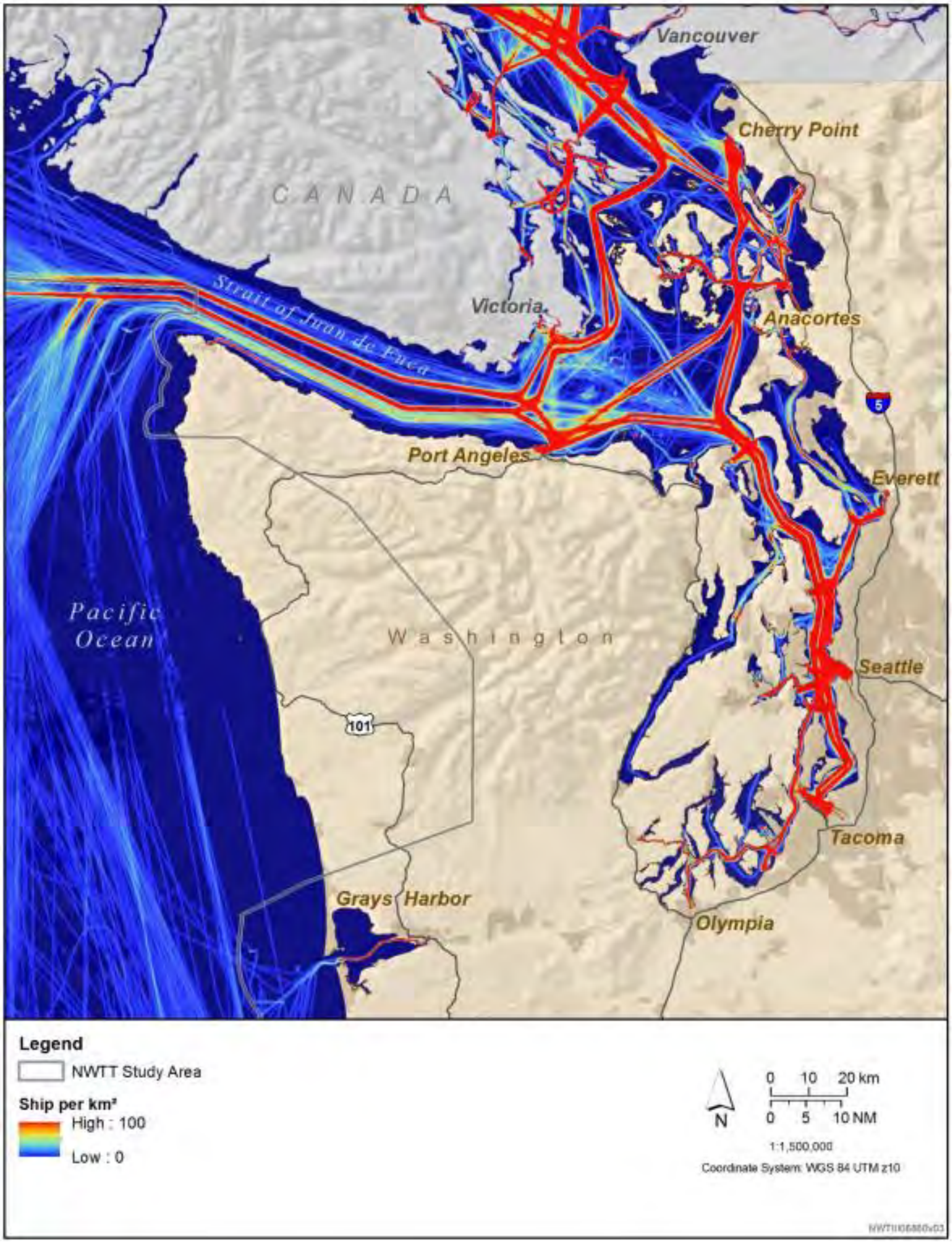

Figure P.3. Relative density of vessel traffic. Image: U.S. Department of the Navy, 2020

Ship Strikes

Whales rely on the highly productive waters of the California Current as part of their migratory routes. Whales are vulnerable to ship strikes as they swim or rest (Sato & Wiles, 2021). Ship strikes are one of the main human-related causes of mortality for large whales (Rockwood et al., 2018). Ship strikes have increased in recent decades due to increasing shipping traffic, vessel speeds, and whale abundance (Sato & Wiles, 2021). Most strikes occur in coastal waters on the continental shelf, where large marine mammals aggregate to feed and vessel traffic is concentrated. Numerous whale species are found in OCNMS, including some endangered or threatened species, such as blue, humpback, orca, and fin whales, among others. Ship strikes are the leading cause of death for blue, humpback, and fin whales along the West Coast; however, of these species, only humpback whales have a modeled mortality risk off of Washington (Rockwood et al., 2018). Between 2013 and 2017 along the West Coast, a total of 65 marine mammals, including 14 humpback and seven gray whales, were reported to have been struck and injured or killed (Carretta et al., 2019). The Navy and USCG are required to report ship strikes with whales to NOAA's National Marine Fisheries Service. Underreporting is assumed, and actual deaths of humpback whales along the West Coast are estimated to be 28 animals annually (Rockwood et al., 2018). In Washington state, from 1980–2017, only two humpback whales were reported to have been killed by ship strikes; the mouth of the Strait of Juan de Fuca was identified as a high-risk area for collision (Carretta et al., 2019). High levels of vessel traffic, increases in abundance and distribution of whales, and changes in feeding areas within the sanctuary increase the risk of ship strikes, which may result in injury or death to whales.

Oil Spills

Washington is one of the nation's primary petroleum refining centers, with 20 billion gallons of oil moving through the state annually. Crude oil moves into the state via tank vessels inbound to Puget Sound refineries. Large quantities of crude oil also move through the Trans Mountain Pipeline from Canada. Refined products are exported from Washington to other western states primarily via pipelines, rail, barges, and tanker vessels. These transportation corridors are the greatest risk for major spills (Figure P.4; Washington State Department of Ecology, 2017a). Total oil moved within Washington state has remained stable at 20 billion gallons since 2008, with a slight change in mode of transportation, namely a reduction in vessels and increase in rail (Figure P.5).

Biodiesel refineries exist in Grays Harbor and along the Columbia River. The Grays Harbor Biodiesel Plant is the largest biodiesel production facility in the U.S., with an annual capacity of 100 million gallons. Biodiesel is a renewable fuel manufactured from vegetable oils, animal fats, or recycled restaurant grease. Biodiesel and other biofuels can spill and pose risks similar to those of oil spills; biofuels are toxic to aquatic and marine ecosystems and are highly flammable.

Cargo, fishing, and passenger vessels involved with Pacific Rim commerce can also hold substantial quantities of petroleum products in their fuel tanks and are at risk for spills through groundings, collisions, sinkings, and other vessel incidents.

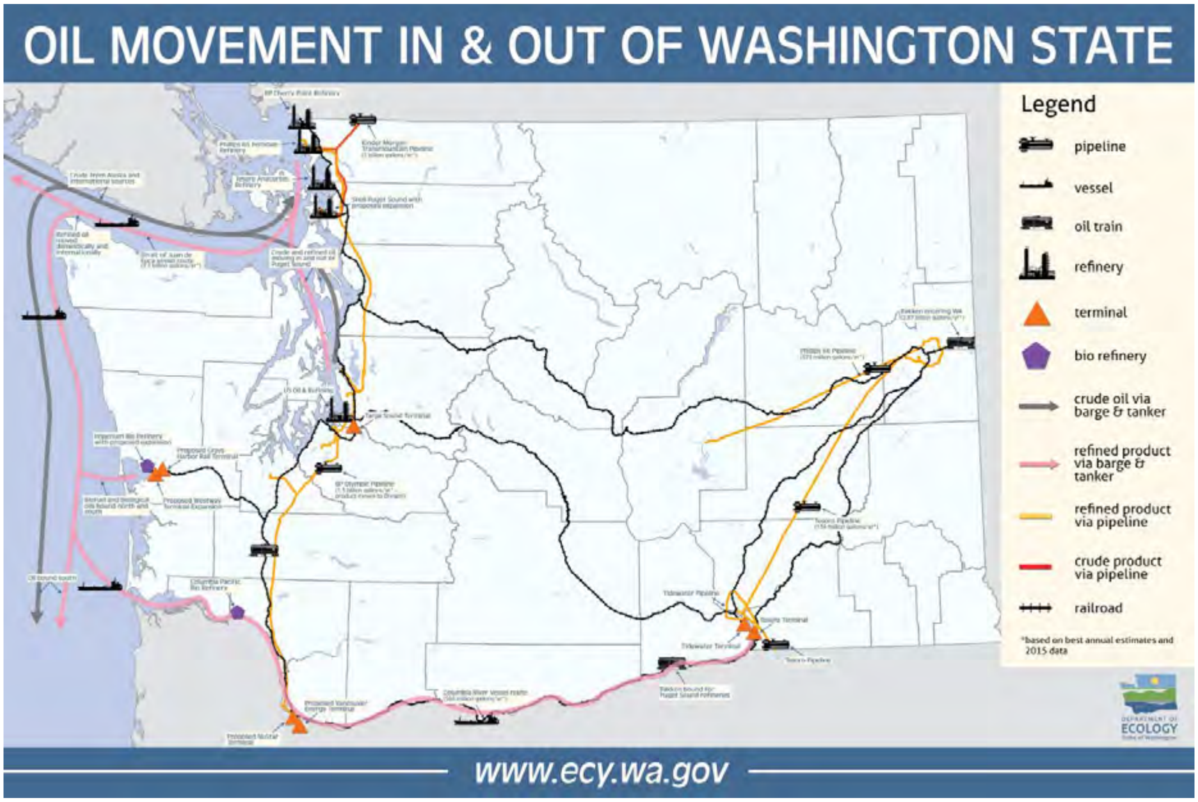

Figure P.4. Oil movement within Washington state via railroads, pipelines, vessels, and refineries. Image: Washington State Department of Ecology, 2017a

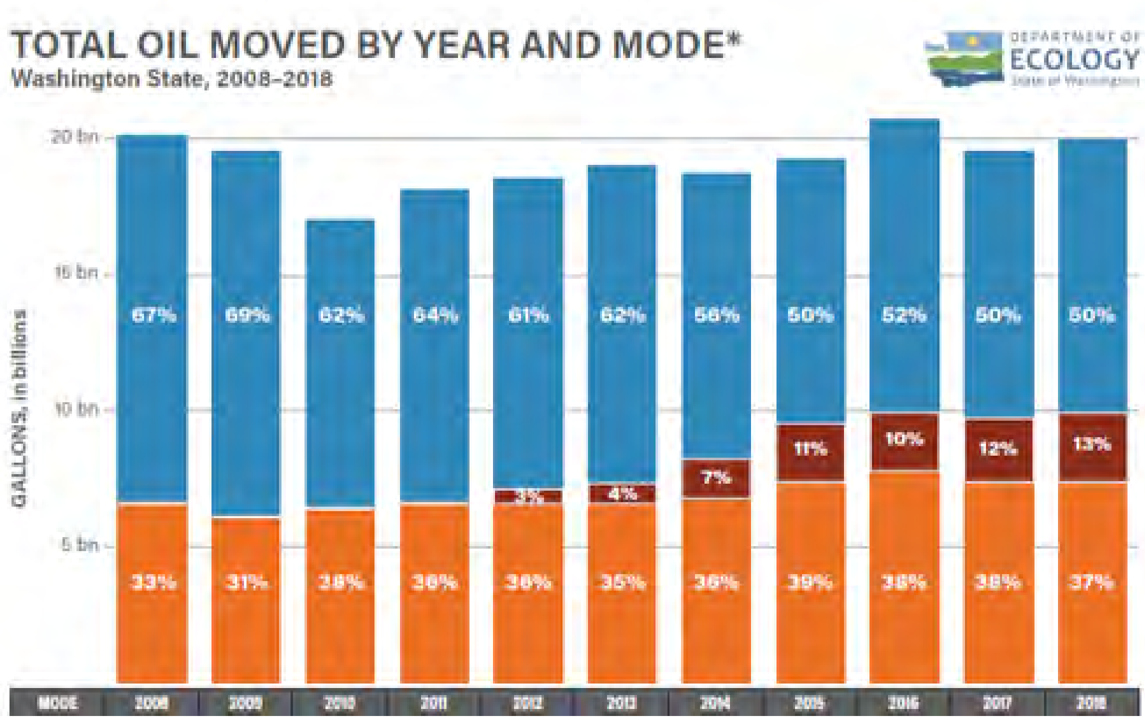

Figure P.5. Twenty billion barrels, on average, are moved through Washington state annually by vessel (blue), rail (red), and pipeline (orange). In recent years, there has been a slight decrease in oil movement by vessel and an increase in the use of rail. Image: Washington State Department of Ecology, 2017a

Oil spills directly and adversely impact water quality, plants, animals, and habitats (Washington State Department of Ecology, 2018). 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 wipe out at least one generation of a population and, in a worst-case scenario, extinguish multiple species on a local or regional scale. Sea otters and many species of seabirds that inhabit or use the ocean's surface are particularly susceptible to damage from oil in nearshore environments.

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, causing long-term negative effects on the economy of local tribes and other coastal harvesters. Oil spills and associated response methods could also impact fish at various life history stages, affecting juvenile survival and future fish stocks. Nearshore habitats, critical for survival of juvenile fish, can also be severely impacted by oil spills that smother or poison kelp, seagrasses, and other marine plants. Oiling and subsequent cleanup of intertidal areas can cause significant damage to invertebrates, habitats, and cultural sites, with negative impacts that can linger for decades. In Prince William Sound, there are still pockets of residual, unweathered oil found along the shoreline more than a quarter of a century following the Exxon Valdez spill (Shigenaka, 2014).

Responses to oils spills, such as chemical dispersants, can also have negative consequences for marine life (DeLeo et al., 2015); response choices (e.g., booming, skimming, dispersing, and burning) need to be carefully considered in light of their potential impacts beyond those of the spill itself.

The Washington coast has endured damage from several large oil spills, including the 1972 *USS General M.C. Meigs* wreck that spilled 115,500 gallons of heavy fuel oil off Shi Shi Beach on the Makah Indian Reservation. The 1988 *Nestucca* barge spill released 231,000 gallons of fuel oil into waters off Grays Harbor, impacting many kilometers of coastline as far north as Canada. In 1991, a fishing vessel, *Tenyo Maru*, spilled 361,000 gallons of diesel fuel that spread as far south as Oregon but most heavily impacted the Makah Indian Reservation and Olympic National Park wilderness coast (Figure P.6). The *Tenyo Maru* spill killed thousands of common murres and 7–10% of the total outer coast population of marbled murrelets (Skewgar & Pearson, 2011). No large oil spills have occurred off the Olympic Coast since 1991.

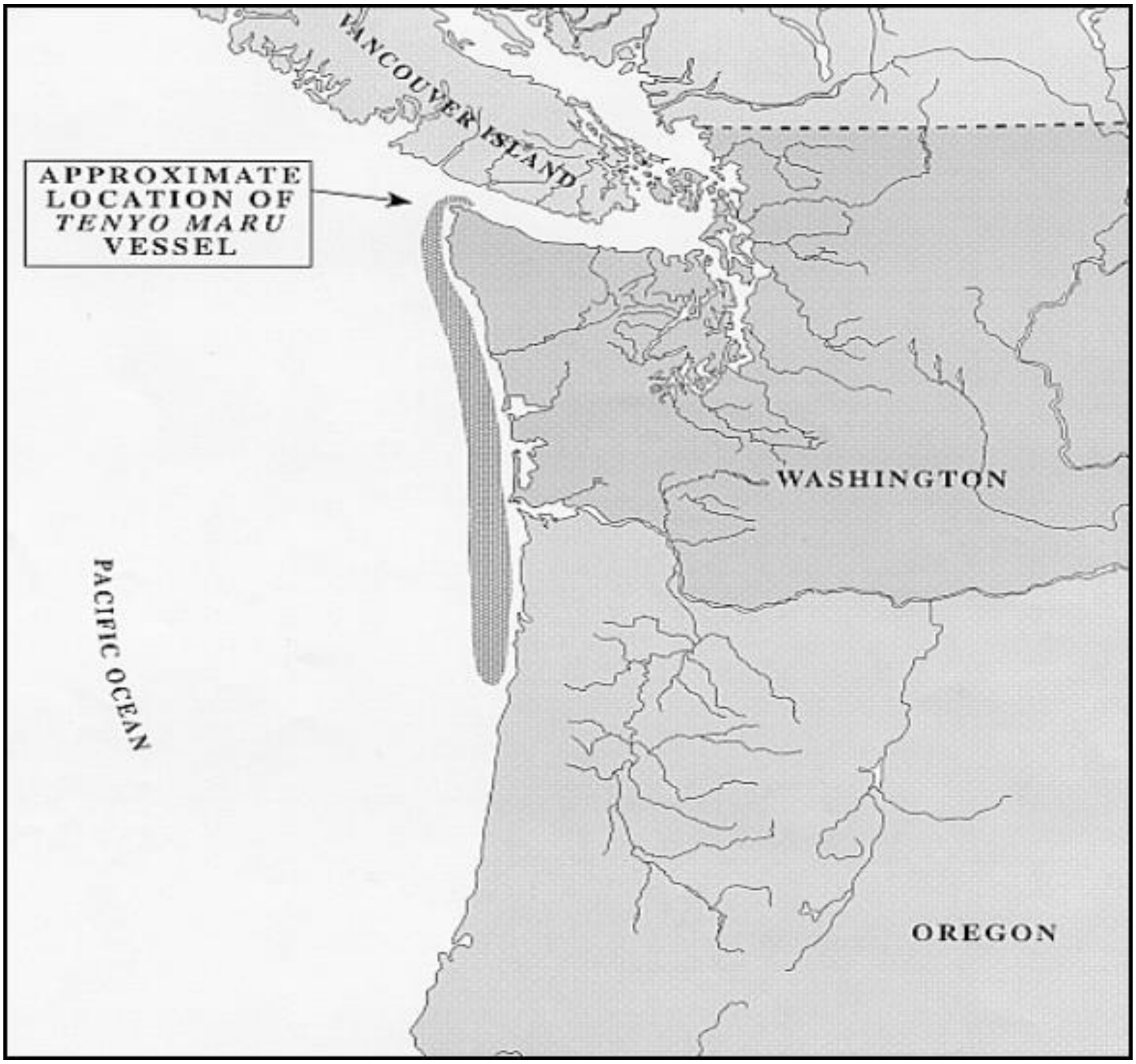

Figure P.6. Approximate area impacted by 1991 *Tenyo Maru* Oil Spill. Image: The *Tenyo Maru* Oil Spill Natural Resource Trustees, 2000

While generating significant damage, large oil spills are rare; smaller spills occur far more frequently, representing an ongoing, chronic stressor (Washington State Department of Ecology, 2018). Although state and federal oil spill prevention and response policies are continually improving, the potential for severe environmental damage remains a strong concern in the region. Furthermore, the remoteness of the Olympic Coast, which complicates beach access and hinders staging of response equipment, increases potential for impacts to cultural sites and resources from any incident in this region.

Vessel Discharge and Ballast Water

Vessel discharges can impact water quality through introduction of pathogens, nutrients, or toxins (Washington State Department of Ecology, 2018). All types of vessels generate wastewater that necessitates discharge or disposal; the type and volume of the discharge depends on the type of vessel and passenger load (Washington State Department of Ecology, 2018). Wastewater includes sewage (raw or treated), graywater (water from showers or dishwashing), bilgewater (a mixture of leakage from machinery, water leaking through the hull, cleaning agents, and other products), and ballast water (used to stabilize a vessel). Sanctuary regulations prohibit the discharge of vessel sewage within the sanctuary (except from approved marine sanitation devices), requiring vessels to use onshore pumpout facilities. However, there are currently no functioning pumpout facilities adjacent to the sanctuary. The closest functioning sewage pumpout facilities are Westport and Port Angeles. Furthermore, the closest oily bilge pumpout facility is in Seattle. The current lack of appropriate facilities makes compliance with the regulations problematic.

Enormous volumes of seawater are routinely carried around the world as ballast aboard oil tankers and other commercial vessels to increase stability at sea. If ships empty their ballast tanks of water transported from other regions there is a risk of introducing non-native fish, invertebrates, and plants, many of which can alter ecosystems, sometimes in catastrophic ways. Washington state implemented regulations to minimize this risk by requiring ballast water treatment or exchange in offshore waters beyond the sanctuary. State ballast water management regulations require "ships to perform an open sea ballast water exchange...to minimize discharge of high-risk coastal species" if the vessel does not have an approved ballast water treatment system (Cordell et al., 2015, p. 5). Even with these regulations in place, invasive species can also be introduced through a variety of other mechanisms, including hull fouling, smaller commercial and recreational vessels, aquaculture practices, release of captive animals and plants (e.g., aquarium specimens), floating marine debris, or range expansion.

Cruise Ship Discharges

The cruise ship industry in Seattle experienced a ten-fold increase in the number of passengers carried by cruise ships between 2000 and 2019, with a 26% increase between 2008 and 2019 (Figure P.7; Port of Seattle, 2019). In 2019, 445 cruise ships transited near the sanctuary, with 179 passing directly through sanctuary waters. While cruise ship numbers are increasing, it is possible wastewater discharges have decreased due to several management changes. In 2011, as a result of a review of the sanctuary's management plan, regulations prohibiting all discharges from cruise ships within the sanctuary were implemented. Furthermore, since 2004, Washington state has had a memorandum of understanding with the cruise industry to prevent wastewater discharges in state waters and OCNMS. The agreement bans wastewater discharges (except discharges treated with advanced wastewater treatment systems), allows the Washington State Department of Ecology to inspect the wastewater treatment system on each vessel, and requires cruise lines to sample and monitor wastewater discharges from their ships, including submitting an annual report on their practices. The Washington State Department of Ecology is able to inspect each vessel's wastewater records and equipment to verify compliance. The agreement covers only cruise lines that are members of the Cruise Lines International Association North West & Canada and does not cover non-member, smaller passenger ships (<249 passengers), Washington state ferries, Alaska Marine Highway ferries, or large cargo ships. Almost all member cruise lines have decided not to discharge in waters covered by the memorandum of understanding. Furthermore, cruise ships have self reported discharge violations within the sanctuary.

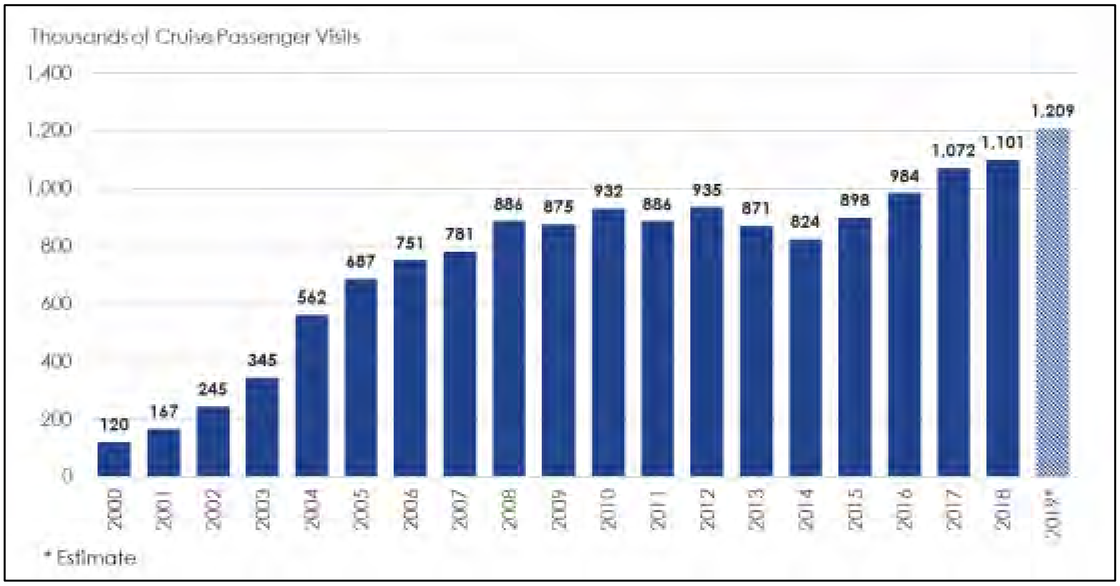

Figure P.7. Passenger embarkments, disembarkments, and in-transit stops at the Port of Seattle, 2000–2019. Image: Port of Seattle, 2019

Exhaust Gas Cleaning System

The adverse effects of exhaust emissions from internal combustion engines and boiler exhaust gases on human beings and sensitive ecosystems have been well documented by the scientific community (Teuchies et al., 2020). In 2000, sulfur dioxide emissions from shipping were estimated to be three times greater than that from all road traffic and aviation (Eyring et al., 2005). The Marine Environment Protection Committee of the IMO adopted the 1997 Protocol to the International Convention for the Prevention of Pollution from Ships, which added Annex VI, Regulations for the Prevention of Air Pollution from Ships. This annex went into effect on May 19, 2005. To reduce the harmful effects of sulfurous emissions on human health and the environment, Regulation 14 to Annex VI introduced a worldwide limit of 4.5% on the sulfur content of marine fuels (further limited to 1.5% within designated sulfur emission control areas). Further reductions have led to a limit of 0.1% (1000 ppm) within OCNMS waters. For comparison, automotive diesel fuel sulfur limits are currently at 15 ppm.

In 2010, the IMO designated waters off North American coasts as an Emission Control Area; within this area, stringent international emission standards apply to ships. Beginning in 2012, fuel standards (e.g., 0.1% fuel sulfur standard) were implemented, and in 2016, stringent nitrogen oxide engine standards went into effect. These standards are expected to be met through fuel switching; however, some vessels may equip exhaust gas cleaning systems. Exhaust gas cleaning systems, also known as scrubbers, remove sulfur from diesel exhaust and are currently being used to enable vessels to meet IMO air emission standards. These scrubbers achieve the required emission reduction, but generate effluent that is discharged into the marine environment. There is a risk for acidification, eutrophication, and accumulation of polycyclic hydrocarbons, particulate matter, and heavy metals from these discharges (Endres et al., 2018). For several metals (arsenic, copper, lead, nickel, and selenium), concentrations in wash water discharge have been shown to exceed EPA's National Recommended Water Quality Criteria for the protection of aquatic life for saltwater organisms (EPA, 2011). In addition, the Predicted No-

Effect Concentration for polycyclic hydrocarbons is regularly exceeded even in properly operating systems. If scrubbers become a central tool for atmospheric pollution reduction from shipping, then modeling and experimental studies will be needed to determine the ecological and biogeochemical effects of discharge from scrubber wash water on the marine environment (Endres et al., 2018).

Submarine Cables

There are several submarine cables that have been installed within the sanctuary, many of which were in place at the time OCNMS was designated in 1994. Since 1994, three fiber optic cables have been installed in the sanctuary. Table P.1 provides information on cables that are indicated on area nautical charts. A number of the older cables have been identified as abandoned, but it is unknown if they were removed or abandoned in place.

Table P.1. Records of submarine cables within the boundaries of OCNMS. Source: NOAA Office of Coast Survey

Cable Name	Cable Type	Number of Cables	Year Installed
Pacific Crossing (PC-1)	fiber optic communication cable	2	1999 and 2000
Alaska United	fiber optic communication cable	1	1998
Quinault Range Cable/U.S. Navy	underwater test range	multiple	1982
Pacific Beach Cable/U.S. Navy	unknown	1	1958
Referenced as L370/81 & BP113154-155 (Abandoned)	unknown	1	unknown
ATT WA-AK (Abandoned)	communications	2	1956
ATT British Columbia to Southwest Pacific (Abandoned)	communications	1	unknown
Tatoosh Island cable #132472 (Abandoned)	utility	potentially multiple in the same area	1976
Department of Army, Destruction Island cable	reference made to submarine cables and pipelines	potentially multiple in the same area	1949

In 1999–2000, a pair of submarine fiber optic telecommunication cables, called the Pacific Crossing-1 (PC-1) system, were laid across the northern portion of the sanctuary. Totalling 11,201 nautical miles (20,800 km), one cable (PC-1 North) runs from Mukilteo, Washington, to

Japan (Figure P.8), and the other (PC-1 East) runs from Washington to Grover Beach, California. The cables cross approximately 29 nautical miles (52 km) of the northern portion of OCNMS, roughly parallel to one another and separated by several hundred meters at water depths of 100–330 meters. The minimum anticipated service life for these cables was 25 years (David Evans & Associates, 1998).

The installation of submarine cables can damage benthic habitat in the immediate vicinity of the cable, but the impacts are localized to within a few meters of the cable route. Submarine cable installation involves substantial seafloor disturbance along a narrow swath as a plow cuts about a meter into the substrate to bury and protect the cable and to avoid future entanglement with anchors, fishing gear, or organisms. Although successful cable burial was reported, surveys of the PC-1 cables in the sanctuary in 2000 revealed that substantial portions of each cable were not buried at a sufficient depth to avoid risks, and in many places, the cables were unburied and suspended above the seafloor. In this condition, cable movement could increase the area of seafloor damage, and cables are susceptible to damage by fishing trawl gear, requiring repairs that could repeatedly disturb seafloor communities. Additionally, where unburied and suspended, the cables pose a serious safety concern for fishers employed in bottom contact fisheries. The risk of gear entanglement also causes fishers to avoid areas in which cables are exposed, limiting access of treaty tribal fishers to portions of their treaty-reserved U&A fishing areas. In light of these risks, the cable owners agreed to recover and re-lay the cables in the sanctuary, an effort that was completed in late summer 2006. There have been no reports of fisheries interaction with the submarine cable. In 2020, a compliance survey indicated that despite some changes in burial depth, each cable has remained in position and is over 95% buried (AECOM, 2021).

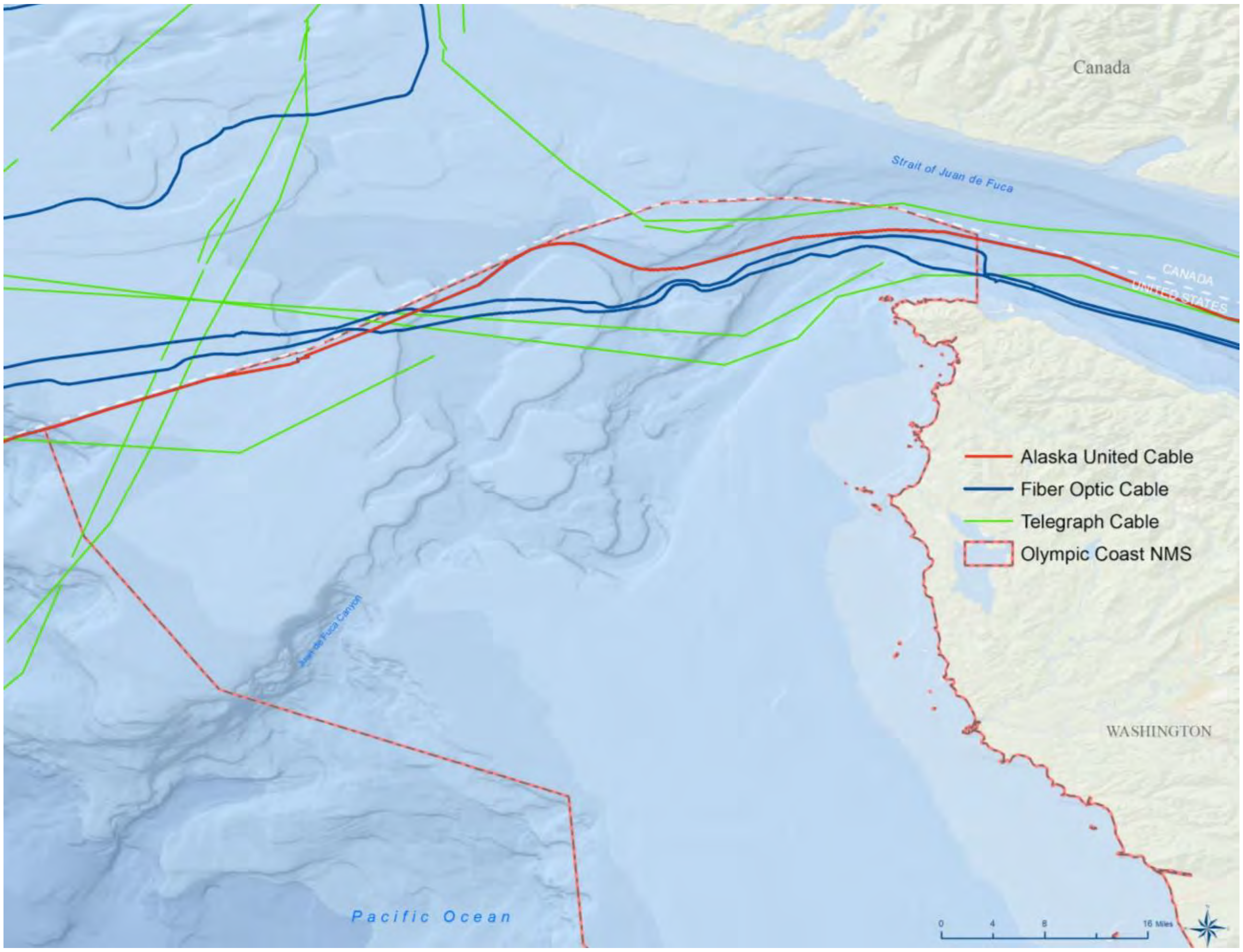

Figure P.8. Location of different types of submarine cables installed in the northern portion of OCNMS. Image: NOAA

Fishing

Commercial and recreational fishing are important to the coastal economy and provide valuable food resources to the Pacific Northwest and beyond. The management of fisheries resources on the Olympic Coast is part of a comprehensive, complex mixture of federal, state, and tribal management. For the Coastal Treaty Tribes, fishing is a treaty-reserved right and provides significant cultural, spiritual, economic, and subsistence benefits to tribal communities. Furthermore, the Coastal Treaty Tribes are co-managers of fishery resources. While fishing occurs within the sanctuary, OCNMS does not manage fisheries. Some aspects of fishing practices and regulations have been under scrutiny from co-managers or environmental non-governmental organizations for their potential negative impacts to habitat, maritime archeological resources, water quality, and/or ecosystem functions. For instance, bottom contact fishing gear can alter hard bottom habitats and damage biogenic habitat (i.e., deep sea corals and sponges, which are long-lived and slow growing). However, fishery managers have made gear adjustments and implemented spatial restrictions to freeze the footprint of and reduce impacts from bottom contact fishing on sensitive habitats. Furthermore, bottom trawling with small-footrope gear has been shown to have minimal impacts on both the seafloor and invertebrate communities in soft sediment habitats (Lindholm et al., 2013).

At-Sea Processors

Pacific hake (or Pacific whiting, *Merluccius productus*) is one of the most abundant groundfish in the California Current ecosystem. Whiting are harvested using mid-water trawls and are processed either at shore-based facilities or at sea via motherships or catcher-processor vessels. At-sea processors process the whiting and discharge water and unutilized whiting biomass. Seafood processing waste is thought to exacerbate ocean acidification and low-oxygen conditions due to an influx of decomposing organic matter (EPA, 2017); however, there are no direct or baseline data available to inform this assumption. In 2015–2016, OCNMS and the U.S. Environmental Protection Agency (EPA) conducted a Section 304(d) consultation under the National Marine Sanctuaries Act on the proposed issuance of the National Pollutant Discharge Elimination System General Permit for Offshore Seafood Processors in Federal Waters off the Washington and Oregon Coast, banning discharge in waters shallower than 100 meters. This permit went into effect on May 1, 2019; as such, trend data are not yet available.

Derelict Fishing Gear

Rough waters and complex seabed features of the sanctuary increase the potential for fishing gear entanglement and loss. Crab pots are especially susceptible to being lost and/or becoming derelict. Roughly 10% of commercial crab pots are lost off the Olympic Coast every year. Lost or abandoned fishing gear can remain for decades, potentially entangling and killing species that encounter the gear (Natural Resources Consultants, Inc., 2008). The phenomenon in which derelict gear continues to fish by attracting, trapping, and killing a wide variety of target and non-target species has been called "ghost fishing." Dead organisms attract other animals, resulting in serial unintended mortality until the gear degrades. However, derelict crab pots have a rot cord, which is designed to degrade and allow organisms to escape a lost pot through the lid or escape panel.

A direct economic impact of ghost fishing is the reduction of fishery stocks otherwise available for commercial and recreational harvest. Accumulations of gear on critical spawning and rearing habitat can significantly impact fishery stocks. Derelict fishing gear also can threaten human safety; restrict other legitimate sanctuary uses, such as fishing, anchoring, and operation of vessels; and diminish aesthetic qualities for recreational activities. Derelict fishing gear also increases the risk of whale entanglements.

Whale Entanglement

NOAA has responded to a 2.5x increase in large whale entanglements on the West Coast from 2014–2019 compared to 2008–2013 (Figure P.9). The West Coast annual average between 1982 and 2013 was nine confirmed entangled large whales, but this jumped to an annual average of 41 confirmed entanglements between 2014 and 2017 (Saez et al., 2021), with 46 in 2018. Gray and humpback whales are the most frequently reported entangled species. Gillnet and commercial Dungeness crab pots are the most common fishing gear types associated with large whale entanglements. The increase in reported entanglements may be due to multiple factors, including, but not limited to, an increase in public awareness and reporting and changes in the spatial distribution and abundance of whales, fishing effort, and ocean conditions. For example, shoreward shifts in prey caused by changes in upwelling force whales closer to shore, where fishing effort is more concentrated. This trend, combined with increasing whale populations, results in more entanglement (Santora et al., 2020).

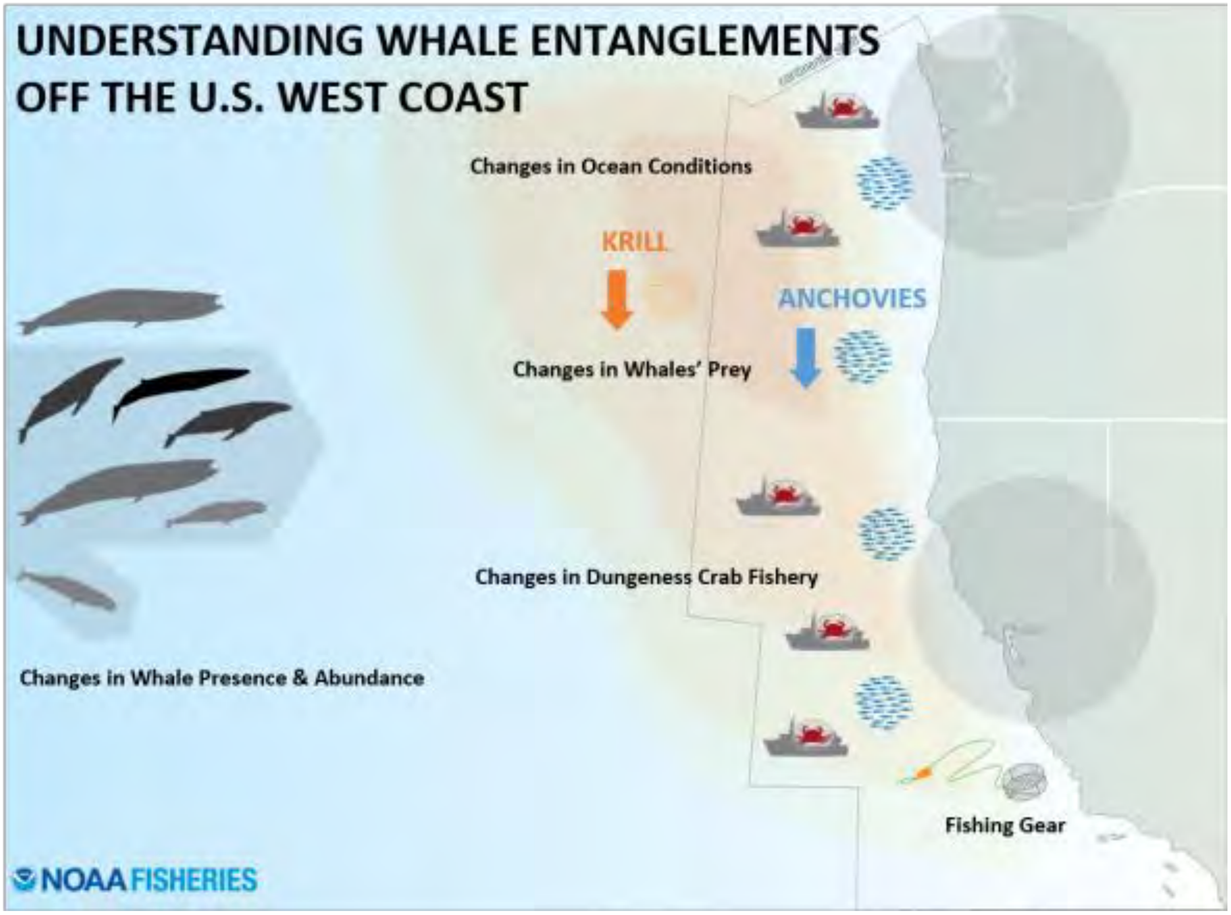

Figure P.9. Factors that contribute to changes in the frequency of whale entanglements along the West Coast. Image: Santora et al., 2020

Military Activities

The offshore area of the Navy's Northwest Testing and Training (NWTT) Study Area overlaps the majority of the sanctuary (Figure P.10). NWTT Study Area activities ensure that the Navy meets its statutory mission, and include anti-submarine warfare testing, sonar testing and training, non-explosive mine countermeasures and neutralization testing, unmanned underwater testing and training, and acoustic and oceanographic research. The Navy also conducts aerial training using EA-18G Growler jets over portions of the Olympic Peninsula and outer coast. An average of 2,300 flights are conducted over the Olympic Military Operations Area annually (approximately 6.3 flights per day). The majority occur during daylight hours on weekdays and 95% are above 10,000 feet (U.S. Department of the Navy, 2020). According to the Federal Aviation Administration, approximately 25% of all flights that occur over Olympic National Park are military. Military activities in these areas consist of subsurface, offshore surface, and aerial training activities, as well as other military operations as discussed in the sanctuary's original environmental impact statement (Sanctuaries and Reserves Division, 1993).

Most Navy activities take place outside of OCNMS. Furthermore, the use of explosives is prohibited within the sanctuary.

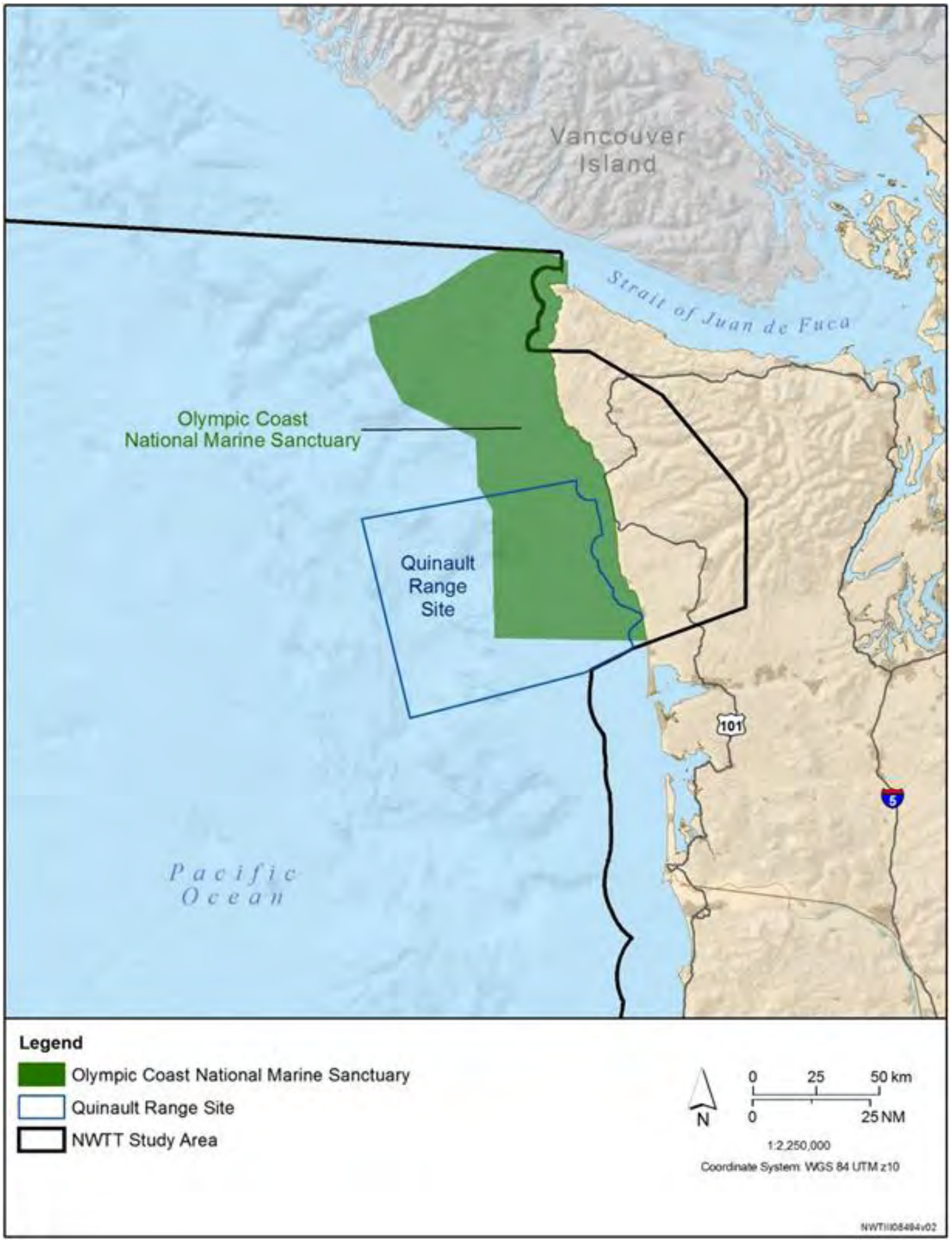

Figure P.10. The location of the NWTT Study Area and the Quinault Range Site relative to OCNMS. Image: U.S. Navy, 2020

The Naval Undersea Warfare Center Division Keyport operates and maintains the Quinault Range Site. This site is instrumented to track surface vessels, submarines, and various undersea vehicles. It is the policy of Naval Undersea Warfare Center Division Keyport to avoid testing in the presence of cetaceans. Both the Quinault Range Site and the larger NWTT Study Area extend beyond the boundaries of OCNMS. The Navy has expanded the Quinault Range Site's area more than 40 fold to support existing and future needs in crewed and uncrewed vehicle program development; the expanded area now includes a surf zone landing site. The Quinault Range Site, where testing activities subject to consultation occur, was originally 48 square nautical miles (overlapping 2% of OCNMS) when the sanctuary was designated, but is now 809 square nautical miles (overlapping 34% of OCNMS).

The Navy has established three geographic mitigation areas for testing and training activities from 2020–2027, including an OCNMS Mitigation Area, Marine Species Coastal Mitigation Area, and Seafloor Resource Mitigation Area. The use of explosives is not allowed within the OCNMS Mitigation Area.

Potential effects associated with Navy testing and training activities were recently evaluated in separate environmental impact statements via the National Environmental Policy Act process and 304(d) consultation with OCNMS. During 304(d) consultation, the sanctuary considered a wide variety of issues, including: disturbance to birds, fish, and mammals from increased activity and noise; accidental discharges of pollutants; interference with tribal fishing and subsistence harvest activities; restrictions on the ability of sanctuary and affiliated scientists to conduct research; and recommendations regarding research priorities. OCNMS recommended measures to reduce potential impacts to marine mammals, including use of passive acoustic monitoring, additional observers, and engagement with whale reporting alert networks, as well as additional monitoring of the soundscape to assess the Navy's impact and continuation of salmon distribution monitoring. While many OCNMS-recommended alternatives were not accepted by the Navy, annual meetings and information sharing continue.

Marine Debris

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. Marine debris can include a wide variety of objects (e.g., lost fishing gear, lost vessel cargo, plastics, balloons) from multiple sources (e.g., stormwater runoff, landfills, recreational and commercial activities, military activities).

The amount of marine debris in open-ocean and coastal systems is on the rise throughout the world. Impacts from marine debris include entanglement and drowning of animals, inadvertent ingestion of plastics by marine species (mammals, turtle, birds, fish, and invertebrates), transfer of diseases from land-based sources to marine wildlife, fouling of active fishing gear, introduction of non-native species, and degradation of benthic habitat. The prevalence of debris within the sanctuary is affected by both natural and human factors.

Many types of marine debris exist in the sanctuary and accumulate at various locations. Plastic is the most prevalent type of marine debris found in the ocean and accounts for 92% of the debris found on beaches on the outer coast of Washington (Washington State Department of Ecology, 2018). Rather than disappear, plastics in the marine environment tend to fragment into smaller pieces, eventually breaking down into microplastics (plastic less than five millimeters in length). Recent research suggests these microplastics can accumulate in marine species, particularly shellfish (Smith et al., 2018).

In March 2011, a magnitude 9.0 undersea megathrust earthquake occurred off the coast of Japan, claiming nearly 16,000 lives. The government of Japan estimated that the tsunami generated five million tons of marine debris and that 70% of that debris sank nearshore. However, some debris came ashore in OCNMS, including boats, docks, and numerous other items (Figure P.11). The majority of this debris arrived between 2012 and 2014, ranging in size from fishing boats to plastic bottles; 90% of larger debris items (e.g., boats and docks) were removed from beaches. There was a ten-fold increase in debris influx to sites in northern Washington state compared to the nine-year period prior to the tsunami event (Clarke Murray et al., 2019). Biofouled marine debris transported by ocean currents to the West Coast (including OCNMS) resulted in 289 non-indigenous species being introduced to the U.S., with the majority landing in Washington and Oregon.

Figure P.11. Dock washed ashore following the Japanese tsunami. Photo: National Park Service

Crushed cars litter the northern portion of OCNMS. Open-deck barges from Canada, stacked with crushed cars, routinely travel through the sanctuary enroute to scrap yards in Portland, Oregon. Since 2011, at least four crushed cars have been pulled up in fishing gear of Makah tribal members (Figure P.12). In 2015, a survey off Cape Flattery revealed an additional thirteen cars in the sanctuary, and there are no requirements or plans to remove them. While some measures have been enacted to reduce the potential for lost cargo, like improving loading techniques by leaving extra room around the edge of the barges, it is likely that cargo will continue to be lost.

Figure P.12. Crushed car pulled up in fishing gear by a Makah tribal member. Photo: Larry Buzzell

2011 Tsunami

In 2011, an earthquake off Japan created a massive tsunami that caused the Fukushima nuclear disaster and severe destruction to the eastern coastline of Japan. The resulting debris was swept into the Pacific Ocean and, over the next few years, was carried thousands of miles. Some tsunami-generated debris ended up on the Washington coastline. The majority of this debris arrived between 2012 and 2014, ranging in size from plastic bottles to fishing boats and floating docks. In total, more than 289 non-indigenous species are believed to have arrived with the debris. Ninety percent of larger debris items were removed from beaches. Removal efforts may have prevented some non-indigenous species from becoming established (Hansen et al., 2018; Clarke Murray et al., 2019); however, a long-term survey site has been set up in Grays Harbor, Washington to monitor the establishment of species introduced by the 2011 tsunami (Clarke Murray et al., 2019).

Non-Indigenous and Invasive Species

Non-indigenous species are any plants, invertebrates, vertebrates, parasites, and even diseases that are introduced into a non-native environment. Those that harm resources in that environment are called invasive species. Several established and expected non-indigenous species, such as the invasive brown alga *Sargassum muticum*, the invasive red alga *Caulacanthus okamurae*, and the European green crab (*Carcinus maenas*) threaten both critical habitat and important commercial species in the Pacific Northwest. In 2017, European green crabs were found in two estuaries on the Makah reservation, adjacent to OCNMS (Figure P.13). A dedicated trapping effort by Makah Fisheries Management has caught over 2,500 green crabs since 2017, the most anywhere in Washington state. European green crabs may compete with native species, like Dungeness crab, and have devastated eelgrass habitats on the east coast (Malyshev & Quijón, 2011). There is widespread recognition that invasive species can affect fisheries, waterways, and adjacent facilities, as well as the functioning of natural ecosystems. The introduction of aquatic invasive species into the coastal waters of the Pacific Northwest poses serious economic and environmental threats recognized by resource managers, the aquaculture industry, non-governmental organizations, and concerned citizens. Coastal estuaries in Washington, which provide critical habitat for many commercially important species such as Dungeness crab, shellfish, and many marine fish species, are particularly susceptible to rapid development of aquatic invasive species populations.

Figure P.13. European green crab trapped on Makah reservation. Photo: Washington Sea Grant

Contaminants

Chemical contaminants (i.e., metals, persistent organic pollutants, hydrocarbons, dioxins) can adversely affect marine waters and resources therein. Contaminants enter marine systems through stormwater, wastewater, air deposition, biological transport, and direct pathways. Furthermore, watershed alterations from increased land use, such as timber harvest and agriculture, may affect water quality by increasing sediment loads and nutrient runoff. Excessive sediment introduced to the nearshore environment can suffocate benthic marine life and reduce water clarity. On the Olympic Coast, there are no point sources for pollution and limited facilities resulting in the potential for human waste issues. However, portions of Vancouver Island, including Victoria, British Columbia, have been discharging raw sewage into the Strait of Juan de Fuca due to lack of wastewater treatment plants.

Some persistent industrial chemicals, even those no longer in use in this country, such as dichloro-diphenyl-trichloroethane (DDT), PCBs, and polybrominated diphenyl ether (PBDE), have found their way into marine food webs and can be detected in tissue samples of higher-order predators (Southern Resident Orca Task Force, 2018). These persistent organic pollutants bioaccumulate in upper trophic level species and can result in “immunotoxicity, neurotoxicity, and reproductive impairment” (Mongillo et al., 2012, p. 263). This is especially true for PCBs and PBDEs, which are found in high levels in marine mammals. This is particularly concerning for the endangered Southern Resident killer whale population, which comprises 74 individuals at the time of this report, and their prey, several stocks of which are also ESA listed (Southern Resident Orca Task Force, 2018).

There are several contaminants of emerging concern, including pharmaceuticals, detergents, personal care products, microplastics, and others that enter marine waters through wastewater treatment plants, stormwater outfalls and runoff, industrial outfalls, aquaculture operations, landfills, and agricultural runoff (Southern Resident Orca Task Force, 2018; Masura et al., 2015). Microplastics enter waterways as either primary (manufactured raw plastic material including plastic pellets, scrubbers, and microbeads) or secondary (fragments of larger plastic items) microplastics (Masura et al., 2015). Microplastics are small enough to pass through wastewater treatment systems and may concentrate hydrophobic contaminants, which in turn are ingested by marine species (Masura et al., 2015).

Research Activities

There are numerous research activities that occur at any given time within OCNMS. This research helps monitor ocean conditions, understand fish stocks for fisheries management, track distribution and abundance of marine mammals and seabirds, measure ocean sound dynamics, and inform a variety of other topics that are reflected throughout this condition report. Many of these research activities involve setting or releasing monitoring equipment that affects sanctuary habitats and resources. For example, many deep moorings are not able to recover their anchors, resulting in areas of anchor abandonment that can impact seafloor habitats. Furthermore, research activities occur within the U&A fishing areas of the Coastal Treaty Tribes and can interfere with or disrupt treaty fishing activities, including through entanglement of fishing gear on moorings or abandoned anchors.

Offshore Aquaculture

Aquaculture is the rearing or cultivation of fish, shellfish, or other aquatic plants and animals. Shellfish aquaculture is a major industry in Washington state, which is ranked first among all U.S. states in sales of aquaculture products (Washington State Department of Ecology, 2018). Washington state has banned non-native fish net pen aquaculture within state waters following the 2017 failure of an Atlantic salmon net pen near Cypress Island in Puget Sound, in which approximately 250,000 Atlantic salmon were released (Wash. Rev. Code § Chapter 79.105; Wash. Rev. Code § Chapter 77.125; Wash. Rev. Code § Chapter 90.48). There are currently no aquaculture activities occurring or proposed within the sanctuary.

The NOAA Fisheries Office of Aquaculture is currently exploring possibilities for open-ocean or offshore aquaculture production in federal waters, which include all sanctuary waters more than three nautical miles (5.5 kilometers) off the Washington coast. Open-ocean aquaculture is a controversial issue for some segments of the public and raises regulatory concerns with regard to pathogens, nutrient loading, fishing area restrictions, and habitat and ecosystem impacts. Although sea conditions are dynamic and challenging in the sanctuary, technological developments in anchoring and structural design may make such development feasible in the sanctuary in the future. If projects are proposed for the sanctuary, it will be necessary for sanctuary staff to investigate potential environmental impacts and weigh these against sanctuary goals and mandates while making permitting decisions.

Offshore Energy

While there are no offshore oil or gas leases off of the Washington coast, and there has been a moratorium on new offshore oil and gas leasing across the West Coast since 1988, Executive Order 13795 (2017) directed the Department of the Interior to develop an updated Outer Continental Shelf Oil and Gas Leasing Program, which included reviewing the entire Outer Continental Shelf for offshore oil and gas leasing (with the exception of national marine sanctuaries, where regulations prohibit the activity). The 2019–2024 proposed program is still under development and a final program may or may not include the West Coast for leasing consideration. However, if this activity is permitted on the West Coast, even outside of OCNMS, construction operations or an oil spill in adjacent waters could still impact sanctuary resources.

Renewable energy can be produced in offshore areas from wind, waves, tides, or currents. Typically, cables run from offshore energy-generating devices to an onshore energy grid. There are barriers for marine renewable energy projects off of the Washington coast, including transmission grid infrastructure, existing uses, energy costs, and local community concerns (Washington State Department of Ecology, 2018). Several marine renewable energy areas have been proposed in California (Diablo Canyon, Morro Bay, and Humboldt) and Oregon (Newport). We are not aware of any current marine renewable energy proposals off the Washington coast.

In 2007, there was a significant effort to develop the Makah Bay Offshore Wave Energy Pilot Project. The in-water portion of the project was within sanctuary boundaries, and the shore-based facilities would be located on Makah tribal land. In December 2007, the project was issued a conditional license by the Federal Energy Regulatory Commission; this was the first federal license for an ocean energy project in the U.S. The one-megawatt (enough to power 150 homes) demonstration project would have tested a novel technology and delivered power to the Clallam County Public Utility District's grid from a renewable energy source—ocean waves. As proposed, the project included four interconnected, floating buoys tethered to the ocean floor with a complex anchoring system and a submarine electrical transmission cable laid across the seabed to the shore and routed underground past sensitive nearshore habitat. Authorization from the sanctuary was required, but the original project proponent (Finevera Renewables) changed ownership and moved their wave energy efforts to Scotland.

Increased Visitation

The Olympic Coast is remote and largely rugged wilderness with limited public access locations. Long-time residents as well as tourists from around the world are drawn to the many recreational opportunities of the Olympic Coast, including hiking, sport fishing, kayaking, surfing, wildlife viewing, clamming, and beachcombing (Figure P.14). While there are limited at-sea whale watching opportunities, the Whale Trail promotes shore-based whale watching, with several sites along the Washington coast. In 2013, Washington residents alone took an estimated 5.2 million person-trips to the coast, with 6% of Washington households recreating within the sanctuary (Leeworthy et al., 2016). While much of this recreation occurs outside of the sanctuary's boundaries on the shore, recreational use can put unintended pressures on the coastal ecosystem. There is limited infrastructure within Olympic National Park; during the summer season, large aggregations of recreators visit these remote beaches and leave behind human waste due to lack of sanitation facilities. Beachgoing and tidepooling can involve trampling and often includes beachcombing and other collecting by visitors. Motorized and non-motorized recreational boaters and sight-seeing pilots can inadvertently disturb wildlife. Although human access to most seabird colonies is restricted by the USFWS Washington NWR Complex regulations (USFWS, 2007), the Makah Tribe's restrictions for Tatoosh Island, or the Quileute Tribe's restrictions for James Island, wildlife on the refuge islands is vulnerable to disturbance from low-flying aircraft that do not comply with the 2,000-foot elevation requirement established by the sanctuary and by the increasing use of uncrewed aerial vehicles (UAVs or drones). Cliff-nesting seabirds often abandon their nests when frightened, leaving eggs and nestlings exposed to avian predators. Resting pinnipeds can abandon their haulout sites for the water when disturbed, often at a large energetic cost, especially to young animals. While use of commercial and recreational UAVs has increased over the past decade, the documentation of impacts to birds or marine mammals is still limited (Rhodes & Speigel, 2018). UAVs (especially electric devices) are quieter than crewed aircrafts and can be flown lower without increasing the level of harassment (Marine Mammal Commission, 2016). Other beach users, such as bird watchers, dog walkers, and surfers, can displace foraging migratory birds at important resting and staging areas. The risk of damage to cultural sites (e.g., middens, petroglyphs) and scavenging of artifacts also increases with increasing visitation.

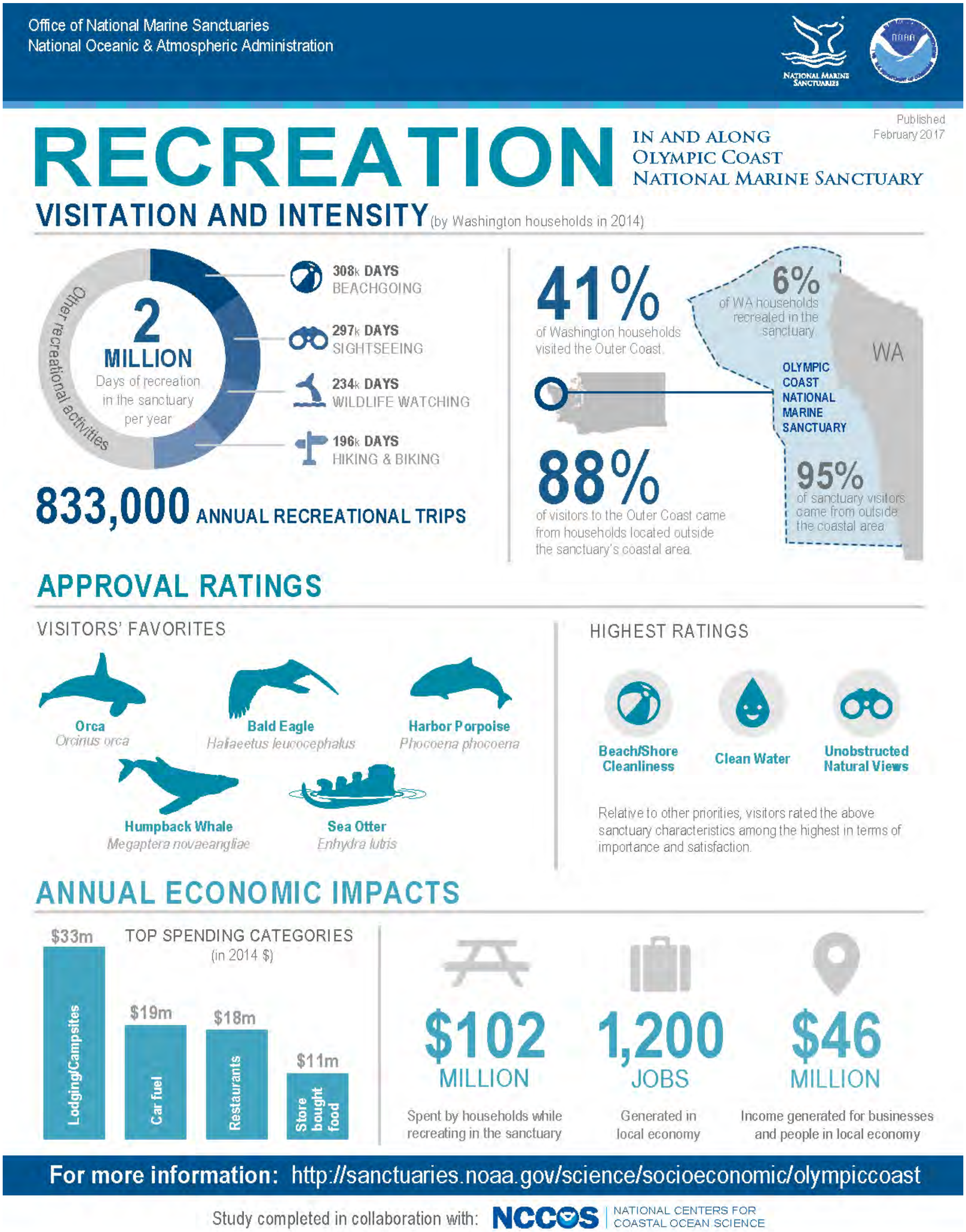

Figure P.14. Socioeconomic summary for OCNMS. Image: NOAA

State of Drivers and Pressures on the Sanctuary

Below are answers to 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 January 14–16, 2020 to discuss and determine status and trend ratings in response to a series of standard condition report questions.[10] 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 January 2020). 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.

Driver Rating (Question 1)

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

Not rated

Rationale: ONMS and OCNMS staff decided not to rate the status and trend of influential human drivers at OCNMS. 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. 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.

The primary drivers influencing pressures on OCNMS resources were previously described in the Drivers section of this report. Drivers help to explain the origins of pressures on resources and potentially estimate future trends for those pressures. Drivers reflect the relationship between the supply and demand of goods and services that humans consume. More specifically, drivers help to illustrate the direction and magnitude of demand for different ecosystem goods and services. Drivers include economic factors, such as income and spending; 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 human preferences and, consequently, the levels of demand for different resources and services.

[10] A follow-up virtual workshop was held on May 4, 2020 with an expanded group of subject matter experts who were unable to attend the January 2020 workshop. Experts discussed indicators and datasets with the goal of determining a status and trend rating for Question 5: What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?

After thoughtful consideration, ONMS and OCNMS staff decided not to rate the status and trend of influential human drivers at OCNMS. 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 (see About This Report). 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 commercial and recreational vessel-based activities, and fishing activities.

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) and ocean dumping 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 gases) 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.P.2.1. 2008 (left) and 2008–2019 (right) status, trend and confidence ratings for the human activities questions.

2008 Condition Report Questions	2008 Rating	2008–2019 Condition Report Questions	2008–2019 Condition Report Rating
N/A	N/A	1. Influential Drivers	Not rated
4.Human activities and water quality	—	2. Human activities and water quality	Good/Fair —
8. Human activities and habitat	▲	3. Human activities and habitat	Fair ?
14. Human activities and living resources	▲	4. Human activities and living resources	Good/Fair ▲
17. Human activities and maritime archaeological resources	?	5. Human activities and maritime heritage resources	Fair ?

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

Good/Fair —

Status Description: Some potentially harmful activities exist, but they have not been shown to degrade water quality to a degree that raises substantial concern.

Rationale: Several human activities have the potential to adversely influence water quality, but generally do not seem to be doing so within OCNMS waters, except on very localized, short-term scales. Activities of concern include oil spills from vessels, vessel discharges from sewage and exhaust gas cleaning systems, and at-sea seafood processing.

Comparison to 2008 Condition Report

In the 2008 condition report, this question was rated good/fair and not changing. The basis for judgment was the threat of oil spills from vessels (Table S.P.2.1 and Appendix H). Since 2008, levels of human activities affecting water quality within and around the sanctuary have generally remained steady. However, new information regarding some ongoing activities (e.g., offshore seafood processing) became available. Other activities, such as large commercial vessels generating a new type of effluent from exhaust gas cleaning systems, are new since 2008. The amount of published data on these human activities was limited. The cumulative effects of these anthropogenic activities have the potential to alter water quality in the sanctuary. However, from 2008–2019, these activities did not seem to have an adverse effect except on a very localized, short-term basis. Therefore, the status for this question was still good/fair (medium confidence). The trend rating remained not changing (medium confidence).

New Information in the 2008–2019 Condition Report

The Strait of Juan de Fuca (Figure S.P.2.1) serves as the entrance to the nearby ports of Seattle and Tacoma, Washington and Vancouver, British Columbia, Canada. Because OCNMS encompasses the entrance to the Strait of Juan de Fuca, it sees approximately 8,300 transits from deep-draft vessels annually (Washington State Department of Ecology, 2019a; Figure S.P.2.2). Maritime traffic can be used as an indicator of the risk of oil spills, as well as other potential impacts. An oil spill in the Strait of Juan de Fuca traffic lanes could impact large areas of the sanctuary; this occurred during the F/V *Tenyo Maru* oil spill in July of 1991. Additional information on oil spills is provided in the Pressures section.

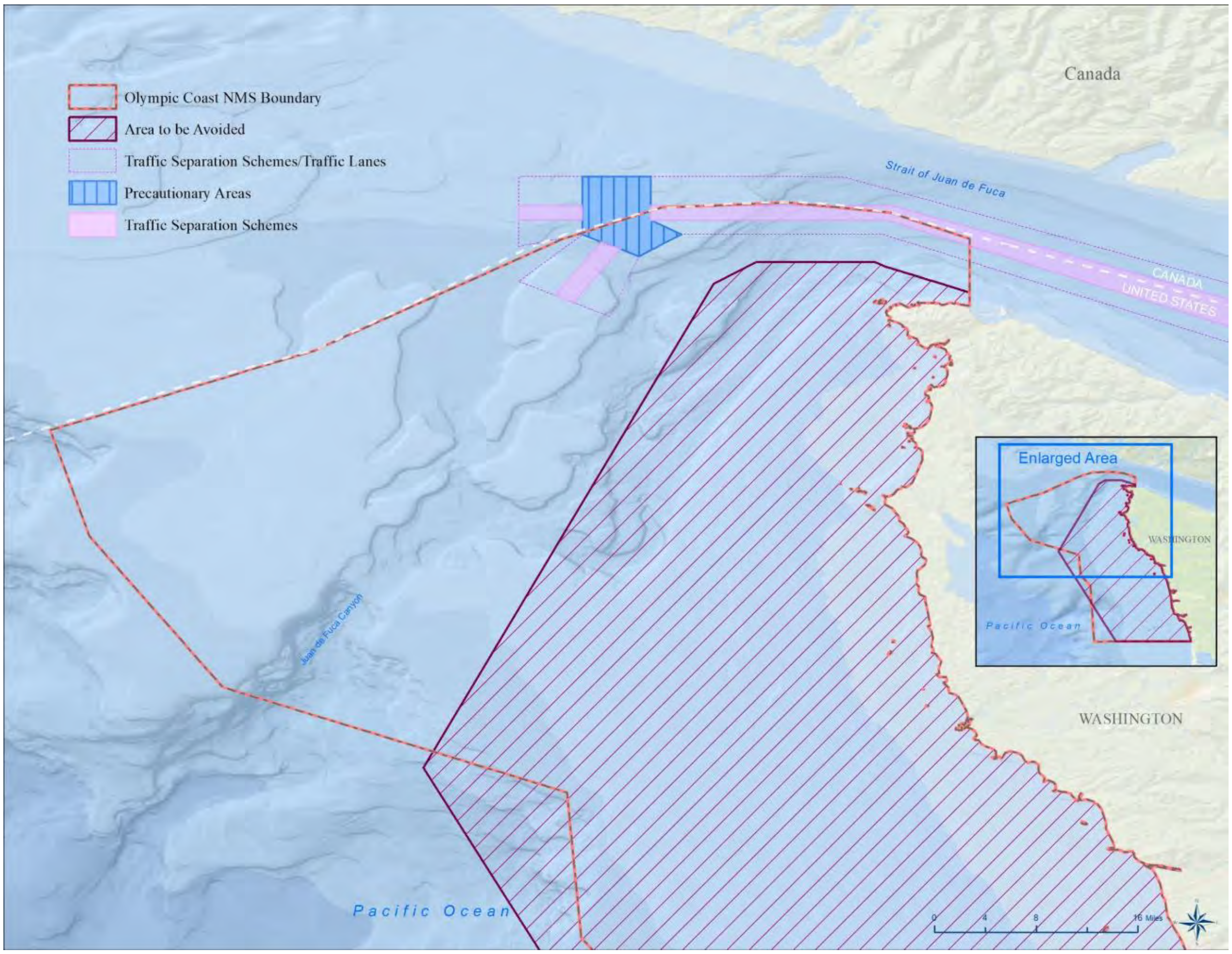

Figure S.P.2.1. Map showing the northern portion of the sanctuary relative to the entrance to the Strait of Juan de Fuca, international shipping lanes and traffic separation schemes, and the Area to be Avoided designated by the IMO to reduce risks to the Olympic Coast from vessels over 400 gross tons. Image: T. Reyer/NOAA

The Washington State Department of Ecology produces an annual report on vessel transits into and out of the Strait of Juan de Fuca, the Vessel Entries and Transits Report (Washington State Department of Ecology, 2019a). This report includes data on cargo and passenger vessels 300 gross tons and larger, tank ships, and oil tank barges. From 2008 through 2019, shipping varied by vessel type and destination. During the same time period, there was a 13% increase in cargo and passenger vessel transits and a 24% decrease in tank ships; overall, shipping via the Strait of Juan de Fuca increased by 7% (Figure S.P.2.2).

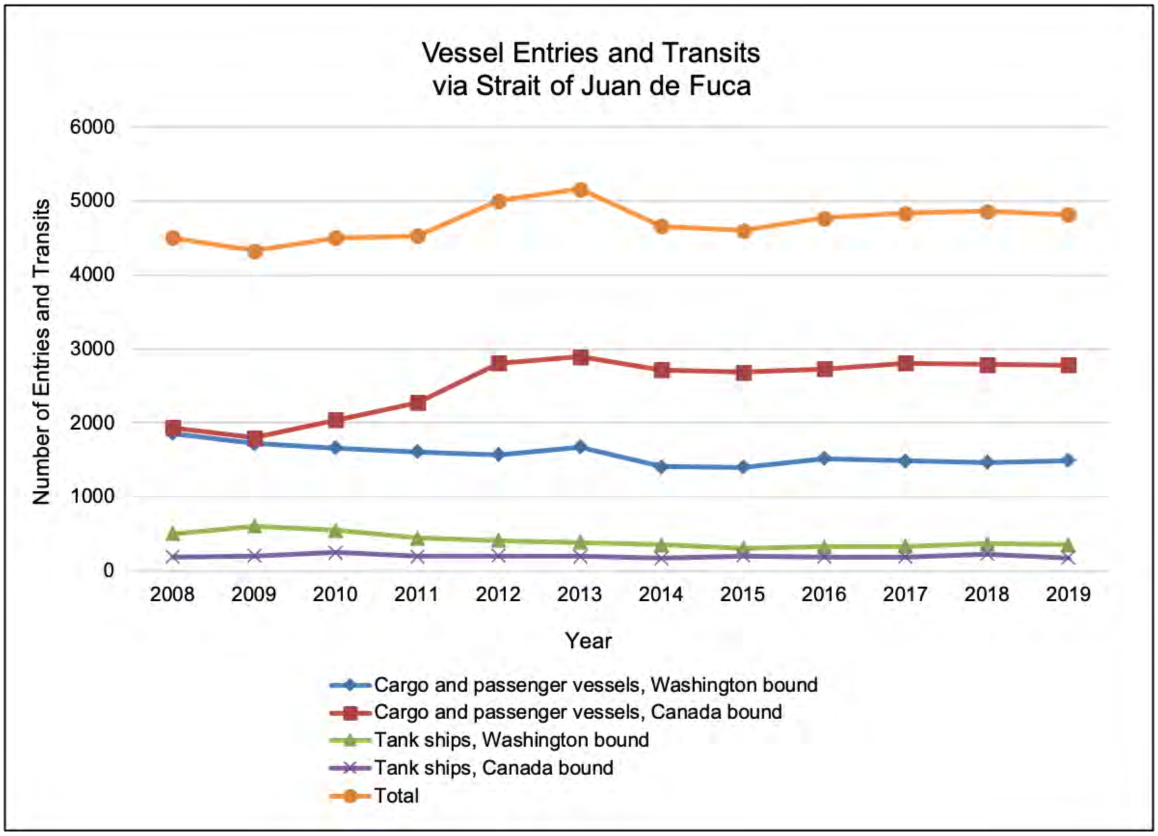

Figure S.P.2.2. Number of inbound vessel transits to the Strait of Juan de Fuca, including cargo and passenger vessels 300 gross tons and larger, and tank ships and tank barges (transporting oil) of any tonnage, from 2008–2019. Data collected from 2008–2019 demonstrate an overall 7% increase in vessel entries and transits, with a 13% increase in cargo and passenger vessel transits and a 24% decrease in tank ships. Source: Washington State Department of Ecology, 2020

No major oil spills occurred in the sanctuary from 2008 through 2019. Oil spills reported during this time period originated from smaller vessels (19 to 78 feet), with reported spill volumes of up to approximately 3,800 gallons of diesel fuel (Galasso, 2017). The NOAA Office of Response and Restoration considers diesel fuel spills of 500–5000 gallons to be small, and, while acutely toxic, when spilled in open water and unconfined, small spills evaporate or naturally disperse within a few days (NOAA Office of Response and Restoration, 2020). Therefore, for the purposes of assessing human activities that may adversely influence water quality, the number of incidents and volume of oil spilled do not indicate a significant change in oil spill risk. The OCNMS incident database shows that the most incidents were reported in 2012 and 2016, with five incidents each. The year with the greatest reported volume of oil spilled was 2011, with 3,825 gallons (Galasso, 2017). The number of lost vessels (22) and volume of spilled oil (approximately 10,000 gallons) over an 11-year period is not believed to have caused a significant impact on sanctuary water quality.

The amount of sewage and graywater produced by commercial vessels, including commercial, recreational, and charter fishing vessels, was estimated in the 2011 OCNMS management plan and environmental assessment (OCNMS, 2011). Sewage and graywater discharge data from 2009 were summarized for 14 vessel categories. Passenger vessels (>1,600 gross tons) were the largest contributors, discharging 63.3% of the all estimated sewage and 74.9% of the all estimated graywater. Based on this analysis, OCNMS changed its discharge regulations to prohibit most discharges from passenger vessels. Overall discharge of sewage and graywater in the sanctuary is thus assumed to have decreased; however, cruise ships have self-reported accidental illegal discharges on six occasions since 2011 (NOAA Office of General Counsel, 2021).

Another discharge into sanctuary waters occurs during the offshore processing of Pacific whiting. This activity is not new, but more information about the process has become available. Pacific whiting, or hake, is a semi-pelagic, schooling species of groundfish. There are three stocks of Pacific whiting: a migratory coastal stock, a Puget Sound stock, and a Strait of Georgia stock. While the latter two stocks have declined significantly, the coastal stock remains large and healthy and is the most abundant commercial fish stock on the West Coast.[11]

Pacific whiting are processed in several ways, with at least two methods of at-sea processing: at-sea mothership processors and catcher-processor vessels. After the usable portions of the fish are processed and boxed for marketing, the scraps are ground and discharged from the vessel.[12] Increasingly, offshore processors are incorporating meal plants into their at-sea operations to generate byproducts such as fish meal, fish oil, and bone meal, reducing discharges of the fish byproduct and waste produced during processing. In 2019, EPA Region 10 issued a National Pollutant Discharge Elimination System General Permit to seafood processing vessels that discharge in federal waters off the coast of Washington and Oregon.[13] Vessels operating under the permit are required to submit an annual report, including a summary of discharges (EPA, 2020). These annual reports may be an important source of information for future condition reports, and the amount of discharge could be a potential indicator. OCNMS received copies of these reports for 2019, but a trend could not be determined with only one year of information, and these data were thus not considered in the rating of this question (Figure R.2).

Exhaust gas cleaning system discharges in OCNMS are another source of concern. These systems remove sulfur from diesel exhaust to meet stringent IMO emission standards. However, they also generate effluent that is released into the marine environment and has the potential to harm the ecosystem (see Pressures on the Sanctuary: Maritime Transportation for more information). Despite this potential risk, local data on air pollution, collected by the Olympic Region Clean Air Agency at the Cheeka Peak Atmospheric Observatory, located on the Makah Reservation, may indicate a local benefit of these emission standards. A study from January 2011 and December 2014 investigated source factors contributing to ambient concentrations of particle pollution, specifically PM2.5. The first factor, identified as marine-traffic residual fuel

[11] The coastal stock of Pacific whiting is managed through the bilateral Pacific Whiting Agreement between the United States and Canada and by the Pacific Fishery Management Council's Pacific Coast Groundfish Management Plan.
[12] Offshore seafood processors in federal waters off the coast of Washington and Oregon are regulated under EPA general permit (WAG520000).
[13] Areas excluded from the general permit include state waters and waters shallower than 100 meters in depth and shoreward during April 15th–October 31st, unless the permittee can demonstrate that discharge will not contribute to hypoxic conditions.

oil, was the highest contributor to PM2.5 during late summer. Over the four-year analysis, the residual fuel oil percent contribution to total PM2.5 declined. This is consistent with previous studies elsewhere, and may be attributed to regulations restricting the sulfur content of ship fuel (Hadley, 2017). Little is currently known about the impacts of exhaust gas cleaning system discharges in OCNMS and how they are offset by benefits from improved air quality; thus, this information was not used in rating this question.

Conclusion

Several human activities have the potential to adversely influence water quality, but generally do not seem to be doing so to a concerning degree. Human activities considered include vessel traffic, sewage discharges, and at-sea seafood processing. The primary consideration for this rating continues to be the level of shipping in the sanctuary as an indicator for oil spill risk, as that remains the largest human risk to water quality in the sanctuary. Data gaps identified in addressing human activities that adversely influence water quality include, but are not limited to: volume and impacts of vessel discharges, including black water and gray water discharges, offshore seafood processing, and exhaust gas cleaning system effluent.

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

Status Description: Selected activities have caused measurable resource impacts, but effects are localized and episodic, rather than widespread or persistent.

Rationale: There have been shifts in the location of trawl impacts and improved management of bottom-contact gear. Activities of potential concern to benthic habitats include use of bottom-contact fishing gear; abandoned, lost, or derelict crab pots; lost vessels; and ocean dumping.

Comparison to 2008 Condition Report

In the 2008 condition report, this question was rated fair and improving (see Table S.P.2.1 and Appendix H). The basis for judgment was a decrease in bottom trawling and, presumably, impacts to hard bottom habitats. Since 2008, the level of non-tribal trawling in the sanctuary has remained relatively stable, with a shift in activity from the north to the south. In addition, state and tribal fishery managers have taken management actions to reduce the level of abandoned, lost, or derelict crab pots. OCNMS has also tracked the number of lost vessels and learned of incidents of lost cargo from ships. The lack of data for some of the known or suspected pressures considered in the current report, however, led experts to rate the trend as undetermined.

New Information in the 2008–2019 Condition Report

NOAA Fisheries' California Current Integrated Ecosystem Assessment (CCIEA) Ecosystem Status Report for 2020 (Harvey et al., 2020) provided the Pacific Fishery Management Council with an annual update on the status of the California Current Ecosystem. The CCIEA evaluates and tracks ecosystem indicators for the entire California Current to assess ecosystem attributes of interest, such as ecosystem health and resilience and socioeconomics. One such indicator is bottom trawl contact with the seafloor, which estimates effort in the groundfish fishery and potential impacts to seafloor habitats. OCNMS requested that CCIEA staff evaluate bottom trawl contact with the seafloor within and in areas immediately adjacent to OCNMS from 2008–2019 to identify shifts in trawling locations and trends in distances trawled. Figure S.P.3.1 shows bottom contact indicators for the federal, non-tribal groundfish fisheries operating within the boundaries of, and adjacent to, OCNMS from 2002–2019.

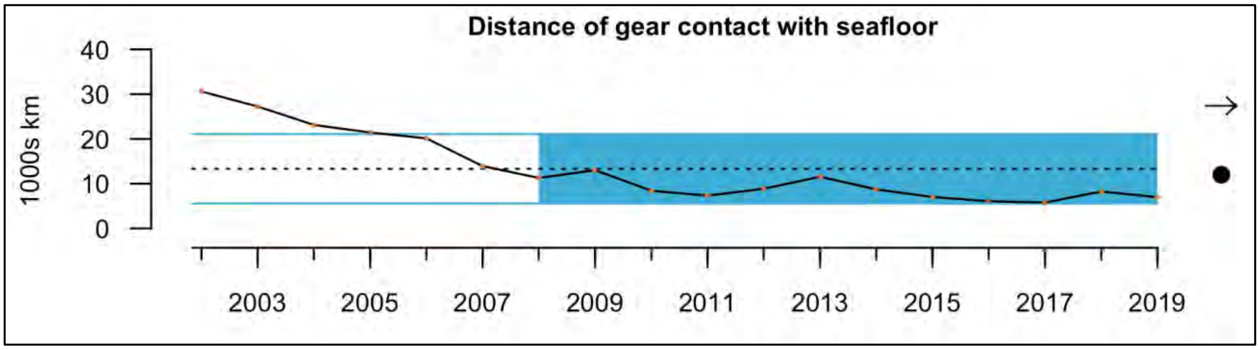

Figure S.P.3.1. Seafloor contact (in thousands of kilometers) by bottom trawl gear from federal groundfish fisheries operating within the boundaries of OCNMS from 2002–2019. The dashed line is the mean distance for the entire time series and the solid horizontal lines are ±1 standard deviation of the mean. Arrow at upper right indicates there was no trend in seafloor contact from 2008 to 2019 (shaded region). Symbol at lower right (•) indicates the mean from 2008 to 2019 was within 1 standard deviation of the long-term mean. Source: NOAA Northwest Fisheries Science Center, Fisheries Observation Science Program

Figure S.P.3.2 provides the spatial distribution of non-tribal bottom trawl effort, calculated from annual distances trawled within 2x2 kilometer grid cells (2002–2019). The left panel shows mean distance trawled annually from 2002 to 2007 and the middle panel shows mean distance trawled annually from 2008 to 2019. These maps indicate a large decrease in the footprint of non-tribal bottom trawling effort in the northern regions of the sanctuary between the two time periods, explaining much of the overall decrease observed over time (Figure S.P.3.1). The right panel shows the trend in bottom trawling effort from 2008 to 2019, highlighting the increasing trend in effort in the southwest region of the sanctuary. Figure S.P.3.3 shows changes in non-tribal bottom trawling effort among six habitat types in the sanctuary during the same time period. Since 2008, most trawling has occurred in soft habitats, with slight increases in soft, shelf habitats and slight decreases in soft, upper slope habitats.

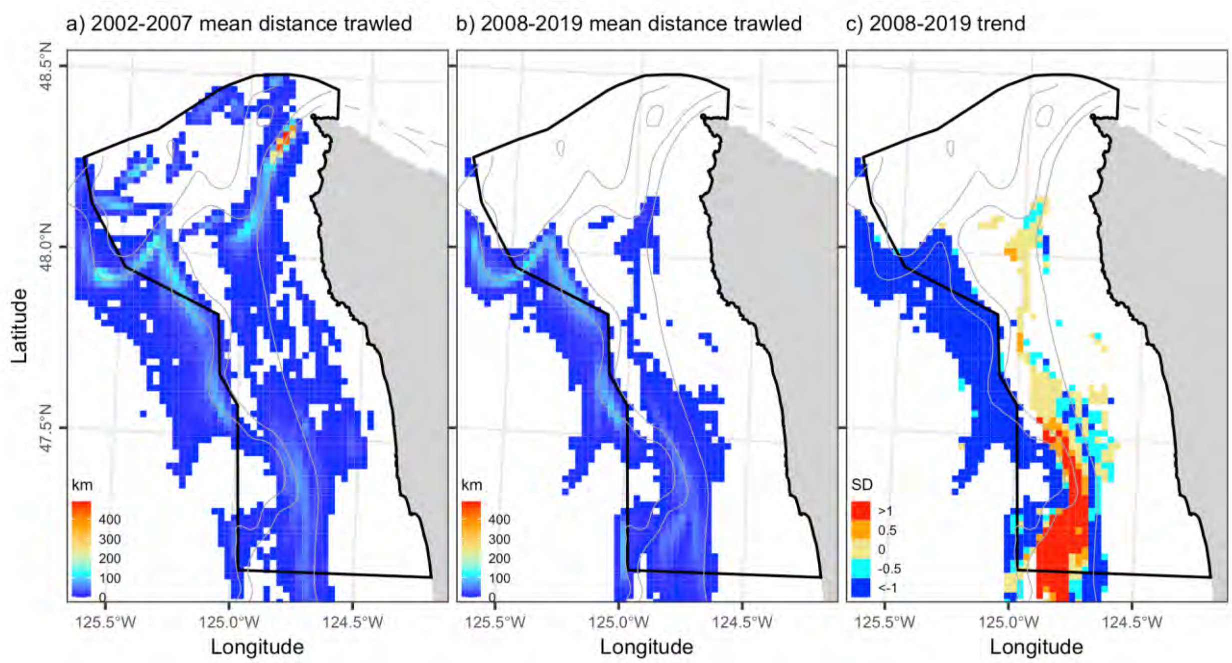

Figure S.P.3.2. Spatial representation of seafloor contact by non-tribal bottom trawl gear from federal groundfish fisheries operating within and near OCNMS. Panel (a) shows mean distance trawled annually from 2002 to 2017. Panel (b) shows mean distance trawled annually from 2008 to 2019. Panel (c) shows the trend in bottom trawling effort from 2008 to 2019. Grid cells with <3 vessels operating within the time period represented have been removed due to confidentiality. Cell colors in (c) indicate levels relative to the long-term mean (2002–2019) (e.g., red indicates >1 standard deviation above the mean and blue indicates >1 standard deviation below the mean). Source: NOAA Northwest Fisheries Science Center, Fisheries Observation Science Program

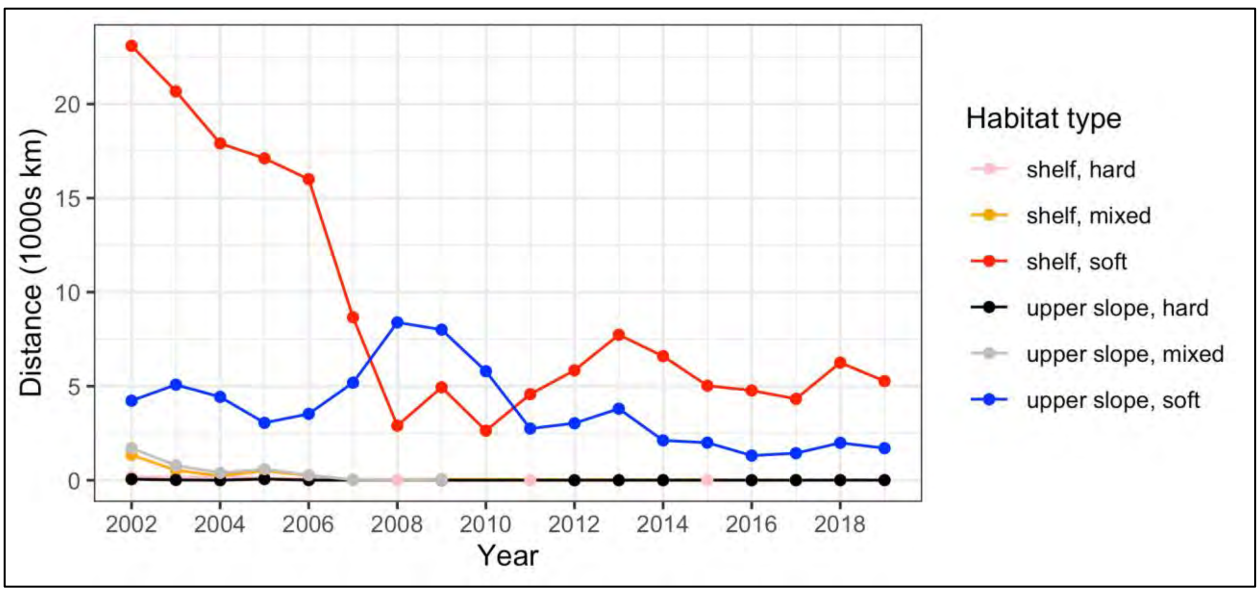

Figure S.P.3.3. Extent of seafloor contact among habitat types by bottom trawl gear from federal groundfish fisheries operating within the boundaries of OCNMS (2002–2019). Source: NOAA Northwest Fisheries Science Center, Fisheries Observation Science Program

Another significant user of bottom-contact gear in the sanctuary is the Dungeness crab fishery, managed by both Washington state and the Coastal Treaty Tribes. Washington state implemented a two-tier pot limit structure for the coastal Dungeness crab fishery in 2000. Each existing license was permanently assigned either a 300-pot or 500-pot limit based on historical landings. This has not changed in the 2008–2019 reporting period. It is estimated that approximately 10% of the 37,000 crab pots set in the sanctuary each year are lost (D. Ayres, personal communication, May 14, 2020). While the number of pots set annually has remained constant, both Washington and tribal resource managers have implemented pot recovery programs to reduce the number of abandoned, lost, or discarded pots in Washington state waters.

Experts also considered other pressures resulting from human activity, such as anthropogenic debris on the seafloor. In 2017, OCNMS completed a report on incidents that resulted in vessels being lost in or near the sanctuary (Galasso, 2017). The report included vessels that have sunk, grounded, or capsized, regardless of whether the vessel was salvaged. Since 2008, 30 vessels have been lost in the sanctuary, the majority of which were small recreational or commercial fishing vessels. In that period, there was no consistent trend, though contributing factors certainly include operator experience, sea state, and weather. The greatest number of vessels lost in a single year was six, in 2016; only two total vessels were lost in the following three years.

Makah fishers reported recovering crushed cars in their nets on four occasions in recent years (2011, 2013, 2016, and 2017; Figure S.P.3.4). When a recovered license plate was tracked, the registered owner reported delivering the car to the metal recycling yard of Amix Recycling/Schnitzer Steel Industries, Inc. in New Westminster, British Columbia, Canada in October 2007. OCNMS identified additional documented cases of scrap metal being lost from open deck barges. This included a 2010 case in which an entire barge capsized off the Columbia River, losing its entire 4,500 ton load (Ryan, 2019). Impacts to sanctuary resources from large amounts of debris can include changes in habitat, release of contaminants, crushing of organisms, as well as impeding Coastal Treaty Tribes' access to their treaty-protected resources, putting fishers at risk from increased entanglement, and the damage or loss of expensive gear and equipment.

Figure S.P.3.4. Crushed cars entangled in trawl nets. Photos: (clockwise from upper left) Jason Roberts/Makah Tribe, Larry Buzzell/Makah Tribe, Eric Soeneke/Makah Tribe, Eric Soeneke/Makah Tribe

Using vessel monitoring data, OCNMS attempted to identify the transit that could have been involved in the loss of the vehicle delivered to the recycling yard in October 2007. Several potential transits were identified, with the most likely occurring on December 13, 2007. OCNMS also identified additional transits with the same profile. This analysis, which covered the period between October 2007 and February 2013, identified 44 southbound transits between the New Westminster and Portland recycling yards.

Following this period, no additional transits were identified until February 9, 2018, when OCNMS staff observed a scrap metal deck barge westbound from Port Angeles (Figure S.P.3.5). This transit followed the same route as those previously identified between 2007 and 2013.

Figure S.P.3.5. Ocean Mariner towing an open-deck barge carrying scrap metal off Port Angeles on February 9, 2018. The vessel originated in New Westminster, British Columbia and was enroute to Portland, Oregon through OCNMS. Photo: G. Galasso/NOAA

Conclusion

The rating of fair was based primarily on the effects of bottom-contact fishing gear and various forms of debris on the seafloor. The effects of human activities are measurable, but localized. Following a large decrease in trawling activity prior to the reporting period, activity levels have been relatively consistent, with shifts in the location of trawling. Activities of primary concern include bottom-contact fishing gear; abandoned, lost, or derelict crab pots; lost vessels; and ocean dumping. Additional information is required on lost cargo and marine debris to better understand human activities that may adversely influence habitats.

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

Status Description: Some potentially harmful activities exist, but they have not been shown to degrade living resource quality to a degree that raises significant concern.

Rationale: Despite recent spikes in the number of whale entanglements, impacts from human activities overall either declined during the assessment period (e.g., a reduction in the number of overfished species) or remained at lower levels than earlier periods (trawling, and, presumably, gear impacts).

Comparison to 2008 Condition Report

In the 2008 condition report, this question was rated fair and improving (see Table S.P.2.1 and Appendix H). The basis for judgment was decreased pressure from commercial and recreational fishing. Since 2008, levels of human activity within and around the sanctuary have varied, with both increases and decreases in harmful activities or impacts related to human activities. The level of non-tribal trawling in the sanctuary has remained relatively stable, with a southward shift in activity (Figure S.P.3.1 and Figure S.P.3.2). There have been management actions undertaken to reduce the level of abandoned, lost, or discarded crab pots. In 2011, the Department of the Navy significantly expanded the Quinault Range Site, which overlaps considerably with the sanctuary. There has been an increase in the number of whale entanglement cases coastwide, including in OCNMS. In 2018, the number of reports of whale entanglement in Washington and Oregon was exceptionally high. Marine debris loading increased in 2012 with the arrival of debris from the 2011 Japanese tsunami and again in 2015 with the onset of a strong El Niño event.

New Information in the 2008–2019 Condition Report

Impacts from groundfish trawling are of concern to OCNMS because bottom-tending[14] gear affects both non-target species and other benthic organisms through seafloor disturbance and by-catch. Many organisms, like corals and sponges, are slow to recover (Miller et al., 2012).

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[14] NOAA Fisheries defines bottom-tending gear as: bottom longline, bottom trawl, buoy gear, dredge, pot or trap, and bottom anchoring by fishing vessels.

While such damage is caused primarily by bottom-tending gear, unintended bottom contact by mid-water trawls, as well as impacts from lost gear, can have similar effects.

As discussed in Question 3, the NOAA Northwest Fisheries Science Center used data from their Fisheries Observation Science Program to look specifically at OCNMS, and immediately adjacent areas, from 2008–2019. Figure S.P.3.1 shows a substantial decrease in seafloor contact from bottom trawl gear used by federal groundfish fisheries operating within the boundaries of OCNMS from 2002–2019. This decrease slowed after 2008, but annual levels were below the long-term mean for the entire study period (shaded region).

Through careful, science-based management and collaboration among fishers, the Pacific Fishery Management Council, tribes, West Coast states, and NOAA Fisheries, many stocks, including canary rockfish, bocaccio, darkblotched rockfish, and Pacific Ocean perch, rebounded faster than expected and are now fully rebuilt. Research and stock assessments by NOAA's Northwest and Southwest Fisheries Science Centers documented this trend, facilitating more harvest opportunities (Figure S.P.4.1). Other stocks, such as yelloweye rockfish, have also been found to be recovering much faster than anticipated (NOAA Fisheries, 2018). OCNMS contains large areas of untrawlable, and therefore unassessed, habitat that is used extensively by some of these species. Tribes and others have noted for years that the NOAA Fisheries trawl surveys don't account for the fish in these areas. Rocky habitat in OCNMS has acted as refuge for many species, especially some rockfish (J. Schumacker/Quinault Indian Nation, personal communication, July 22, 2020).

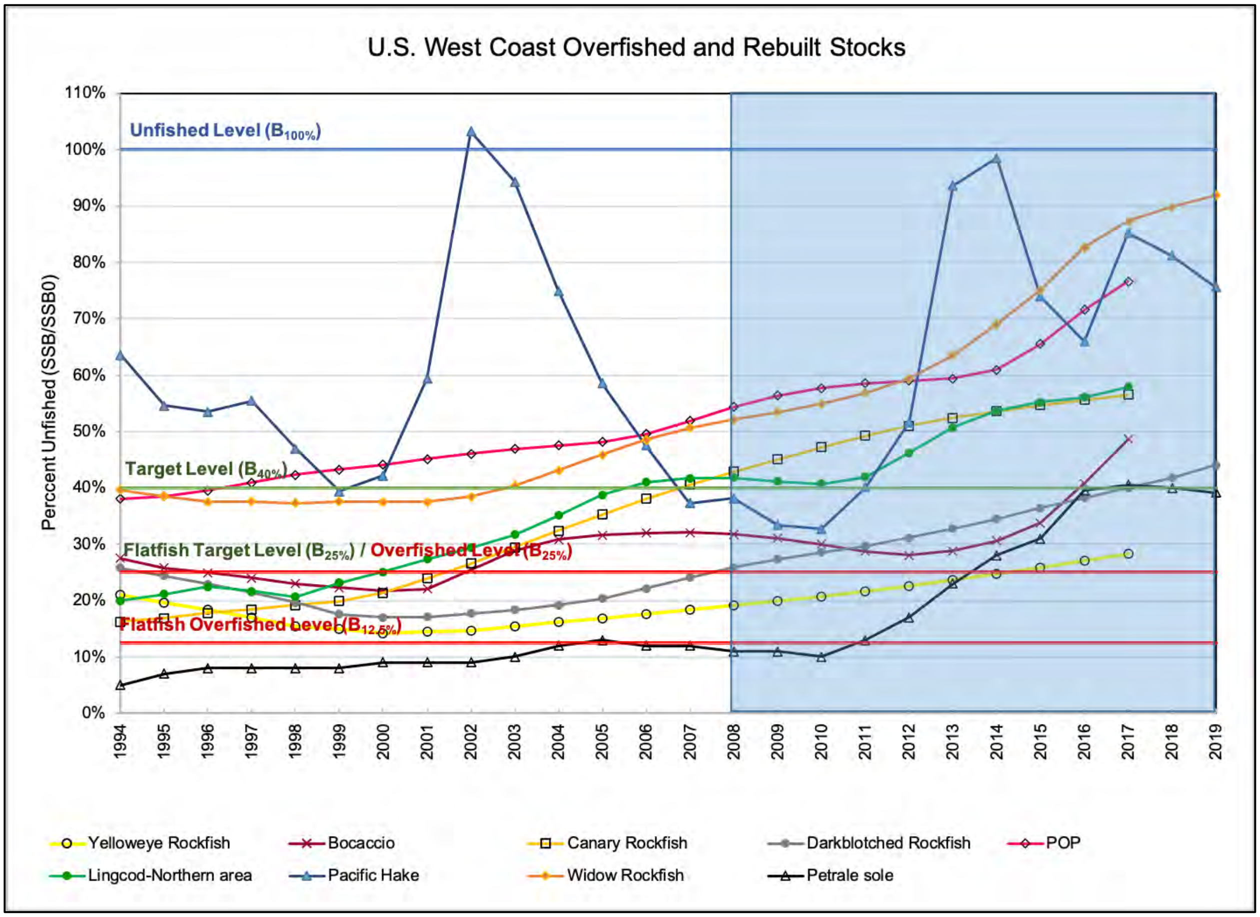


Figure S.P.4.1. Fishing levels (as percent unfished) for overfished and rebuilt West Coast stocks from 1994 to 2019 (POP = Pacific Ocean perch). The shaded area indicates the study period for the 2008–2019 condition report. Source: NOAA Fisheries, 2021a

The U.S. Navy has a long history of testing and training activities in the Pacific Northwest, which predates the sanctuary's 1994 designation. The types and frequency of naval activities have continued to evolve. Since the last OCNMS condition report was published, the Navy has produced four National Environmental Policy Act documents that cover activities in the sanctuary (Naval Underwater Warfare Center, 2010; U.S. Department of the Navy, 2010, 2015, 2020). The Navy has also invested considerable resources into researching impacts of naval activities on natural marine resources and consults regularly with NOAA on the ecological implications of these impacts.

In 2010, the Navy expanded the Quinault Underwater Testing Range (now known as the Quinault Range Site) from 48.3 square nautical miles (overlapping 2% of OCNMS) at the time the sanctuary was designated to 809 square nautical miles, with 759 square nautical miles in the sanctuary (overlapping 34% of OCNMS). The Navy also proposed the testing of vehicle propulsion systems, submarines, inert mine detection, uncrewed undersea vehicles, uncrewed aerial systems, and shore deployment systems, as well as an increase in the average annual number of tests and days of testing and the addition of a surf zone at Pacific Beach.

In accordance with section 304(d)[15] of the NMSA, the Navy and NOAA Fisheries consulted with OCNMS on the Navy's Northwest Training and Testing activities in the sanctuary (in 2015 and 2020) and for associated National Marine Fisheries Service authorization of incidental take under the Marine Mammal Protection Act (in 2020). As part of the consultations the Navy (in 2015 and 2020) and NOAA Fisheries (in 2020) prepared sanctuary resource statements. The purpose of sanctuary resource statements is to provide ONMS with enough information to understand the nature of the proposed activity and its potential impacts on sanctuary resources. Activities that had the potential to injure sanctuary resources were included in the 2015 and 2020 sanctuary resource statements. The following activities are those that: 1) could occur within OCNMS (e.g., testing activities); 2) have the potential for propagation into OCNMS (e.g., training activities); or 3) may injure a marine mammal as defined under Section 304(d).

Training

- Anti-submarine warfare tracking exercise – submarine (2015)
- Anti-submarine warfare tracking exercise – surface (2015)
- Anti-submarine warfare tracking exercise – maritime patrol aircraft (2015)
- Surface ship sonar maintenance (2015)
- Submarine sonar maintenance (2015)
- Uncrewed underwater vehicle training (2020)

Testing

- Torpedo testing (non-explosive) (2015)
- Autonomous and non-autonomous vehicles: uncrewed underwater vehicle (2015)
- Fleet training/support: anti-submarine warfare testing (2015)
- Acoustic component test: countermeasures testing (2015)
- Anti-surface warfare/anti-submarine warfare testing countermeasure testing (2015)
- New ship construction: anti-submarine warfare mission package testing (2015)
- At-sea sonar testing (2020)
- Mine countermeasures and neutralization testing (2020)
- Mine detection and classification testing (2020)
- Uncrewed underwater vehicle testing (2020)
- Undersea warfare testing (2020)
- Acoustic and oceanographic research (2020)

In annual meetings between the Navy and OCNMS, actual testing and training that occured within the sanctuary in the previous year is discussed, as security allows. Actual training and testing activities often occur at lower levels than projected in the Navy National Environmental Policy Act documents. This makes trends in Navy activities difficult to assess. However, NOAA Fisheries and USFWS have found that higher levels of Navy activity on scales larger than the sanctuary have negligible impacts on marine mammals and do not jeopardize listed species, especially in light of added minimization measures over time. The Navy's permit authorizations

[15] Pursuant to Section 304(d) of the NMSA, consultation is required when federal agency actions are "likely to destroy, cause the loss of, or injure a sanctuary resource."

include monitoring and reporting commitments to ensure authorization levels have not been exceeded.

Over the last few years, NOAA Fisheries has responded to a higher than usual number of large whale entanglements reported to the West Coast Marine Mammal Stranding Network and Large Whale Entanglement Response Network. In 2018, a total of 46 whales were confirmed entangled off the coasts of California, Oregon, and Washington. NOAA Fisheries also reported 32, 55, and 53 confirmed cases of whale entanglement in 2017, 2016, and 2015, respectively. These were the highest annual totals for this region since NOAA Fisheries started keeping records in 1982 (NOAA Fisheries, 2020c).

Data from the adjacent counties of Clallam, Jefferson, and Grays Harbor (Figure S.P.4.2) showed that the highest number of entanglements occurred in 2018, by a substantial margin. Of the 10 reported entanglements in 2018, two were gray whales and eight were humpback whales. The gear causing the entanglement was reported as commercial Dungeness crab gear (3), gillnets (4), and unknown (3).

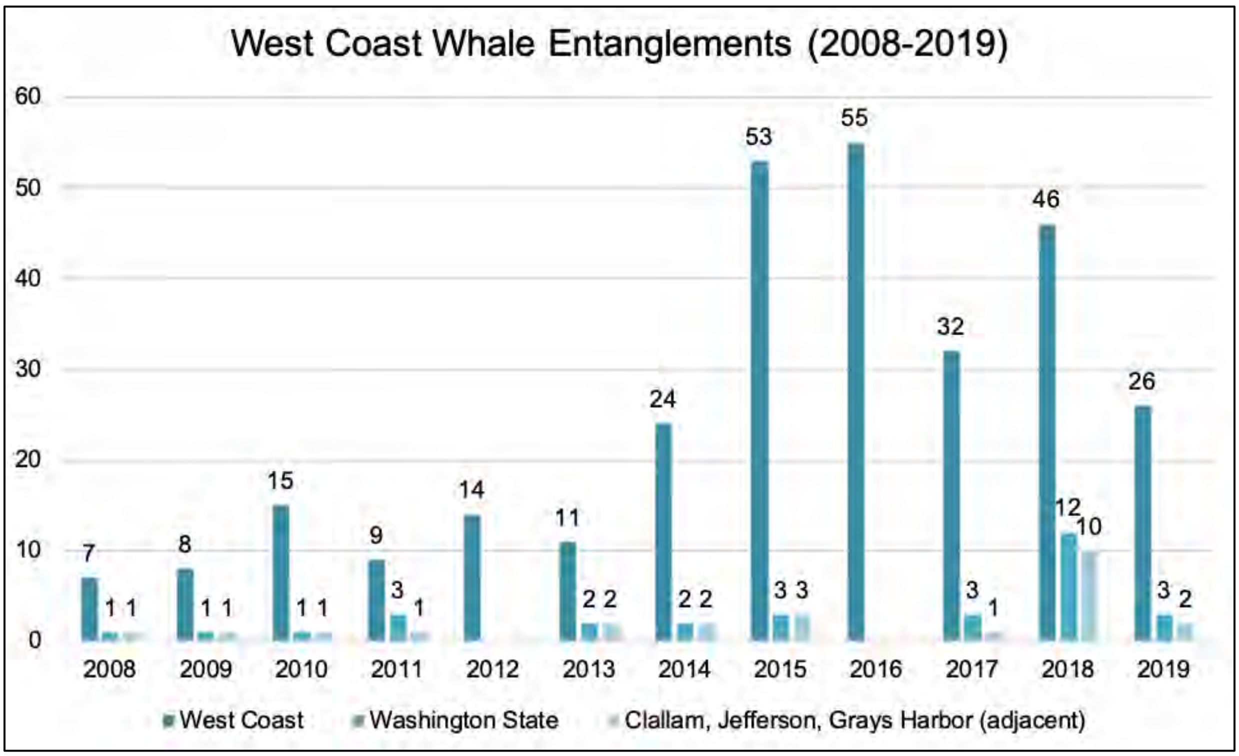


Figure S.P.4.2. Whale entanglements on the West Coast, in Washington state, and adjacent to Clallam, Jefferson, and Grays Harbor counties (considered to be representative of the OCNMS area). Source: NOAA West Coast Marine Mammal Stranding Network

Though most human activities discussed here have remained fairly constant between 2008 and 2019, conditions in the ocean changed dramatically, including an anomalous and persistent marine heatwave from 2014 to 2016. A recent study found that this unprecedented marine heatwave caused habitat compression by restricting coastal upwelling, changing the availability of forage species (krill and anchovy), and forcing foraging whales shoreward, increasing interactions with the Dungeness crab fishery (Santora et al., 2020). This may account for the higher number of whale entanglements.

Marine debris impacts include wildlife entanglement and ingestion. Data from OCNMS show that large debris items increased in 2012 with the arrival of debris from the 2011 Japanese tsunami and gradually decreased following a peak in 2014 (Figure S.P.4.3). Considerably higher levels of debris were also encountered following the strong El Niño event of 2015–2016.

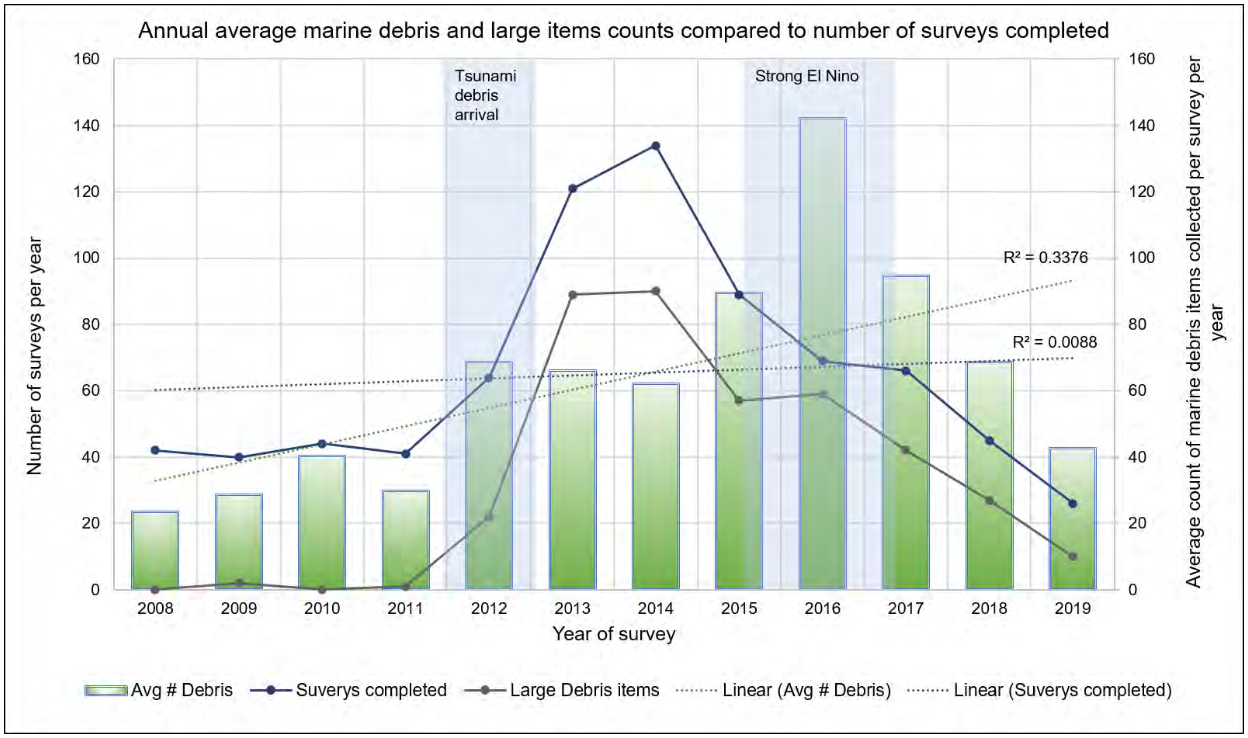


Figure S.P.4.3. Numbers of surveys per year and average count of marine debris items collected annually from 2008–2019. Source: NOAA; Image: C. Butler-Minor/NOAA

Conclusion

The rating of good/fair was largely based on changes in fisheries practices that have led to a reduction in the number of overfished species, a significant management achievement. Negative indicators, such as an increase in whale entanglements and pulses in marine debris, are believed to be short-term events attributable to specific anomalies. The levels of human activities that may adversely influence living resources indicated an overall improving trend. Data gaps in addressing human activities that may adversely influence living resources include, but are not limited to, under-reporting of whale entanglements and ship strikes, as well as acoustic impacts.

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

Status Description: Selected activities have caused measurable impacts to maritime heritage resources, but effects are localized and episodic rather than widespread or persistent.

Rationale: Cumulative damage to shipwrecks from bottom-trawl fishing gear began when trawl gear was first introduced, decades before OCNMS was designated. The level of trawl activity has been relatively steady since 2008, but is reduced compared to historic levels. Additional, but limited, bottom disturbance exists from ocean dumping, lost vessels, and research activities.

Comparison to 2008 Condition Report

Maritime heritage resources include tangible resources such as historic shipwrecks, prehistoric archaeological sites, and archival documents; intangible resources such as oral histories and stories of Indigenous cultures that have lived and used the oceans for thousands of years; and natural resources with cultural value (OCNMS, 2008).

In the 2008 condition report, this question was rated fair with an undetermined trend (see Table S.P.2.1 and Appendix H). The basis for judgment included fishing activities, offshore cable installations, and unauthorized salvaging. Since 2008, non-tribal trawling activity has remained steady, but with a general shift southward. Some areas in the north of the sanctuary have not been trawled by non-tribal fishers for several years (Figure S.P.5.1.). New activity or information on existing cables has not been documented, nor has unauthorized salvage.

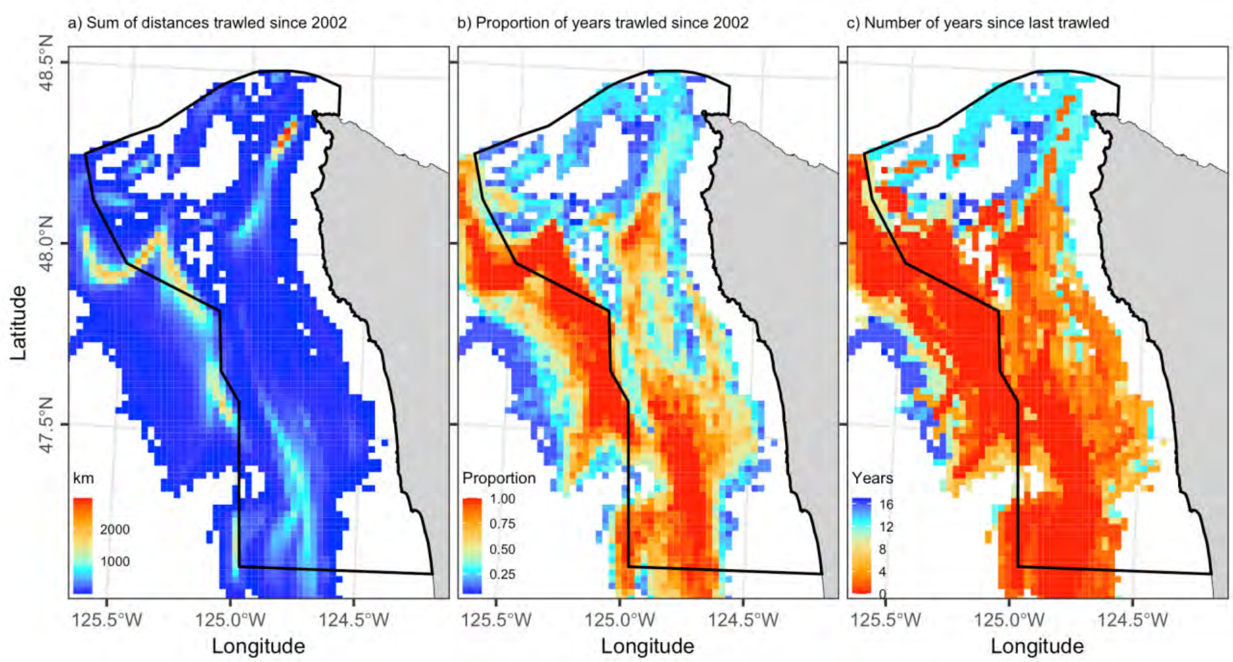


Figure S.P.5.1. Spatial representation of seafloor contact by non-tribal bottom trawl gear from federal groundfish fisheries operating within OCNMS and nearby areas. Panel (a) shows the sum of distance trawled since 2002. Panel (b) shows the proportion of years trawled since 2002. Panel (c) shows the number of years since last trawled. Grid cells with <3 vessels operating within the time period (2002–2019) represented have been removed due to confidentiality. Source: NOAA Northwest Fisheries Science Center, Fisheries Observation Science Program

New Information in the 2008–2019 Condition Report

While the time period for evaluation in this condition report is 2008–2019, impacts to maritime heritage resources are cumulative, as these resources cannot recover in the way that some habitats and living resources can. Impacts to shipwrecks from fishing activity have been documented in the sanctuary.

In June 2016, ONMS partnered with Ocean Exploration Trust on a shipwreck survey of the SS *Coast Trader*, which was torpedoed and sunk in June 1942 by the Imperial Japanese Navy submarine *I-26*. The SS *Coast Trader* was previously believed to be located in OCNMS, but was found approximately three nautical miles to the north in the Canadian EEZ. An analysis of ROV survey footage showed that *Coast Trader* was impacted in three ways from fishing activities: "nets snagged and twisted around parts of the superstructure; nets snagged on jagged areas of torpedo damage and ensnared on the wreck; and trawl gear wedged against the underside of the hull…" (Delgado et al., 2018b, p. 27).

Certain human-made debris on the ocean floor can cause impacts to maritime heritage resources through direct impact, and also complicates inventory activities. Of 46 vessels identified in a 2017 report on vessels lost in or near the sanctuary, 26 remain on the seafloor, likely in the sanctuary. Five surveys were conducted to locate these vessels, and two were located and charted. When possible, OCNMS attempts to locate vessels lost in the sanctuary to assess impacts to resources and update nautical charts. While these wrecks may not be a navigation hazard in the traditional sense, they do represent hazards to fishers who use gear on or near the seafloor (Galasso, 2017).

Another source of debris is lost cargo, previously described in response to Question 3. Makah fishers have recovered crushed cars in their nets on four occasions since 2011. In 2015, OCNMS chartered a survey off Cape Flattery focusing on the area where Makah fishers reported the debris. Using a combination of sidescan sonar and an ROV, a debris field of approximately 13 cars was identified. OCNMS believes that additional lost cargo exists along an identified route within the sanctuary. The presence of debris prevents the Makah Tribe from accessing their traditional, treaty-protected fishing area. Other debris discussed previously can also have an impact on the traditional tribal fishing areas of all Coastal Treaty Tribes.

In consultation with subject matter experts on this question, it was clear that maritime heritage resources are much broader than shipwrecks, including both tangible and intangible resources, such as historic and cultural practices. Important work, such as language programs, tribal historic preservation programs, and tribal cultural landscape characterizations are being carried out by the Coastal Treaty Tribes to prevent further loss of traditional cultural knowledge and resources. There was a consensus that in addressing this question, impacts to cultural resources should be addressed in the future. The sanctuary's knowledge of these resources was identified as an important data gap. This finding is consistent with a broader internal survey conducted in 2019 by the ONMS Maritime Heritage Program, which revealed that multiple sanctuary sites require assistance in engaging tribal and Indigenous groups and appropriately considering cultural heritage resources.

Sanctuary managers have deferred to tribal historic preservation staff in the protection of these resources, which are often shoreward of sanctuary boundaries. An example of this approach is oil spill response, which requires a qualified Historic Properties Specialist to assess emergency response strategies to protect historic properties or cultural resources (Region 10 Regional Response Team and the Northwest Area Committee, 2020). This helps to prevent sensitive location information from being released to the general public. This approach will be reevaluated as a result of recent conversations. Despite the consensus that this question should be considered in a broader context, the rating for this question was based primarily on human impacts on shipwrecks due to a lack of available information.

Conclusion

The rating of fair was based on a number of factors, including bottom-contact fishing and various sources of debris left on the seafloor from other human activities. Where they occur, particular human activities have measurable impacts, but they are localized. Following a decrease in trawling activity in the first decade of the current century, most of which occurred prior to the reporting period, trawling has remained consistent but has shifted in location. Nevertheless, activities of concern include bottom-contact fishing gear, abandoned or lost vessels, and intentional or accidental ocean dumping. Cable installation and operations are also a concern, but were not discussed due to the lack of activity between 2008 and 2019. Data gaps regarding human activities that adversely influence maritime heritage resources include, but are not limited to: the location and status of many historical shipwreck sites and information on sensitive cultural resources.

State of Sanctuary Resources

This section provides summaries of resource status and trends within four areas: water quality, habitat, living resources, and maritime heritage resources. An expert workshop was convened by OCNMS staff on January 14–16, 2020 to discuss and evaluate 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 habitat indicators in OCNMS are for the period from 2008–2019. However, in some cases, data series extend into 2020. Answers for each question are supported by data and the rationale is provided at the end of each section for each resource area. 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 January 2020). However, in some 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.

In order to effectively consider all key indicators and relevant data sets, workshop experts were asked to consider each of the six major habitat types that are present in OCNMS: rocky shores, kelp forest, sandy beach, sandy seafloor, deep seafloor, and pelagic (Figure S.1 and Table S.1).

Rocky Shores Habitat

Rocky shores are found primarily along the northern portion of the outer coast of Washington, and are typically characterized by steep, rocky cliffs and rocky intertidal habitats that may have some interstitial sand. Many sea stacks lie just offshore of this area of the coast. Other prevailing features include high wave energy, large tidal exchanges, and a diverse community of hardy macroalgae, macrophytes, and benthic invertebrates distributed throughout subtidal, intertidal, and supratidal zones. Fishes dwell around rocks, in tidepools, and in the surf zone. The steep cliffs and isolated sea stacks provide colonial seabirds with refuge from terrestrial predators.

Kelp Forest Habitat

Kelp forests are typically associated with wave-exposed, rocky reefs from the subtidal zone to about 30 m in depth. The dominant canopy-forming kelp species in Washington is bull kelp, which attaches to the rocky seafloor and extends to the surface during the growing season. Giant kelp is also present, along with many understory kelp species found beneath the canopy. Kelp provides three-dimensional habitat structure for many pelagic and benthic species at the margins of intertidal and open ocean communities. This includes nursery habitat for young-of-the-year rockfishes. Both live and detached kelp provide detritus that is fed upon by grazers and scavengers; detached kelp subsidizes food webs in adjacent habitats.

Sandy Beach Habitat

Sandy beaches are the dominant habitat type along the southern and central Washington coast, although sandy beaches also exist in places along the northern Washington coast. Beaches may be composed of sediments of various grain sizes, ranging from sand to gravel and cobble. They are characterized by unconsolidated sediments, twice-daily high and low tides, direct exposure to high wave energy, and relatively little in the form of habitat-structuring components such as macroalgae or seagrasses. Much of the productivity on beaches is subsidized by production in adjacent systems. Olympic Coast beaches host many burrowing and tunneling invertebrates, a specially adapted community of fishes and invertebrates in the highly active surf zone, and many species of birds. Bears and other terrestrial mammals are also known to forage in beach habitats.

Sandy Seafloor Habitat

Sandy seafloor habitats are areas dominated by unconsolidated sediments (i.e., sand, mud, silt) at water depths shallower than ~30 m. Sandy seafloor may harbor important species such as halibut and other flatfishes, Dungeness crab and other crab species, and a variety of invertebrates living on or in seafloor sediments.

Deep Seafloor Habitat

The deep seafloor habitat includes bottom features and waters close to the bottom at depths greater than 30 m on the continental shelf and slope. The deep seafloor at OCNMS is dominated by soft sediments—sand, mud, and silt—with occasional rocky areas or other features, such as seamounts or submarine canyons. Sunlight is limited or absent in this habitat, and production is mostly subsidized by the overlying pelagic zone. A great variety of species inhabits the seafloor. Some prefer rocky habitats or live among sponges and corals, while others dwell on soft sediments; many foray into the pelagic zone.

Pelagic Habitat

The pelagic habitat represents the water column off the coast of Washington, over the continental shelf and the upper reaches of the continental slope, and is roughly equivalent to the area covered by the deep seafloor habitat. Pelagic habitat is characterized by dynamic masses of open water that are constantly moving and changing, and is inhabited by planktonic and free-swimming species that range from the surface to the deep water near the seafloor. Many of these species occur in large schools or patches concentrated at different points in time or space. Some species make large vertical migrations each day (e.g., planktonic creatures that live at deeper depths in the daytime, ascending to shallower depths at night) or make long distance migrations on a seasonal basis (from Washington coastal waters to some other region).

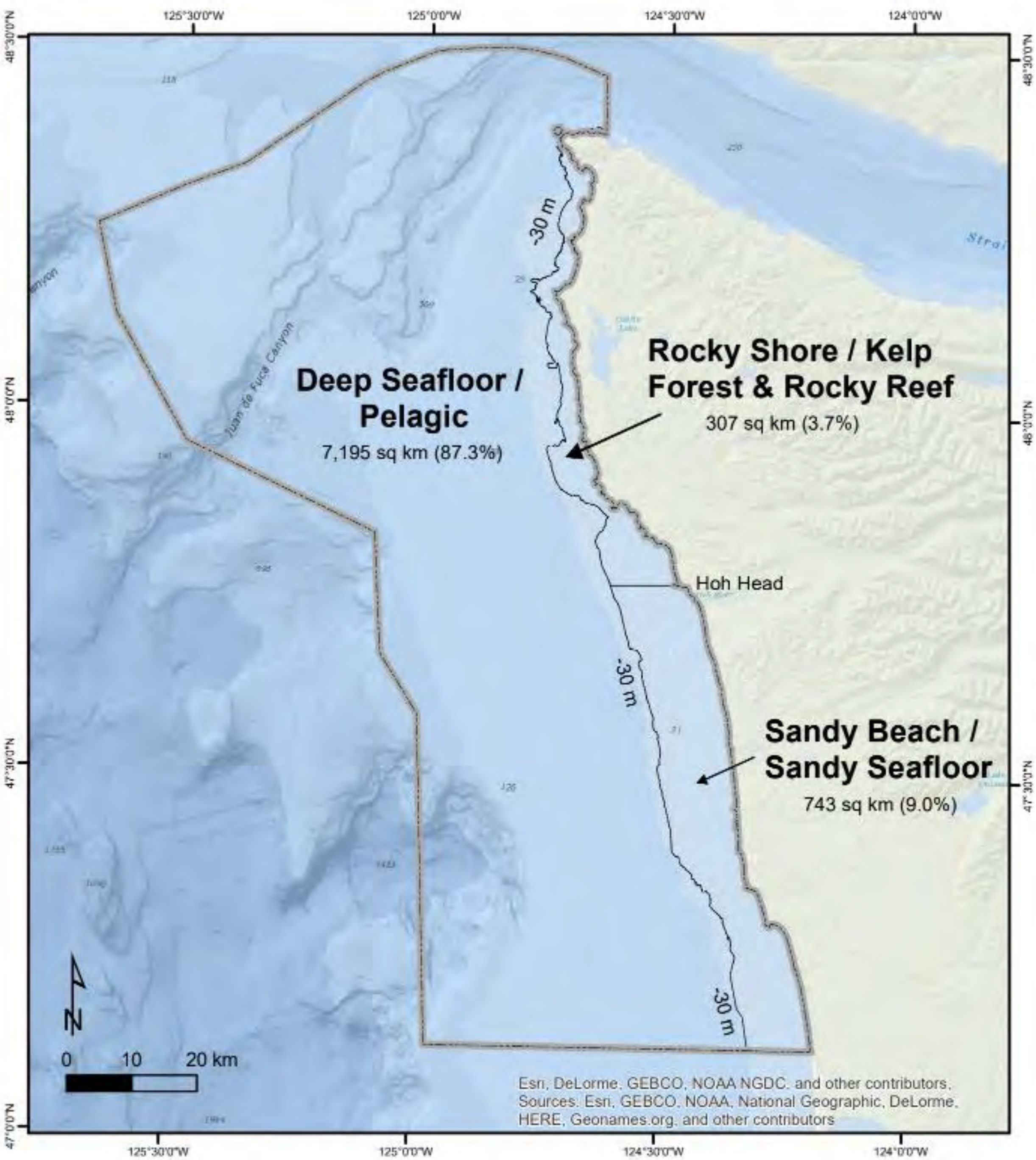


Figure S.1. Map of OCNMS showing the general location and extent of the six major habitat types present. Image: Bryan Costa/NOAA

Table S.1. Approximate area in square kilometers and percent of the sanctuary comprised by each of the six major habitat types found in OCNMS. Deep seafloor and pelagic habitats share the same footprint, but the dominant habitat by volume is the pelagic habitat.

Habitat Type	**Area (km^2)**	**Percent of OCNMS**
Rocky Shores and Kelp Forest	307	3.7
Sandy Beach and Sandy Seafloor	743	9.0
Deep Seafloor and Pelagic	7,195	87.3
Total	**8,245**	**100**

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

Monitoring and assessing water quality is one of the main objectives of the OCNMS management plan, which focuses on improving our understanding of water quality and ensuring protection of natural resources in the sanctuary. The following provides an assessment of the status and trends of key water quality indicators in OCNMS for the period from 2008–2019.

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, beach, and/or seafood contamination (bacteria, chemicals, and biotoxins). Indications of health impacts may include shellfishery 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, fertilizers, pesticides, heavy metals, and sewage from diffuse sources.

Table S.WQ.6.1. 2008 (left) and 2008–2019 (right) status, trend, and confidence ratings for the water quality questions.

2008 Condition Report Questions	2008 Rating	2008–2019 Condition Report Questions	2008–2019 Condition Report Rating
2. Eutrophic condition	–	6. Eutrophic condition	Good –
3. Human health risks	–	7. Human health risks	Fair –
1. Multiple stressors (including climate)	?	8. Climate drivers	Fair/Poor ▼
		9. Other stressors	Good/Fair ▼

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

Status Description: Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.

Rationale: High primary productivity naturally occurs seasonally in OCNMS due to upwelling during the spring and summer. Human contributions to eutrophication (primarily via seasonal inputs of nutrients from the Salish Sea and Columbia River) appeared to be negligible compared to natural cycles controlled by upwelling.

Eutrophication occurs when high levels of nutrients from human sources fuel high rates of primary production and algal biomass accumulation, either as macroalgae or phytoplankton. On the Olympic Coast, upwelling plays a dominant role in high nutrient concentrations found in surface waters in spring and summer, which fuel ecosystem productivity and can contribute to HABs. During the period from 2008 to 2019, the status of eutrophic conditions in OCNMS was rated good with an unchanging trend, both with a high degree of confidence (Table S.WQ.6.1). The rating of good indicates that eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity. These ratings were based on the fact that high primary productivity naturally occurs in OCNMS due to upwelling during the spring, summer, and early fall. Human contributions to eutrophication, primarily via seasonal inputs of nutrients from the Salish Sea and Columbia River, appeared to be negligible in comparison to nutrient inputs from upwelling; however, freshwater outflow from the Columbia River may behave in different ways under certain conditions, potentially acting as a barrier or conduit for transport of HABs along the coast (Figure S.WQ.6.1; Hickey et al. 2013).

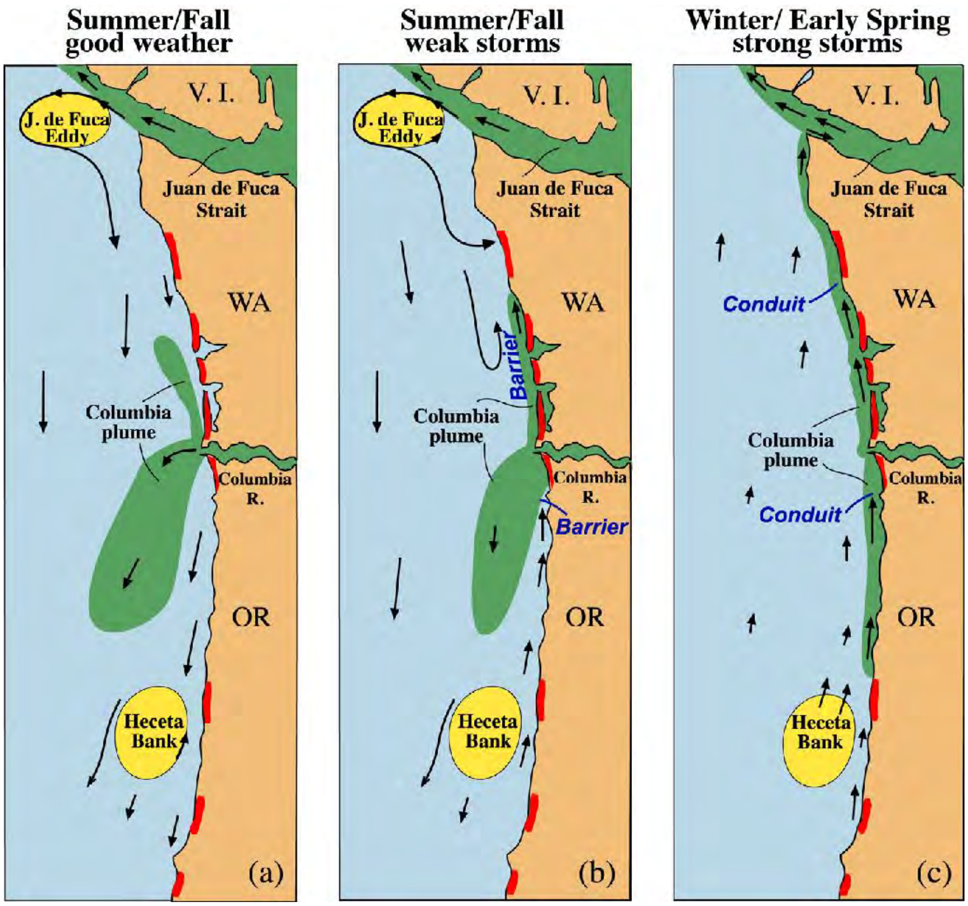


Figure S.WQ.6.1. Environmental conditions that transport toxic *Pseudo-nitzschia* southward from northern (the Juan de Fuca Eddy) and southern (Heceta Bank) sources in summer/fall in the Pacific Northwest (a) under prevailing upwelling-favorable winds; (b) during a reversal to weak downwelling-favorable winds; and (c) in late winter/spring, prior to the spring transition. Surface currents are shown with arrows. Shaded areas on shore are clamming beaches. Shaded areas offshore indicate freshwater plumes from the Columbia River and the Strait of Juan de Fuca. "Barrier" and "Conduit" notations refer to the role of the Columbia plume in transporting HABs to the Olympic Coast under different oceanographic conditions. Image: Hickey et al., 2013

Comparison to 2008 Condition Report

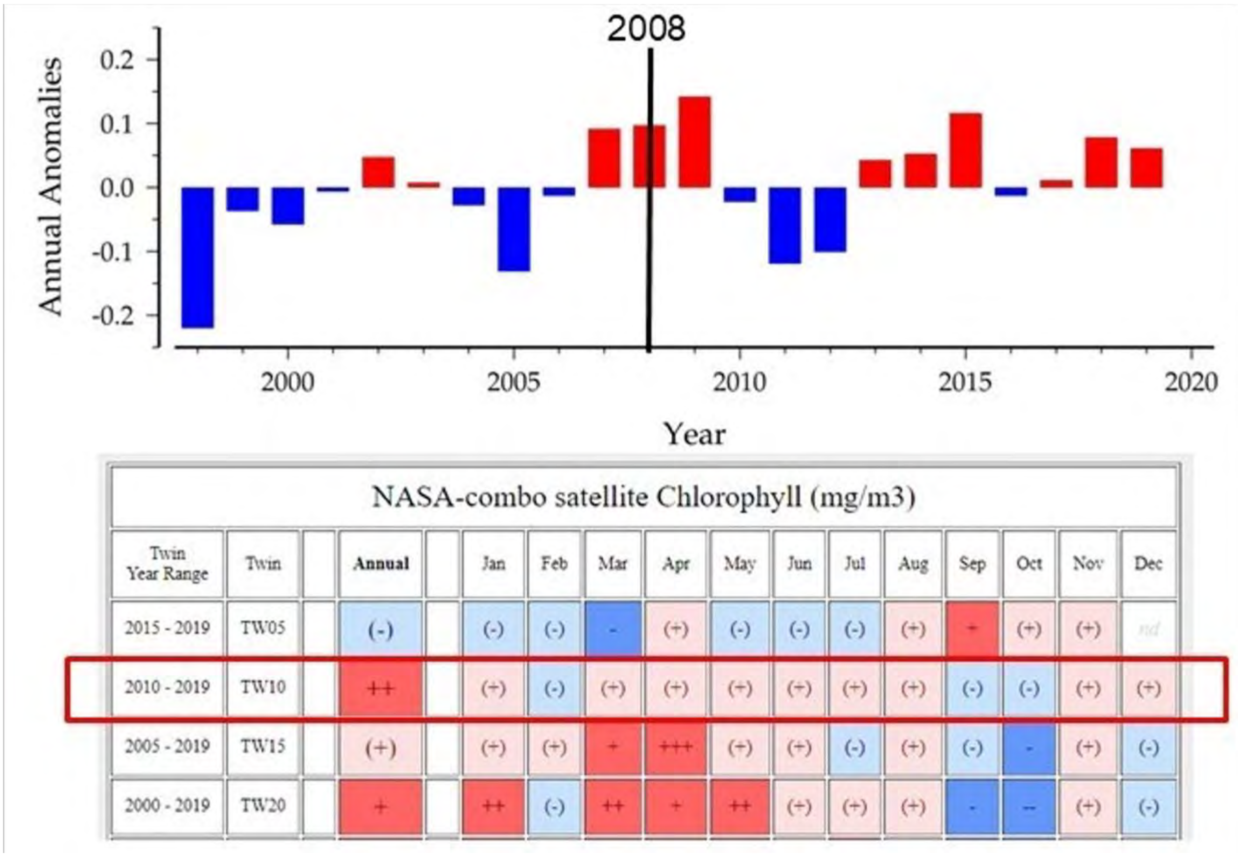
In the 2008 condition report, the rating for this question was good, and the trend was not changing (see Table S.WQ.6.1 and Appendix H). There was no suspected human influence on eutrophication in OCNMS. HABs occurred in the sanctuary as natural phenomena and were not believed to be enhanced by inputs of nutrients from land-based human activities or eutrophic conditions (ONMS, 2008). However, the 2008 report was limited because there were no long-term, *in situ* data describing the status and trends for eutrophication indicators due to insufficient instrumentation in sanctuary waters (ONMS, 2008).

Sanctuary staff and subject area experts assessed the current status and trend information for eutrophic conditions and concluded that 2008–2019 conditions were good and not changing, similar to the findings in the 2008 report. There was high agreement and confidence among the experts on this rating, although there was medium evidence to support their decision. The current report provides information and data analysis on critical indicators related to eutrophication from different sources that assisted experts in the assessment process. These indicators include: phytoplankton, represented as chlorophyll in NASA satellite images; upwelling indices; nutrient loads in the Columbia River; and bottom dissolved oxygen from sanctuary moorings.

New Information in the 2008–2019 Condition Report

Experts agreed with high confidence that eutrophication in OCNMS was not documented and does not appear to affect ecological integrity. The assessment was mainly based on important indicators such as phytoplankton (chlorophyll concentrations), upwelling indices, and nutrients (i.e., total nitrogen and total phosphorus) in coastal rivers. However, experts also identified analysis gaps for key indicators like nutrients and turbidity that could be obtained from analyses of existing satellite data or other remote sensing capabilities. Additionally, the lack of long-term, *in situ* datasets for some parameters was considered an important data gap for OCNMS. Table S.WQ.6.2 summarizes data gaps that would be beneficial to fill for the next condition report.

For phytoplankton, the LiveOcean model demonstrates seasonal variation using chlorophyll (mg m^{-3}) on the Olympic Coast. Beginning in approximately April of each year, upwelling-favorable conditions are produced by northerly (equatorward) wind patterns, which bring nutrients to the surface along the coast, producing phytoplankton blooms and increasing chlorophyll concentrations to ~20 mg m^{-3} (LiveOcean, 2021). Trend analysis of information from the Spatiotemporal Data and Time Series Toolkit, previously known as the COPEPODITE Toolkit (NOAA Fisheries, 2020d; O'Brien & Oakes, 2020), showed a significant increase in chlorophyll over the last ten years, with a high annual anomaly in 2015 that corresponded to a HAB event that year (Figure S.WQ.6.2).



NASA-combo satellite Chlorophyll (mg/m3)

Twin Year Range	Twin		Annual		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015 - 2019	TW05		(-)		(-)	(-)	-	(+)	(-)	(-)	(-)	(+)	+	(+)	(+)	nd
2010 - 2019	TW10		++		(+)	(-)	(+)	(+)	(+)	(+)	(+)	(+)	(-)	(-)	(+)	(+)
2005 - 2019	TW15		(+)		(+)	(+)	+	+++	(+)	(+)	(-)	(+)	(-)	-	(+)	(-)
2000 - 2019	TW20		+		++	(-)	++	+	++	(+)	(+)	(+)	-	--	(+)	(-)

Figure S.WQ.6.2. Annual anomalies for chlorophyll (mg/m3), log10-transformed, for 1998–2019. Vertical black line indicates the year of the last condition report (2008). Red bars are positive anomalies, and blue bars are negative anomalies. Red box indicates the highly significant increasing trend for the year range 2010–2019. Decreases are denoted by blue shading and "(-)", and increases are denoted by red shading with "(+)". Significant changes do not have parentheses around the +/- sign. Source: NOAA Fisheries, 2020d; O'Brien & Oakes, 2020; Image: A. Mabrouk/NOAA

For nutrients, inputs to OCNMS from the Salish Sea and Columbia River are believed to be negligible compared to those from upwelling (Hickey et al., 2013; McCabe et al., 2015; Trainer et al., 2017; Anderson et al., 2019). Upwelling plays an essential role in ecosystem productivity on the Olympic Coast. Three indices were selected to estimate upwelling in OCNMS (48 °N). The selected indices were: (1) the Spring Transition Index (STI); (2) the Length of Upwelling Season Index (LUSI); and (3) the Total Upwelling Magnitude Index (TUMI), which estimate timing, duration, and strength of coastal upwelling, respectively (Schwing et al., 1996). Tracking the status of these indices revealed that recent means for STI, LUSI, and TUMI were within one standard deviation of the long-term mean, and trends in these indices were not changing for the last 10 years (Figures S.WQ.6.3–S.WQ.6.4; Integrated Ecosystem Assessment [IEA], 2020a). We encourage future consideration of other newly available indices, including the Coastal Upwelling Transport Index and Biologically Effective Upwelling Transport Index (Jacox et al., 2018), and comparisons among them.

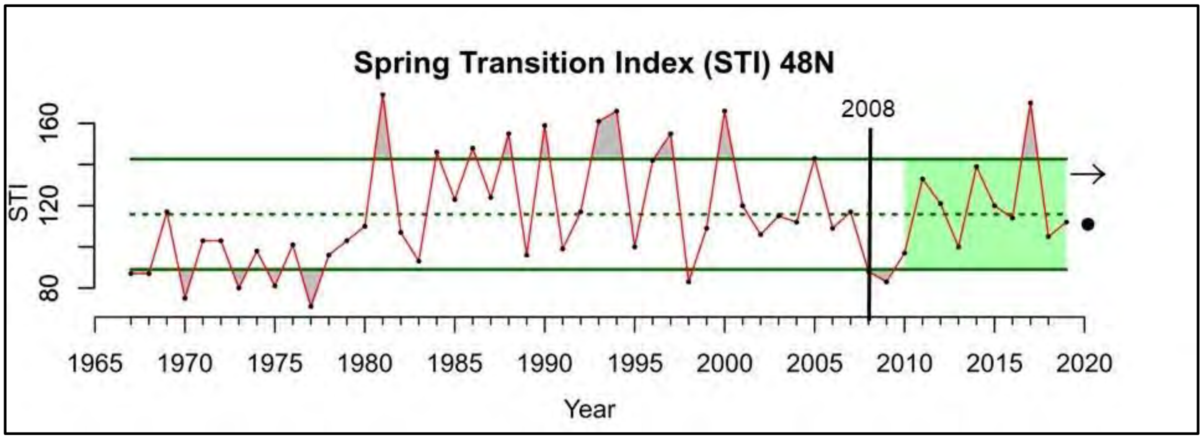


Figure S.WQ.6.3. STI at 48 °N from 1967 to 2019. The black dot (●) indicates that the recent mean (last 10 years) was within 1 standard deviation of the long-term mean. During the last 10 years, the trend has not changed (indicated by arrow →). The dashed line is the long-term mean and solid horizontal lines are ±1 standard deviation. The vertical black line indicates the year of the last condition report (2008). An explanation of index values (y-axis) and associated caveats are provided in Schwing et al. (1996). Image: IEA, 2020

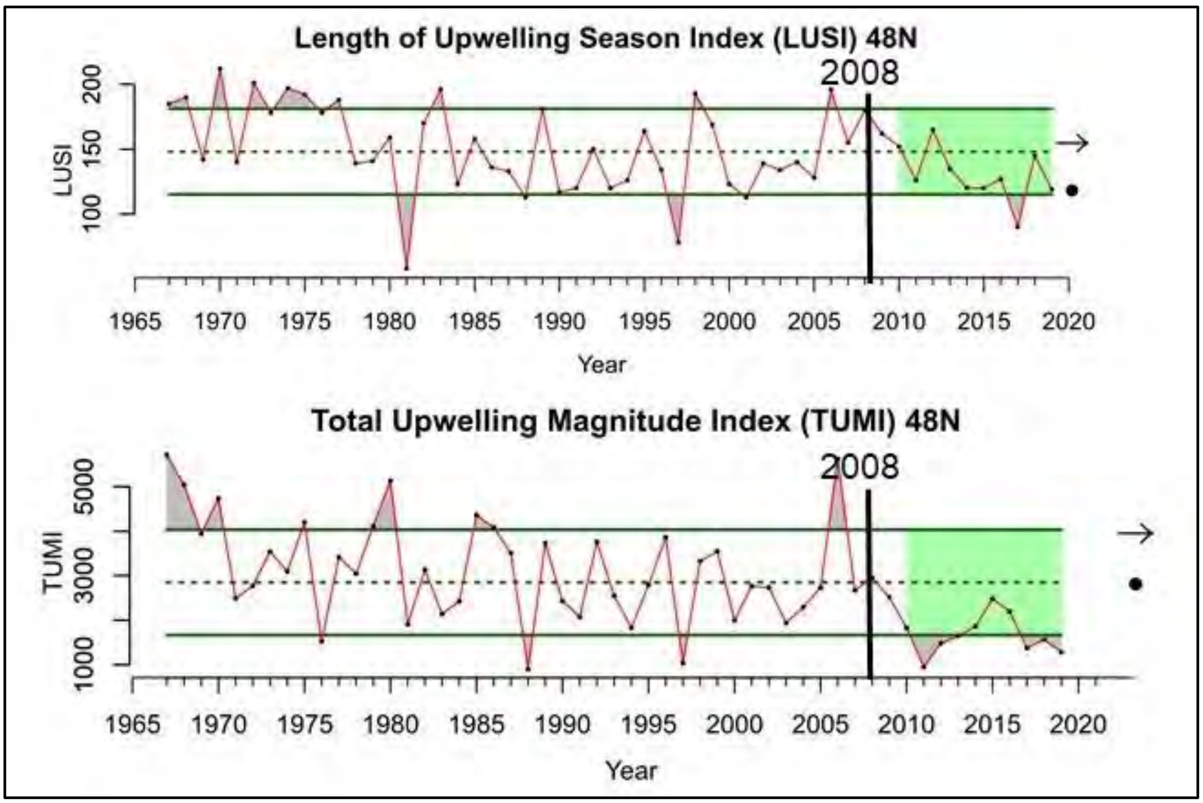


Figure S.WQ.6.4. LUSI and TUMI at 48 °N. Black dots (●) indicate that recent means for the last 10 years are within 1 standard deviation of the long-term mean. During the last 10 years, the trend has not changed (indicated by arrow →). The dashed lines are the long-term means and solid horizontal lines are ±1 standard deviation. The vertical black line indicates the year of the last condition report (2008). An explanation of index values (y-axis) and associated caveats are provided in Schwing et al. (1996). Image: IEA, 2020

According to the U.S. Geological Survey (USGS, 2020) and Oelsner et al. (2017), nitrogen and phosphorus loads for the Columbia River probably decreased between 2002 and 2012. Previous work (Wise, 2020) modeled watersheds throughout Washington state to provide relative levels of streamflow and sedimentation, as well as estimates of total nitrogen and total phosphorus (Figure S.WQ.6.5), as part of the Spatially Referenced Regression on Watershed attributes (SPARROW) effort. These metrics are included here to illustrate the relative contribution of coastal river inputs to OCNMS. Additionally, upwelling and stratification (not eutrophication) are believed to be the main drivers of seasonal bottom hypoxia observed inside the sanctuary (see Question 8 for more detail).

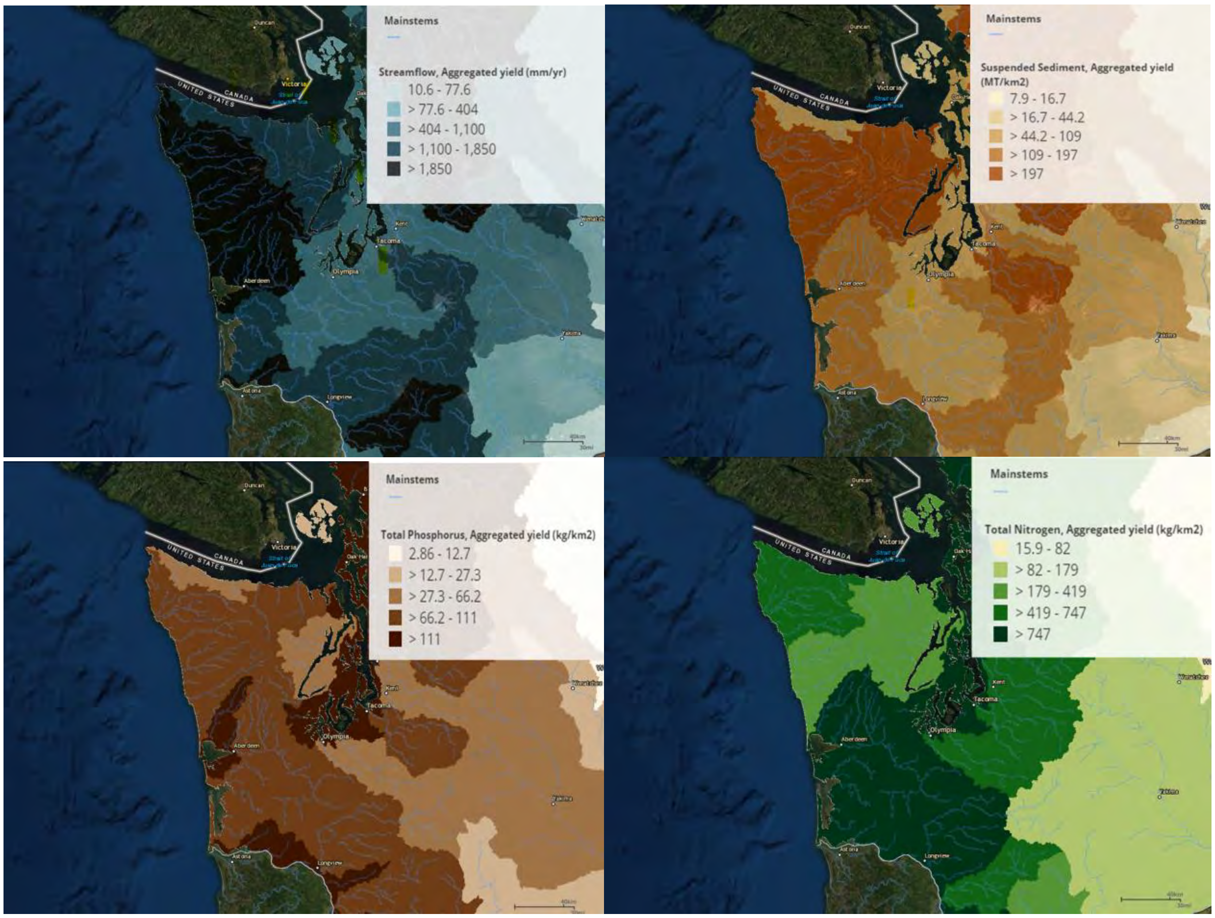


Figure S.WQ.6.5. Maps from USGS SPARROW models, depicting Washington watersheds and relative contributions of streamflow (upper left), suspended sediments (upper right), total phosphorus (lower left), and total nitrogen (lower right) in 2012. Source: Wise, 2020

Another potential source of nutrients is discharge from offshore fish processors. Typically, this discharge is limited to summer and restricted to offshore locations, and it is likely that the few boats processing fish onboard produce localized, temporary impacts (EPA, 2020). This activity is discussed in more detail in Question 2.

In terms of nutrient inputs from the atmosphere, the National Atmospheric Deposition Program (NADP) collects the only long-term dataset on total nitrogen concentration in deposition (1980–2018) at the Hoh River within Olympic National Park. Atmospheric deposition data show no trend in nutrient contributions from the atmosphere (McCaffery & Jenkins, 2018; National Atmospheric Deposition Program [NADP], 2020; Figure App.S.WQ.6.1).

There is considerable uncertainty about how factors related to climate change might influence nutrients and nutrient dynamics in the future. Phenomena such as marine heatwaves, changing ocean dynamics, and stratification are likely to change phytoplankton communities and productivity, and thus eutrophication and its impacts on the food chain.

Conclusion

From 2008–2019, the status of eutrophic conditions in OCNMS was good and the trend was not changing, both with high confidence. While the availability of certain datasets helped increase confidence in these ratings, there were still data and analysis gaps for OCNMS, including a lack of long-term, *in situ* data for chlorophyll concentrations, nutrient concentrations and loads, and turbidity. Additionally, there is a need to process and analyze satellite and remotely sensed data to develop additional relevant indicators such as for chlorophyll, nitrogen and phosphorus concentrations (NOAA Fisheries, 2020d; O'Brien & Oakes, 2020), and turbidity (NASA, 2020).

Table S.WQ.6.2. Status and trends for individual Question 6 indicators discussed at the January 2020 workshop.

Indicator	Source	Habitat	Data Summary	Figures
Phytoplankton: Chlorophyll abundance	NANOOS, 2020a; NOAA Fisheries, 2020b; O'Brien & Oakes, 2020	All habitats	Status: Phytoplankton blooms were recorded in OCNMS in May, August, and September 2019 Trend: Increasing annual anomalies for chlorophyll from satellite data between 2010–2019.	S.WQ.6.2
Upwelling indices LUSI, TUMI, and STI	Jacox et al., 2018; IEA, 2020	All habitats	Status: Recent mean (last 10 years) for LUSI, TUMI, and STI was within 1 standard deviation of the long-term mean Trend: LUSI, TUMI, and STI did not change	S.WQ.6.3, S.WQ.6.4
Nutrients (concentration and load) and total nitrogen deposition	Wise, 2020; NADP, 2020	All habitats	Status: Data gap; nitrogen deposition exceeded critical loads for key resources (Olympic National Park); nitrogen and phosphorus loading from Columbia River is likely down; nitrogen from rivers is believed to be less significant than nitrogen from upwelling/ocean. Most nitrogen entering OCNMS from terrestrial sources is via the Salish Sea to the north and Columbia River to the south. Trend: Data gap; nitrogen deposition had no trend over time (Olympic National Park)	S.WQ.6.5; App.S.WQ.6.1
Bottom dissolved oxygen and hypoxia	Alin et al., 2022a; OCNMS	All habitats	Status: Hypoxic (<2 mg/L or <1.4 mL/L or <60 µmol/kg) conditions were frequently present at southern sites (Kalaloch and Cape Elizabeth) between June and September Trend: Dissolved oxygen decreased at southern sites (Kalaloch and Cape Elizabeth) over time	S.WQ.8.9–S.WQ.8.12
Turbidity	NOAA ERDDAP data server	All habitats	Status: Annual composite maps available but analysis needed Trend: Analysis gap	

Indicator	Source	Habitat	Data Summary	Figures
Data gaps	Long-term, *in situ* datasets for chlorophyll, nutrients (concentrations and loads), and turbidity			
Analysis gaps	Satellite images for turbidity and nutrients (nitrogen and phosphorus); comparisons of upwelling indices; examination of nutrient data collected in OCNMS during NOAA West Coast ocean acidification cruises			

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

Status Description: Water quality problems have caused measurable human impacts, but effects are localized and episodic rather than widespread or persistent.

Rationale: Harmful algal blooms occur naturally in OCNMS, and biotoxins are periodically detected in shellfish, sometimes resulting in trophic transfer of biotoxins to predators like marine mammals and seabirds. However, impacts on human health have been minimized due to effective seasonal monitoring and measures, like beach closures.

Accounts of interactions between humans and HABs have been passed down for centuries through Native American oral history in the Pacific Northwest (Horner et al., 1997; Shaffer et al., 2004; Dalton, 2016). HAB events are particularly noted by tribal members, due to their large economic, cultural, and health impacts (Shaffer et al., 2004; Dalton, 2016). For example, recollections from tribal members indicate periods of time where shellfish were not harvested and clams were tested to determine whether they were safe for consumption by touching them to the lips to see if there was a burning sensation (an indication of biotoxins) (Shaffer et al., 2004). Today, the most concerning HABs for human health and the regional economy involve dinoflagellates of the genera *Alexandrium* and *Dinophysis*, which cause PSP and diarrhetic shellfish poisoning (DSP), respectively, and diatoms of the genus *Pseudo-nitzschia*, which are responsible for production of domoic acid and can cause amnesic shellfish poisoning (ASP). *Pseudo-nitzschia* spp. are the most common HAB species on the outer Washington coast, occurring mainly in the spring and late summer (Trainer et al., 2017; Anderson et al., 2019). Impacts from HABs include a period of months during the year when clams are not collected or eaten by tribes (Shaffer et al., 2004) and when recreational and commercial shellfish closures occur (Dalton, 2016).

Coordinated monitoring was established in 1999 through the Olympic Region Harmful Algal Bloom partnership to protect the local community from the threat of various HABs on the outer Washington coast. The Olympic Region Harmful Algal Bloom partnership provides an early warning of HABs by monitoring harmful algae (dinoflagellates and diatoms) abundances and biotoxin concentrations in seawater (both onshore and offshore), from which member scientists produce the Pacific Northwest HAB Bulletin (NANOOS, 2020a). The partnership includes academic (University of Washington), federal (NWFSC and NCCOS), tribal (Coastal Treaty

Tribes), state (Washington State Department of Health and Washington Department of Fish and Wildlife [WDFW]), and other researchers and managers, and was initially funded by NOAA. In 2016, NOAA and the University of Washington enhanced offshore HAB monitoring inside OCNMS with an advanced, remote, autonomous, near real-time HAB biosensor called the Environmental Sample Processor, which was moored 13 nautical miles offshore of La Push, adjacent to an oceanographic mooring known as Ćháʔba·. Data from the Environmental Sample Processor and the Pacific Northwest HAB Bulletin are accessible through NANOOS (2020a). In 2017, the Olympic Region Harmful Algal Bloom partnership began to regularly monitor *Pseudo-nitzschia* abundance and particulate domoic acid concentration in seawater along the Washington and Oregon coasts. These monitoring and analysis efforts have improved forecasting of HABs and have reduced the negative health and economic impacts to communities on the Washington coast.

For the current condition report (2008–2019), the status of sanctuary waters and their threat to human health was rated as fair (with high confidence), and the trend was not changing (with medium confidence). These ratings indicate that water quality problems “have caused measurable human impacts, but effects are localized and not widespread or persistent” (though a 2015 event was widespread, experts based their judgement on the lack of persistence).

HABs are known to occur naturally in OCNMS, and biotoxins (i.e., those that cause ASP, PSP, and DSP) are periodically detected in shellfish, sometimes resulting in trophic transfer to predators like marine mammals and seabirds. However, in recent years, marine heatwaves are believed to have accelerated the growth rates of HABs (McCabe et al., 2016) and contributed to the production of toxic hotspots, retentive areas of the coastal ocean containing algae with high levels of domoic acid, at coastal locations to the north and south of OCNMS (Trainer et al., 2020b).

Although threats to human health have been significantly minimized due to targeted monitoring, HAB events continue to cause disruptions and prompt fishery closures, and increasing evidence links HAB events to marine heatwaves and climate change (Trainer et al., 2020b). Impacts on human health have been minimized due to effective seasonal monitoring, including real-time HAB monitoring offshore; good coordination among Washington state agencies, Coastal Treaty Tribes, and other members of the Olympic Region Harmful Algal Bloom partnership; and precautionary closures of shellfish harvesting in affected areas to protect public safety.

Comparison to 2008 Condition Report

In the 2008 condition report, the status was good/fair, and the trend was not changing. HABs and biotoxins in shellfish occur naturally in the sanctuary and result in periodic shellfish closures. Prior to 2008, levels of biotoxins in shellfish exceeded the limits that affect human health once or twice a year on average (ONMS, 2008). Selected conditions with the potential to affect human health existed, but human impacts were not reported (ONMS, 2008). The assessment in 2008 was based mainly on the concentration of domoic acid in razor clams. For the 2008–2019 condition report, the status was downgraded to fair, and the trend did not change. This rating was based on *Pseudo-nitzschia* abundance and domoic acid concentration in seawater and shellfish; shellfish fishery closure days; a HABs index developed to estimate closure impacts on coastal communities; and beach closures as a result of high bacteria levels at swimming beaches. While increased monitoring of shellfish has largely resulted in decreased impacts to human health, which is the subject of this section, HABs continue to be a serious concern along the Olympic Coast, given their impacts to fisheries, ecosystems, and communities.

New Information in the 2008–2019 Condition Report

Experts agreed with high confidence that HABs and biotoxins in shellfish are naturally present in OCNMS. Although the status was fair and the trend was not changing, and no acute human health impacts were reported, HABs still pose a potential risk to the health of humans and other vertebrates that prey on contaminated shellfish. The 2008–2019 assessment was based on *Pseudo-nitzschia* concentration and domoic acid in seawater, long-term data on biotoxins (mainly domoic acid in razor clams), closure days for shellfisheries, a HABs impact index, and levels of pathogenic bacteria at two swimming beaches on the Olympic Coast. Between 2007 and 2014, no closures from domoic acid occurred in OCNMS or on the outer Washington coast (Trainer et al., 2017). However, in 2015–2016, a devastating fishery closure occurred due to the presence of high domoic acid in razor clams and Dungeness crabs. These two species are highly important, both economically and culturally, for the Coastal Treaty Tribes and adjacent coastal communities. Climate change is expected to produce worsening future conditions based on the recent identification of linkages between marine heatwaves and biotoxin production off the Washington coast; however, projected worsening trends were not included in this assessment.

Pseudo-nitzschia

There are no time series data for the abundance of *Pseudo-nitzschia* and its toxin domoic acid in seawater that encompass the entire assessment period. Although beach sampling for *Pseudo-nitzschia* between 2017 and 2019 showed low cell abundance, thresholds were exceeded, mainly in spring and fall, at Hobuck Beach and beaches adjacent to La Push (threshold values that trigger additional testing for domoic acid are 50,000 cells/L for large *Pseudo-nitzschia* and 1,000,000 cells/L for small *Pseudo-nitzschia*; NANOOS, 2020a; Figure S.WQ.7.1). Additionally, offshore sampling showed high *Pseudo-nitzschia* abundance at Hobuck in 2017, 2018, and 2019 (Figure App.S.WQ.7.1).

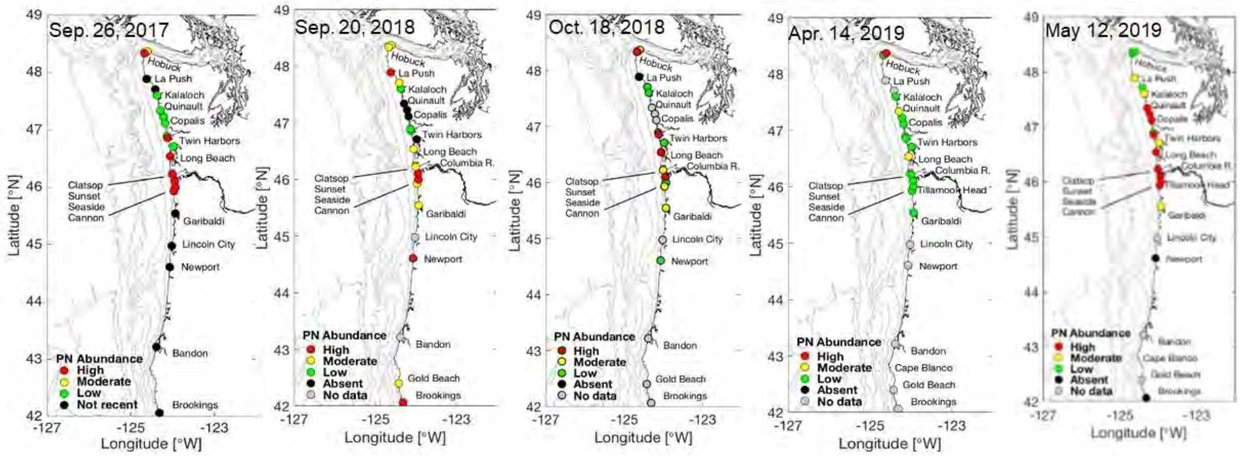


Figure S.WQ.7.1. *Pseudo-nitzschia* abundance for Washington and Oregon beach sampling sites. High: abundance exceeded threshold values (50,000 cells/L for large *Pseudo-nitzschia*; 1,000,000 cells/L for small *Pseudo-nitzschia*) for either cell morphology; Moderate: abundance exceeded 1/3 of threshold value; Low: abundance did not exceed 1/3 threshold. "Absent" denotes absence or non-detection. "No data" indicates that there were no data reported within the previous 15 days. Source: NANOOS, 2020a

Biotoxins

Beach sampling for domoic acid concentration in seawater samples from OCNMS revealed levels that were low and mostly below the toxic threshold of 200 ng per liter of seawater (NANOOS, 2020a). However, offshore sampling showed high domoic acid concentrations near La Push and Hobuck Beach in fall 2017 and 2019, respectively (NANOOS, 2020a; Figure App.S.WQ.7.2).

Razor clams and Dungeness crab are important fisheries species on the Washington outer coast, and biotoxins in animal tissues are closely monitored to prevent impacts to human health. In razor clams, domoic acid concentrations detected from tissue samples were low at Kalaloch and Mocrocks beaches and did not exceed the concern limit of 20 ppm for the years 2008–2014 and 2019. However, domoic acid increased dramatically in 2015 due to a major HAB event that prompted devastating closures in 2015–2016. Additionally, domoic acid concentrations exceeded concern limits in 2017 and 2018, causing short-term closures at both beaches (Figures S.WQ.7.2–S.WQ.7.3; Washington Department of Fish and Wildlife [WDFW], 2019). Maximum domoic acid in razor clams did not change for Mocrocks between 2008 and 2018, although it increased for the Washington coast (Figures S.WQ.7.4–S.WQ.7.5). Similar results were found for domoic acid concentrations in Dungeness crab; levels exceeded the concern limit (30 ppm) only during 2015 in samples collected between Toleak Point and Ocean Shores (WDFW, 2019).

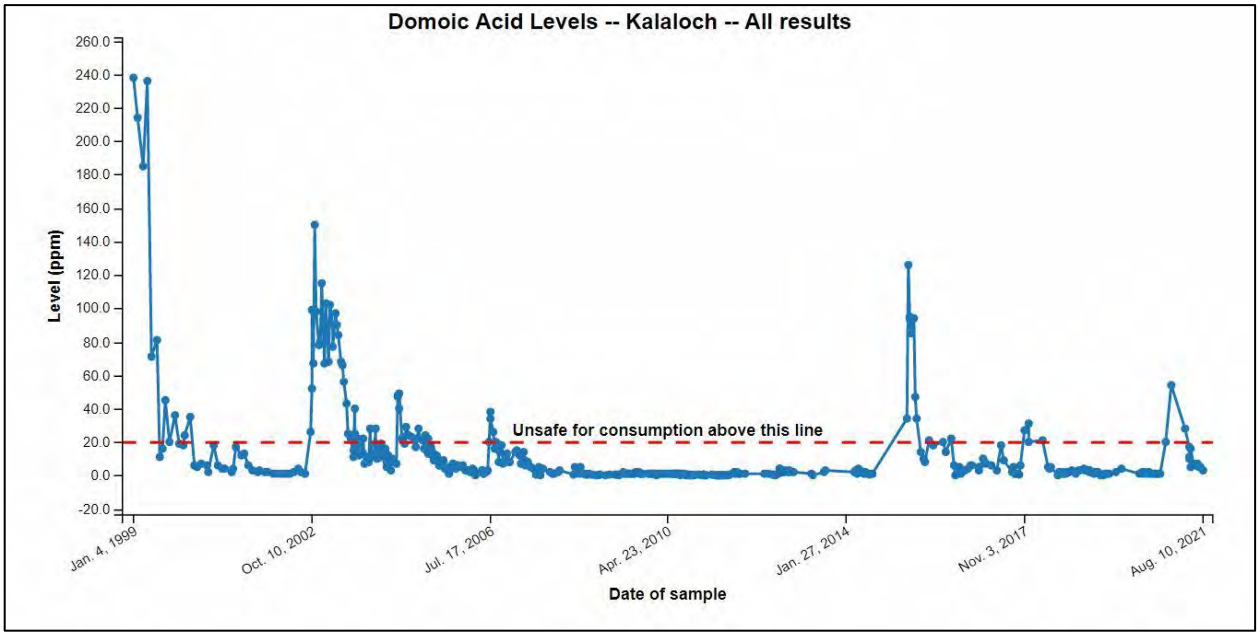


Figure S.WQ.7.2. Domoic acid levels in razor clams for Kalaloch Beach, OCNMS (1999–2021; note that 2021 data was not presented to workshop participants and was not considered when the rating for this question was determined). Dashed line shows the WDFW domoic acid threshold (20 ppm). Source: Washington Department of Health; WDFW, 2021; Image: Dan Ayres/WDFW

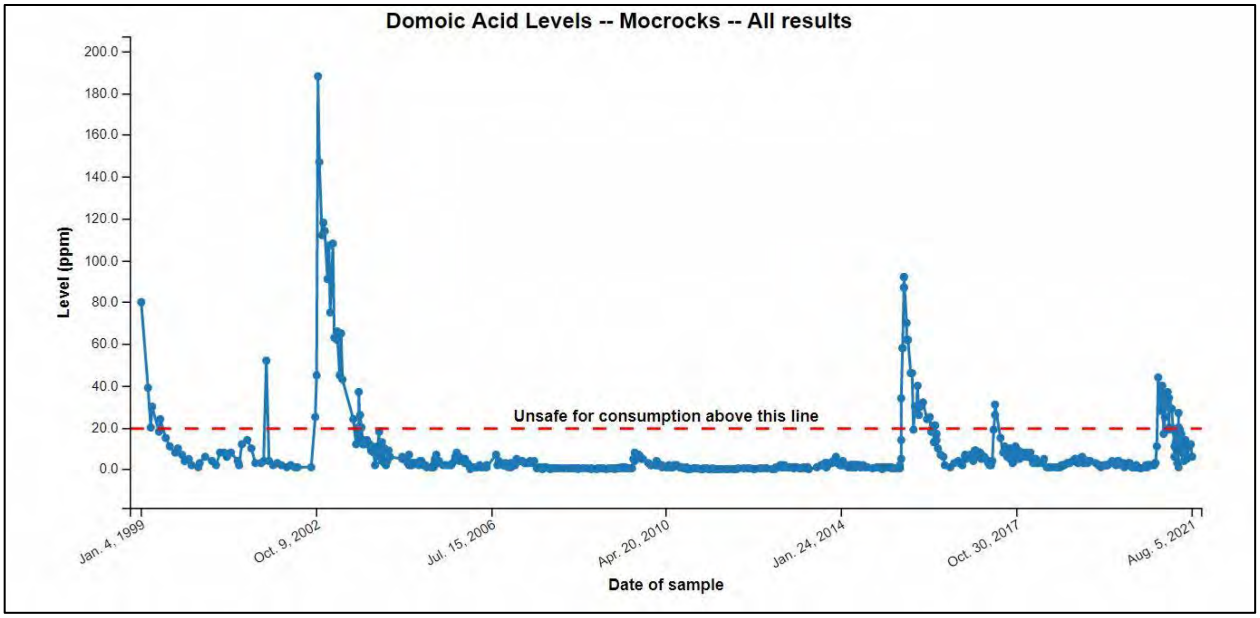


Figure S.WQ.7.3. Domoic acid levels in razor clams for Mocrocks Beach, OCNMS (1999–2021; note that 2021 data was not presented to workshop participants and was not considered when the rating for this question was determined). Dashed line shows the WDFW domoic acid threshold (20 ppm). Source: Washington Department of Health; WDFW, 2021; Image: Dan Ayres/WDFW

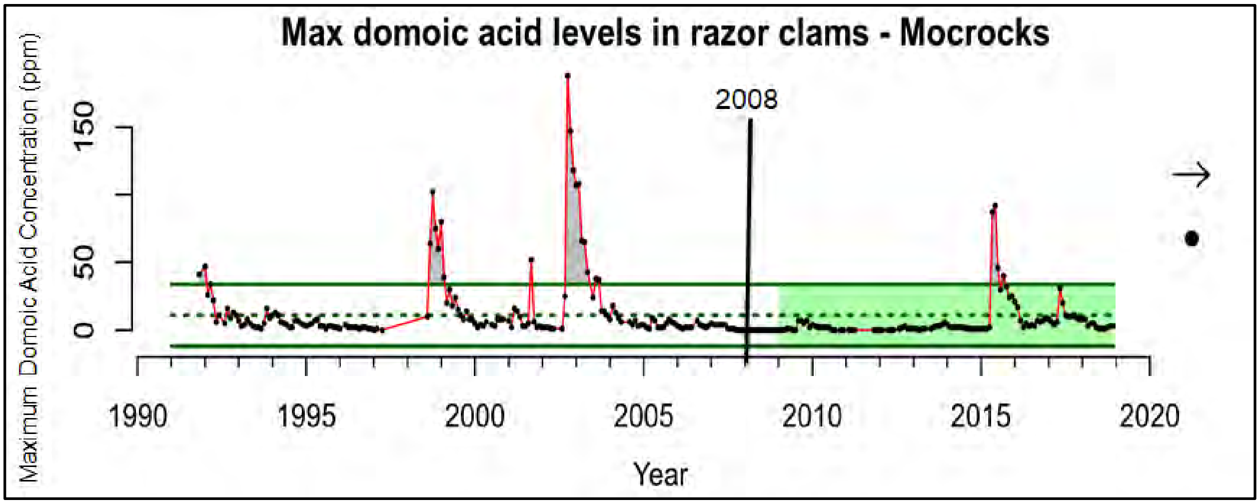


Figure S.WQ.7.4. Maximum domoic acid levels in razor clams for Mocrocks Beach, OCNMS (1991–2019). The vertical black line indicates the year of the last condition report (2008). The black dot (●) indicates that the mean for the last 10 years was within 1 standard deviation of the long-term mean. During the last 10 years, the trend did not change (indicated by arrow →). Solid green lines show ±1 standard deviation. Image: IEA, 2020

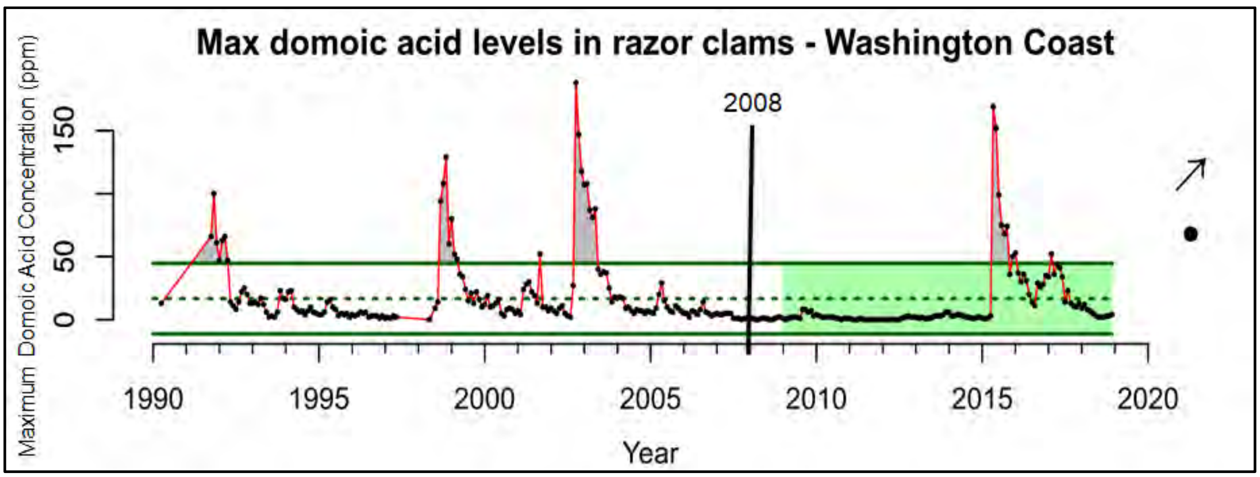


Figure S.WQ.7.5. Maximum domoic acid levels in razor clams for the Washington coast (1991–2019). The vertical black line indicates the year of the last condition report (2008). The black dot (●) indicates that the mean for the last 10 years was within 1 standard deviation of the long-term mean. During the last 10 years, the trend increased (indicated by arrow ↗). The long-term mean is indicated by a green dashed line; solid green lines show ±1 standard deviation. Image: IEA, 2020

Shellfish Harvest

The devastating shellfish harvest closure in 2015 extended into 2016 due to high concentrations of domoic acid, which can cause ASP, detected in tissues of shellfish. However, the total number of harvest closures decreased from 14 recorded between 1991 and 2007 to six closures between 2008 and 2019 (A. Coyne, personal communication, January 16, 2020). These six closures occurred between 2015 and 2018 and were restricted to southern beaches (i.e., Kalaloch, Mocrocks, and Quinault) of OCNMS (Figure S.WQ.7.6). Closures due to PSP risk increased from nine recorded from 1991 to 2007 to 14 between 2008 and 2019, with the latter mainly affecting northern shorelines between Makah Bay and Ruby Beach. Additionally, five out of six closures due to DSP were also documented at northern beaches (Figure S.WQ.7.6).

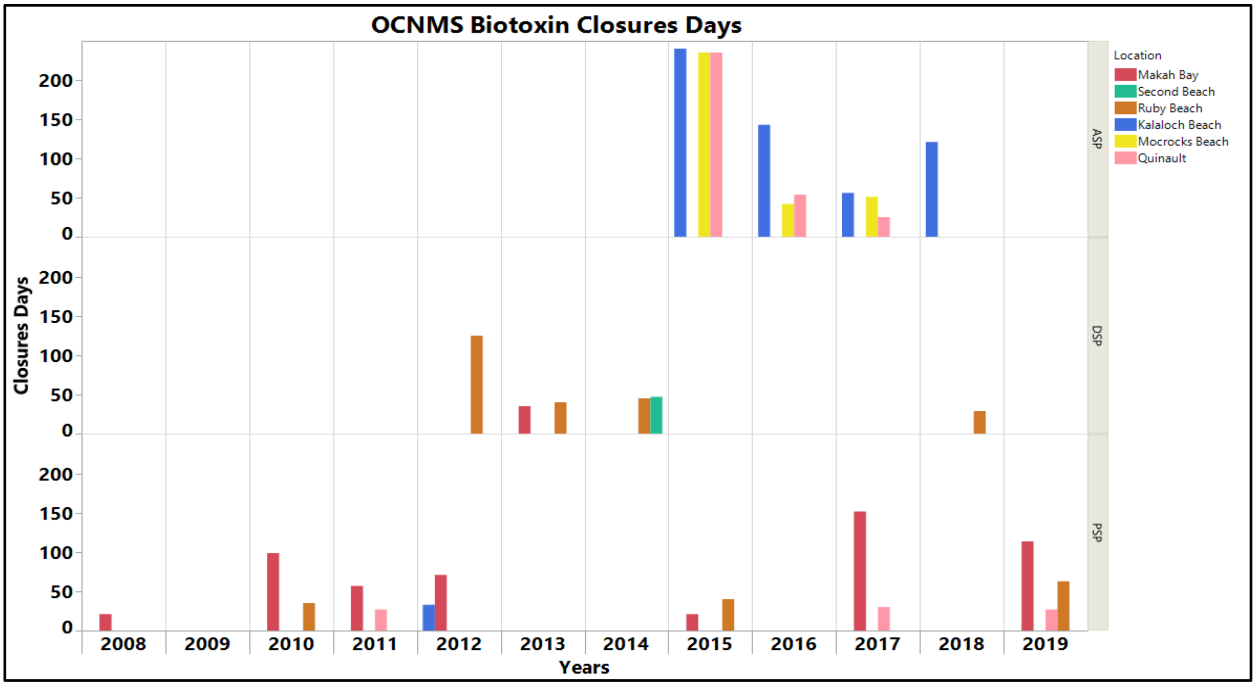


Figure S.WQ.7.6. Shellfish harvest closure days at OCNMS beaches due to risks of ASP (top panel), DSP (middle panel), and PSP (bottom panel). Source: A. Coyne/Washington State Department of Health, personal communication, January 15, 2020; Image: A. Mabrouk/NOAA

To better understand the impact of HABs on coastal communities, a HAB index developed by Moore et al. (2016) was used to compare OCNMS to the rest of the U.S. West Coast. This HAB index identifies and attempts to quantify lost fishing opportunities (number of days fisheries are closed) due to HABs. Higher index values indicate longer fisheries closures during the season. The HAB index for La Push, the only fisheries community in OCNMS that was included in the study, was very low compared to the rest of the West Coast. However, the fishery offshore of this community was closed longer in 2015, and again in 2016, than in any other year since 2005 (Figure S.WQ.7.7).

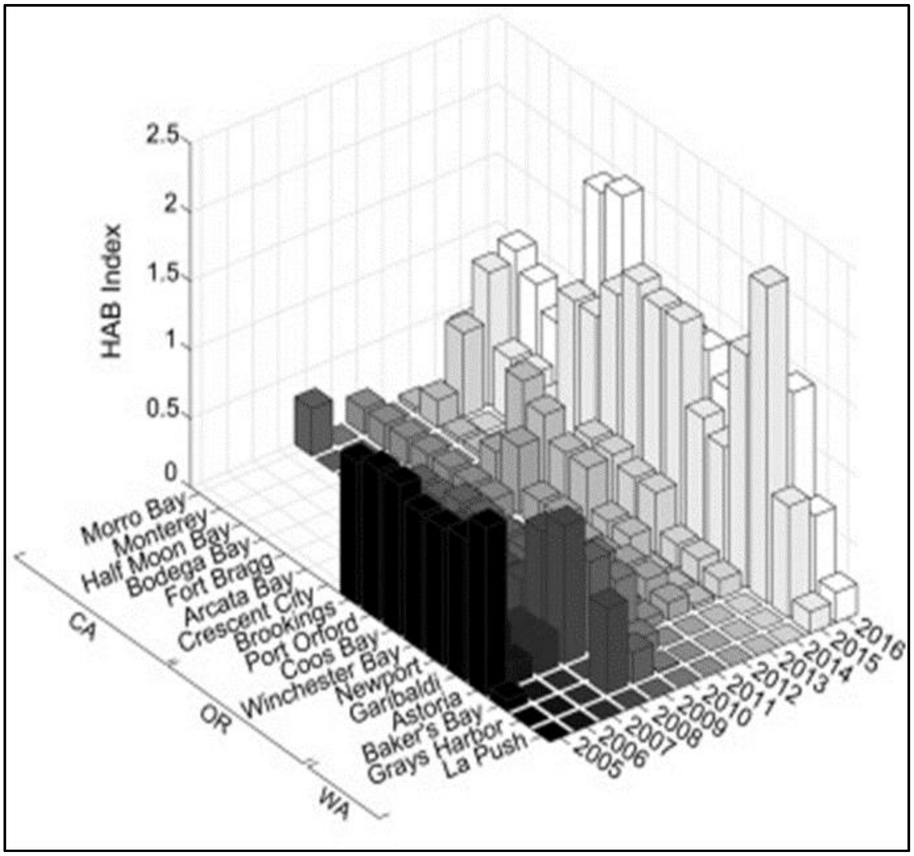


Figure S.WQ.7.7. HAB index (lost fishing opportunities due to HABs) for 17 West Coast fishing communities from 2005 through 2016. La Push is the only fishing community inside OCNMS. Image: Moore et al., 2016

Beach Advisories/Closures

Only two of the five beaches sampled on the outer Washington coast are adjacent to OCNMS (i.e., Hobuck and Tsoo-Yess beaches). Both beaches are in the far north, on the Makah Reservation, and are very popular for swimming and surfing in the summer. Tsoo-Yess beach did not meet Washington state swimming criteria in 2018 and was closed three times that year (Figure S.WQ.7.8) based on concentrations of fecal bacteria (*Enterococcus*; >104 enterococci/100 mL) sampled by state, local, and tribal scientists. Data were acquired and assessed from the State of Washington Department of Ecology, Washington Beach Program, and Coastal Atlas tool (Washington State Department of Ecology, 2020a, 2020b). For more detailed graphs of bacteria concentrations at these two beaches, see Figures App.S.WQ.7.3–App.S.WQ.7.4.

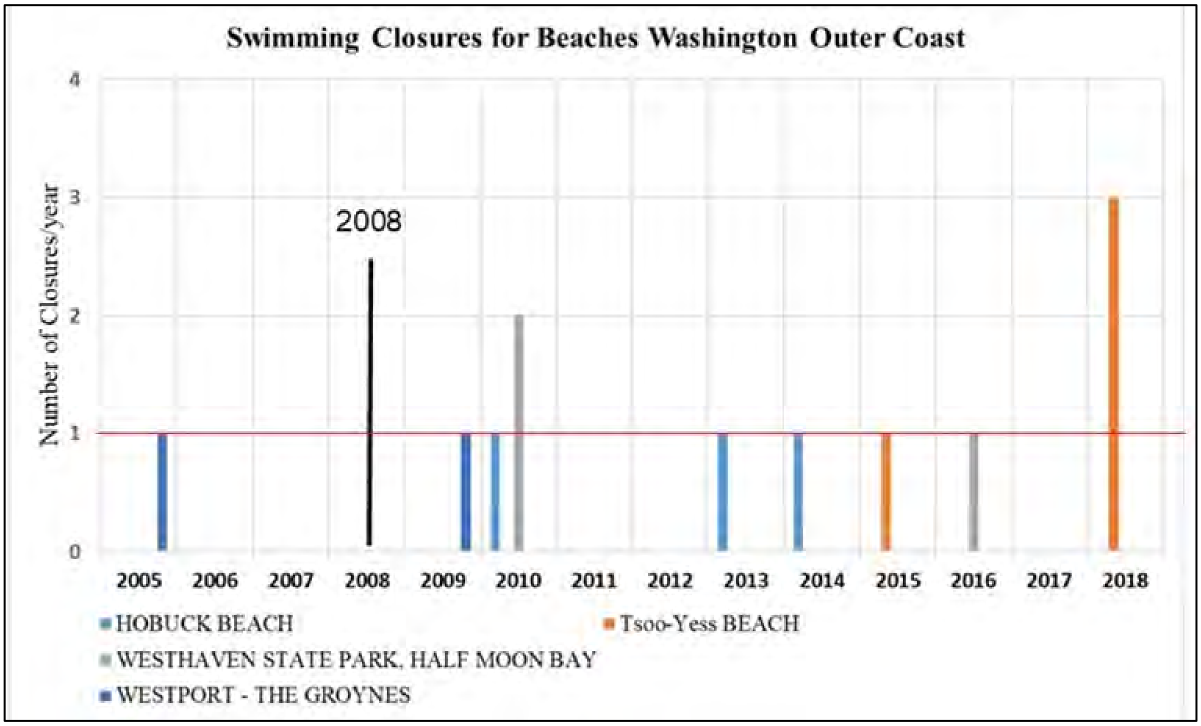


Figure S.WQ.7.8. Number of swimming closures for outer Washington coast beaches (2005–2018); only Hobuck and Tsoo-Yess beaches are adjacent to OCNMS. Westhaven and Westport locations are approximately 15 miles south of the OCNMS boundary. The vertical black line indicates the year of the last condition report (2008). Source: Washington Department of Ecology, 2020a; Image: A. Mabrouk/NOAA

Conclusion

In the 2008–2019 condition report, the status of sanctuary waters and their threat to human health was fair (with high confidence), and the trend was not changing (with medium confidence). While the availability of certain datasets helped increase confidence in these ratings, many data and analysis gaps remain. Among them are data for critical indicators like contaminants (e.g., metals, persistent organic pollutants) in marine organisms in OCNMS and time series data for *Pseudo-nitzschia* and domoic acid in seawater. Analysis gaps include evaluating biotoxins other than domoic acid in shellfish. Beach advisory/closure data are currently limited to two sites near the northern boundary of OCNMS. Consequently, additional data on beach advisories/closures would also improve the sanctuary's ability to understand conditions and trends. Table S.WQ.7.1 summarizes data gaps that would be beneficial to fill for the next condition report.

Table S.WQ.7.1. Status and trends for individual Question 7 indicators discussed at the January 2020 workshop.

Indicator	Source	Habitat	Data Summary	Figures
Pseudo-nitzschia (abundance in seawater)	NANOOS, 2020a	All habitats	Status: Exceeded the threshold, mainly in spring and fall, at Hobuck and La Push beaches between 2017 and 2019 Trend: No time series data available	S.WQ.7.1; App.S.WQ.7.1
Biotoxins (domoic acid in seawater and razor clams)	WDFW; Moore et al., 2016; NOAA IEA	All habitats	Status: Beach sampling showed low particulate domoic acid in seawater between 2017 and 2019, while offshore sampling of Neah Bay (Hobuck) exceeded the threshold in fall 2019. Low domoic acid concentration in razor clams in 2019 at Kalaloch Beach and Mocrocks Beach. Trend: Maximum domoic acid in razor clams did not change between 2008 and 2018, although it increased for the Washington coast.	S.WQ.7.2–S.WQ.7.5; App.S.WQ.7.2
Shellfish harvest (closure days) and HABs Index	Washington Department of Health; Moore et al., 2016	All habitats	Status: There was no closure due to domoic acid (which causes ASP) from 2007 to 2014. However, there was a devastating closure in 2015–2016. Trend: ASP closures decreased from 14 between 1991 and 2007 to six between 2008 and 2019 at the southern beaches. PSP closures increased from 9 between 1991 and 2007 to 14 between 2008 and 2019 at the northern beaches. Additionally, six DSP closures were documented at these beaches. HAB index increased at La Push in 2015 and 2016	S.WQ.7.6–S.WQ.7.7
Beach advisories/ closures	Washington State Department of Ecology	Sandy beach	Status: Only two beaches are sampled (Hobuck and Tsoo-Yess); Tsoo-Yess didn't meet swimming criteria in 2018 Trend: Limited data Data gap: Monitoring at more beaches required	S.WQ.7.8; App.S.WQ.7.3–App.S.WQ.7.4
Legacy contaminant levels in shellfish*	NOAA Mussel Watch Program	Rocky shores	Status: DDT and PCB levels were low in OCNMS shellfish collected at Cape Flattery in 2010. Trend: DDT and PCB levels decreased in West Coast shellfish. Data gaps: Updated data required	S.H.11.2
Contaminant levels in pelagic fish*	EPA; Washington State Department of Ecology	Pelagic	Status: N/A; PCBs have been measured above thresholds (McBride et al., 2005), but no recent study is available for the West Coast Trend: N/A Data gaps: Updated data required	S.H.11.1

Indicator	Source	Habitat	Data Summary	Figures
Data gaps	Time series of *Pseudo-nitzschia* abundance in seawater; Washington State Department of Ecology sampling of water quality at Olympic Coast sites to ensure beaches are safe for swimming or closures/advisories can be issued; updates for contaminant data			
Analysis gaps	Particulate domoic acid in seawater and evaluation of biotoxins other than domoic acid in various shellfish			

*Figure is included in response to Question 11.

Question 8: Have recent, accelerated changes in climate altered water conditions, and how are they changing?

Status Description: Climate-related changes have caused severe degradation in some but not all attributes of ecological integrity.

Rationale: Since 2008, concerning climate-related changes have been documented for several critical ocean indicators, including dissolved oxygen, aragonite saturation, pH, and marine heatwaves, all of which produce detrimental effects on ecosystems.

OCNMS is located within the northern California Current Ecosystem. It is a highly productive coastal ecosystem fueled by seasonal upwelling of cold, nutrient-rich water. This seasonal productivity supports the marine food web, which includes phytoplankton and zooplankton, large fishes, marine mammals, and seabirds (National Marine Fisheries Service, 2017). The California Current Ecosystem has experienced exceptional climate variability that has affected OCNMS over the last ten years, including an unprecedented North Pacific marine heatwave between 2014 and 2016 (see Box 1), coupled with a robust El Niño event in 2015–2016 that was followed by a flux of cool coastal waters and intense storms in the winter of 2016–2017. By the end of 2018, minimal flux of cold, nutrient-rich subarctic water from the North Pacific Gyre caused below-average productivity in OCNMS and the California Current Ecosystem in general (Harvey et al., 2019). In the summer and fall of 2019, another major marine heatwave affected approximately 8.5 million km^2 of the Northeast Pacific over a period of 239 days but dissipated by late January 2020.

Box 1: Marine Heatwaves

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). In 2014–2016, the California Current Ecosystem experienced a marine heatwave popularly known as "the blob." This event began in early 2014 and persisted through mid-2016, causing a rapid onset of persistent positive SST anomalies from Alaska to California. These elevated SSTs coincided with the 2015–2016 El Niño event (Gentemann et al., 2017; Jacox et al., 2019), creating the largest marine heatwave on record (NOAA, 2020). Researchers documented many ecological effects associated with this marine heatwave, including unprecedented HABs, shifting marine life distributions, and changes in the marine food web (Morgan et al., 2019; CCIEA, 2021). Since then, another smaller and shorter lived marine heatwave developed off the U.S. West Coast, and researchers began tracking a third potential marine heatwave in February 2020 (CCIEA, 2021). For the latest information about marine heatwaves in the California Current Ecosystem, please see the CCIEA Marine Heatwave Tracker (CCIEA, 2021).

Observations and impacts of climate change and/or changes in water conditions made by Coastal Treaty Tribe members on the Olympic Coast have been documented and provide extensive detail on the effects and the importance of these changes on economic, cultural, and subsistence resources (Shaffer et al., 2004; Dalton, 2016; Shannon et al., 2016). For example, climate change impacts like coastal erosion from increased wave action, increased riverine sediment loads, increased water temperature, and ocean acidification have multifaceted impacts on coastal wildlife due to the connectivity and fluidity of the marine environment. The Olympic Coast comprises crucial habitats that harbor species of great cultural and economic importance. However, climatological disturbances to these ecosystems can result in habitat loss and degradation, as well as declines in abundance or redistribution of marine species important to tribal communities (Dalton, 2016; Shannon et al., 2016; Anderson et al., 2019). For place-based management, such as sanctuary management and tribal U&A fishing areas, changes in species distribution can be especially impactful.

It is, therefore, essential to study and assess climate and ocean indicators, regional upwelling indicators, and water chemistry indicators that play a critical role in characterizing ecosystem productivity and ecological integrity along the Olympic Coast. For this current assessment, the status of climate-altered water conditions in OCNMS was judged to be fair/poor with a worsening trend, both with high confidence. These ratings indicate that climate-related changes have caused severe degradation in some, but not all, attributes of ecological integrity. Since 2008, concerning climate-related changes have been documented for several critical ocean indicators, such as dissolved oxygen, aragonite saturation, pH, and marine heatwaves. Independently, each of these changes can cause detrimental impacts to the marine ecosystem, and when operating together, they may produce additive or synergistic impacts.

Comparison to 2008 Condition Report

This question is new and was not assessed in the 2008 condition report. However, the topic of climate change was included in the response to Question 1 at that time: "Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?" and the question was rated good/fair' with an undetermined trend (ONMS, 2008). The 2008 report presented limited data on oceanographic indicators related to climate change, mostly related to hypoxic events (low dissolved oxygen) in the sanctuary. In the current report, experts assessed the impact of climate change on water quality and the ecological integrity of OCNMS since 2008. The status and trend ratings were determined to be fair/poor' and worsening, respectively, based on robust evidence and high agreement among experts. This rating is based on oceanographic indicators related to climate change; all have the ability to compromise productivity and food web dynamics within the ecosystem, and often work synergistically to exacerbate impacts. Indicators used to assess recent developments include: basin-scale indices, upwelling indices, water/air temperatures, dissolved oxygen/hypoxia, partial pressure of carbon dioxide (pCO_2), aragonite saturation, and pH.

New Information in the 2008–2019 Condition Report

There was high agreement among experts that changes in climate have accelerated changes in water conditions and caused severe degradation in some attributes of ecological integrity. The assessment was based mainly on robust evidence available for key climate change indicators: climate and basin-scale indices, upwelling indices, SST, air temperatures, hypoxia, and ocean acidification indicators (pCO_2, aragonite saturation, and pH). Although data availability for climate change indicators has increased, analysis gaps remain for many key indicators. Existing data streams, including those from OCNMS moorings and several other regional oceanographic monitoring assets, could be used to provide more sophisticated synthesis information on climate-related variables.

Climate and Basin-Scale Indices

Three large-scale climate indices that affect productivity in OCNMS were used to portray large-scale variability in the region. These indices were: (1) PDO; (2) the North Pacific Gyre Oscillation (NPGO); and (3) ENSO, as described by the Oceanic Niño Index (ONI). Positive PDO and ONI values and negative NPGO values usually indicate conditions that lead to low California Current Ecosystem productivity. In contrast, negative ONI and PDO values and positive NPGO values are associated with periods of high California Current Ecosystem productivity (Harvey et al., 2019). Since 2008, assessments of the status of the three indices (PDO, ONI, and NPGO) revealed that recent means were within one standard deviation of long-term means. The trend for the same period showed that PDO and ONI increased while NPGO decreased, resulting in reduced productivity overall (IEA, 2020; Figures S.WQ.8.1–S.WQ.8.3).

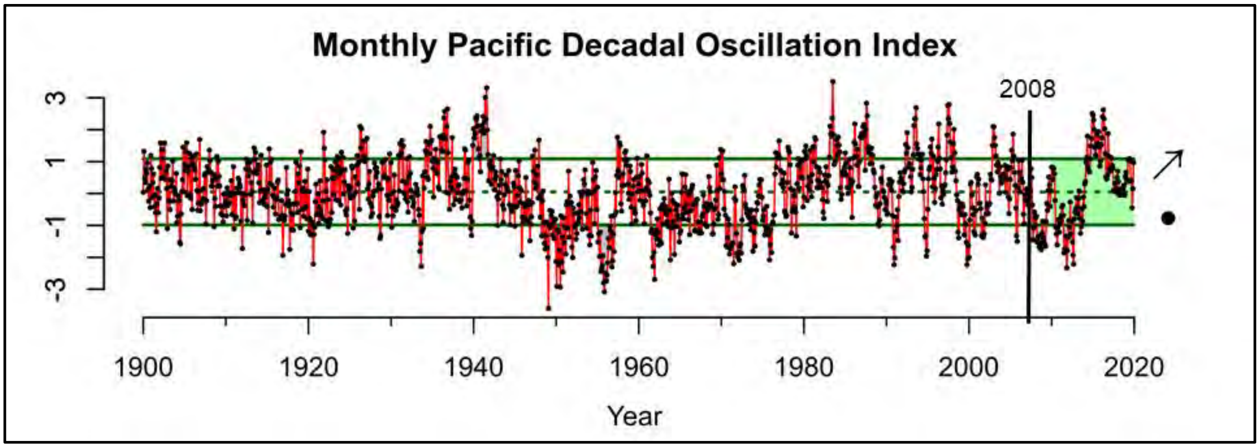


Figure S.WQ.8.1. Monthly PDO index. The PDO describes sea surface temperature anomalies in the Northeast Pacific. Positive PDO values are associated with warmer waters and lower productivity, while negative PDO values indicate cooler waters and higher productivity. The vertical black line indicates the year of the last condition report (2008). The black dot (●) indicates that the recent mean (last 10 years) was within 1 standard deviation of the long-term mean, and there was an increasing trend (indicated by arrow ↗) for the last 10 years. The dashed green line is the long-term mean and solid green lines are ±1 standard deviation. Image: IEA, 2020

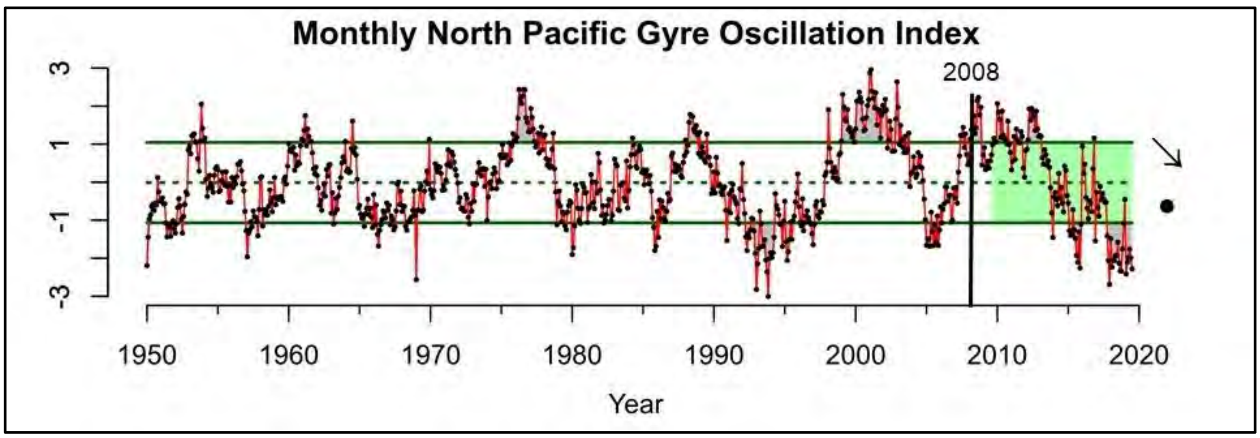


Figure S.WQ.8.2. Monthly NPGO index. NPGO indicates sea surface height, signaling changes in ocean circulation that affect source waters. Positive NPGO values are associated with increased equatorward flow; higher surface salinities, nutrients, and chlorophyll; and higher productivity. Negative values are associated with less productive conditions. The black dot (●) indicates that the recent mean (last 10 years) was within 1 standard deviation of the long-term mean, and there was a decreasing trend (indicated by arrow ↘) for the last 10 years. The dashed green line is the long-term mean and solid green lines are ±1 standard deviation. Image: IEA, 2020

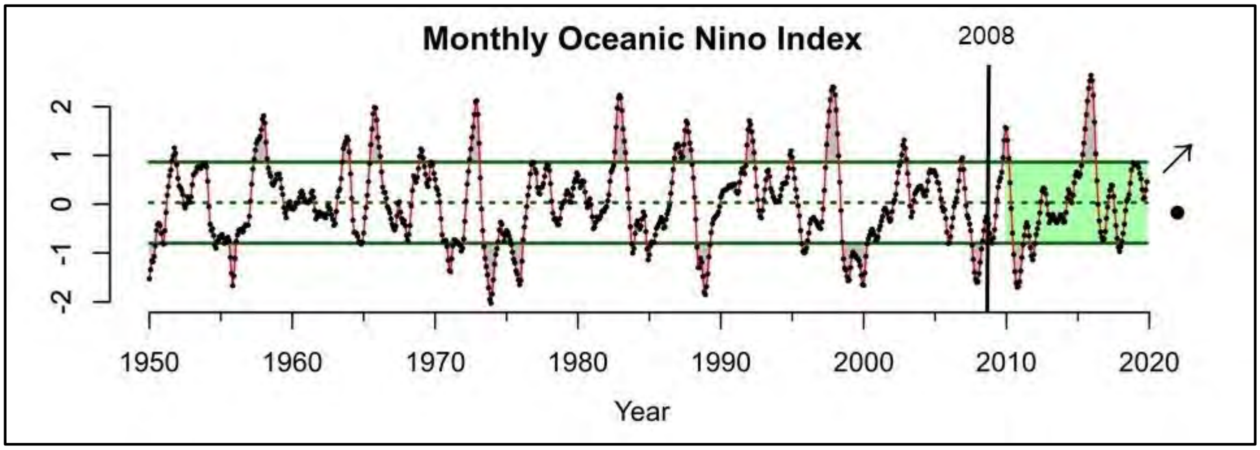


Figure S.WQ.8.3. Monthly ONI index. The ONI describes equatorial conditions related to the El Niño Southern Oscillation; a positive value reflects El Niño conditions with generally lower primary productivity, weaker upwelling, poleward transport of equatorial waters and species, and more storms in the southern portion of the California Current. A negative value indicates La Niña conditions, with generally higher productivity. The black dot (●) indicates that the recent mean (last 10 years) was within 1 standard deviation of the long-term mean, and there was an increasing trend (indicated by arrow ↗) for the last 10 years. The dashed green line is the long-term mean and solid green lines are ±1 standard deviation. Image: IEA, 2020

Upwelling Indices

Over the period considered by this report, the 10-year mean values for upwelling indices remained within 1 standard deviation of the long-term mean. For more information on the status and trends of upwelling indices and their role in sanctuary productivity, please see Question 6 (IEA, 2020; Figures S.WQ.6.3–S.WQ.6.4).

Sea Surface Temperature and Marine Heatwaves

From 2014–2016, the California Current Ecosystem experienced an unprecedented marine heatwave. This event, known as "the blob," caused elevated SST anomalies beginning in early 2014 and persisting through mid-2016 (Figure S.WQ.8.4). The marine heatwave was exacerbated by a 2015–2016 El Niño event (Gentemann et al., 2017; Jacox et al., 2019), and ultimately became the largest marine heatwave detected since NOAA satellites started keeping track in 1981 (NOAA Fisheries, 2019a). Marine heatwave effects on the California Current Ecosystem were widespread, causing severe impacts on marine life (Holbrook, 2019). Warmer water associated with the event also contributed to an unprecedented HAB on the West Coast in 2015 (McCabe et al., 2016). This HAB event increased domoic acid toxins in shellfish, closing fisheries for Dungeness crab and razor clams from 2015 to 2016 and poisoning seabirds and marine mammals (McKibben et al., 2017; Trainer et al., 2017; Anderson et al., 2019).

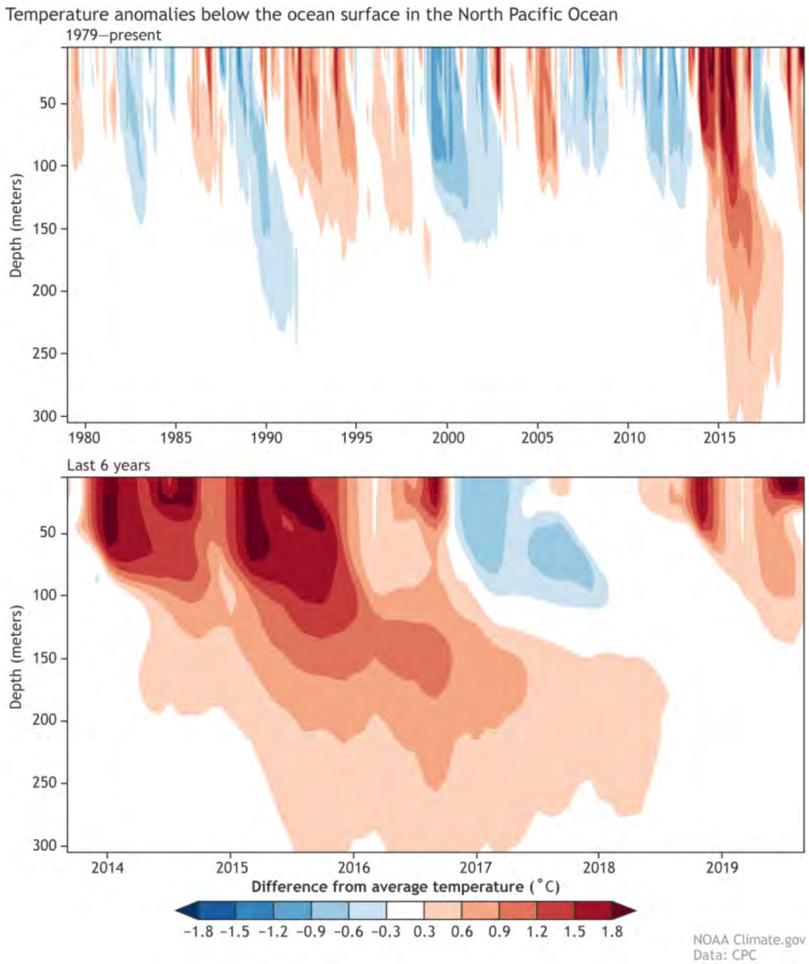
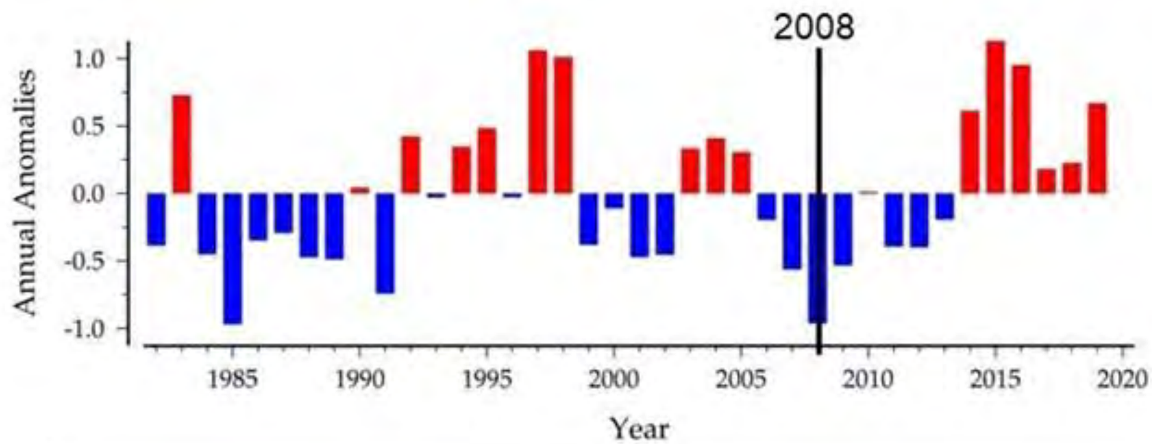


Figure S.WQ.8.4. Subsurface temperature anomalies averaged in the North Pacific Ocean (40–50°N, 150–130°W) from 1980 to present (using an ensemble of ocean reanalysis from various agencies). Source: NOAA Climate Prediction Center; Image: L'Heureux, 2019; C. Wen/NOAA

The blob also caused many ecological changes in the California Current Ecosystem. Notably, the fish assemblage shifted to include species usually found farther south (e.g., skipjack tuna), and a massive number of subtropical and tropical colonial tunicates called pyrosomes clogged nets in Oregon and Washington for months. Krill and forage fish abundance also declined. Humpback whale feeding locations shifted from offshore (krill) to closer inshore (anchovy), resulting in more whale entanglements in crab pots (NOAA Fisheries, 2020d). Due to these severe impacts, oceanographers from NOAA's Southwest Fisheries Science Center (SWFSC) developed the marine heatwave tracker, an experimental tool to study and predict marine heatwaves expected to affect the West Coast (NOAA Fisheries, 2019a). Another marine heatwave developed offshore of the West Coast in the summer of 2019 but declined by January of 2020 (Figure S.WQ.8.4). This marine heatwave lasted for 239 days and was the second largest event in the northern Pacific Ocean since 1982 (L'Heureux, 2019).

To better understand SST, the Spatiotemporal Data and Time Series Toolkit, previously known as the COPEPODITE Toolkit, was used to assess the status and trend of SST anomalies within OCNMS using satellite image data (NOAA Fisheries, 2020d; O'Brien & Oakes, 2020). These data showed that the recent (2009–2019) mean for SST anomalies was within one standard deviation of the long-term mean (1979–2019) for this data set, but that the recent trend was significantly increasing. Annual average anomaly data show the rapid increase of positive SST anomalies from 2014 to 2016 due to the blob, a decline in anomalies in 2017, and a second marine heatwave in 2019 (Figure S.WQ.8.5). Data on seasonal variation in SST and air temperature were retrieved from the National Data Buoy Center (NDBC) for Neah Bay, Destruction Island, and Cape Elizabeth (NANOOS, 2020b). However, more processing and analysis is needed to facilitate comparison with the results from satellite images. For more detail on the NDBC SST and air temperature data for these sites, see Figures App.S.WQ.8.1–App.S.WQ.8.5.



Reynolds OI-SST-v2 Temperature (C)																
Twin Year Range	Twin		Annual		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015 - 2019	TW05		–		(-)	–	–	(-)	+	(-)	(-)	(+)	(-)	-	-	-
2010 - 2019	TW10		+++		(+)	(+)	(+)	(+)	++	(+)	(+)	(+)	(+)	(-)	(+)	(+)
2005 - 2019	TW15		+++		(+)	(+)	(+)	(+)	++	(+)	(+)	+	++	(+)	(+)	(+)
2000 - 2019	TW20		+++		(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	+	+	(+)

Figure S.WQ.8.5. Annual SST anomalies (Reynolds Optimum Interpolation SST-v2) and trends analysis for OCNMS, 1979–2019. Red box illustrates a significant increasing trend for 2010–2019. Blue shading and "-" indicate a significant decrease, while red shading and "+" indicate a significant increase. Symbols in parentheses (i.e., "(-)" and "(+)") do not indicate significant changes. Image: NOAA Fisheries, 2020d; O'Brien & Oakes, 2020

Dissolved Oxygen and Hypoxia

Historically (1950–1986), hypoxia (dissolved oxygen concentration <2 mg/L or <1.4 mL/L or <60 µmol/kg) has been reported in the northern portion of the California Current Ecosystem over the summer upwelling season, particularly on the Washington shelf, and can cause stress, or even mortality, in sensitive species (Connolly et al., 2010; Siedlecki et al., 2015; Harvey et al., 2019), and reduce the availability of suitable habitat. Recently, hypoxic events were documented in 2017 and 2018; the latter was more severe and spatially extensive on the Washington continental shelf (see Box 2 and Figure S.WQ.8.6). Hypoxic events in both years caused widespread die-offs of crabs and other benthic invertebrates, and redistribution of groundfish (Harvey et al., 2019).

Box 2: Hypoxic Events

Hypoxia is the presence of low (<2 mg/L) dissolved oxygen in the water column. It can negatively affect habitat and cause sensitive marine species to become stressed or even die (Cannolly et al., 2010; Siedlecki et al., 2015; Harvey et al., 2019). Hypoxia was historically reported (1950–1986) in the northern portion of the California Current Ecosystem over the summer upwelling season. In 2017 and 2018, the Washington continental shelf experienced two severe and geographically broad hypoxic events. These caused widespread die-offs of crab and other benthic invertebrates, as well as the redistribution of groundfish (Harvey et al., 2019). Impacts were more severe along the southern Washington coastline, which experiences progressively lower oxygen levels seasonally and a greater frequency of hypoxic conditions than in the north (Alin et al., 2022b).

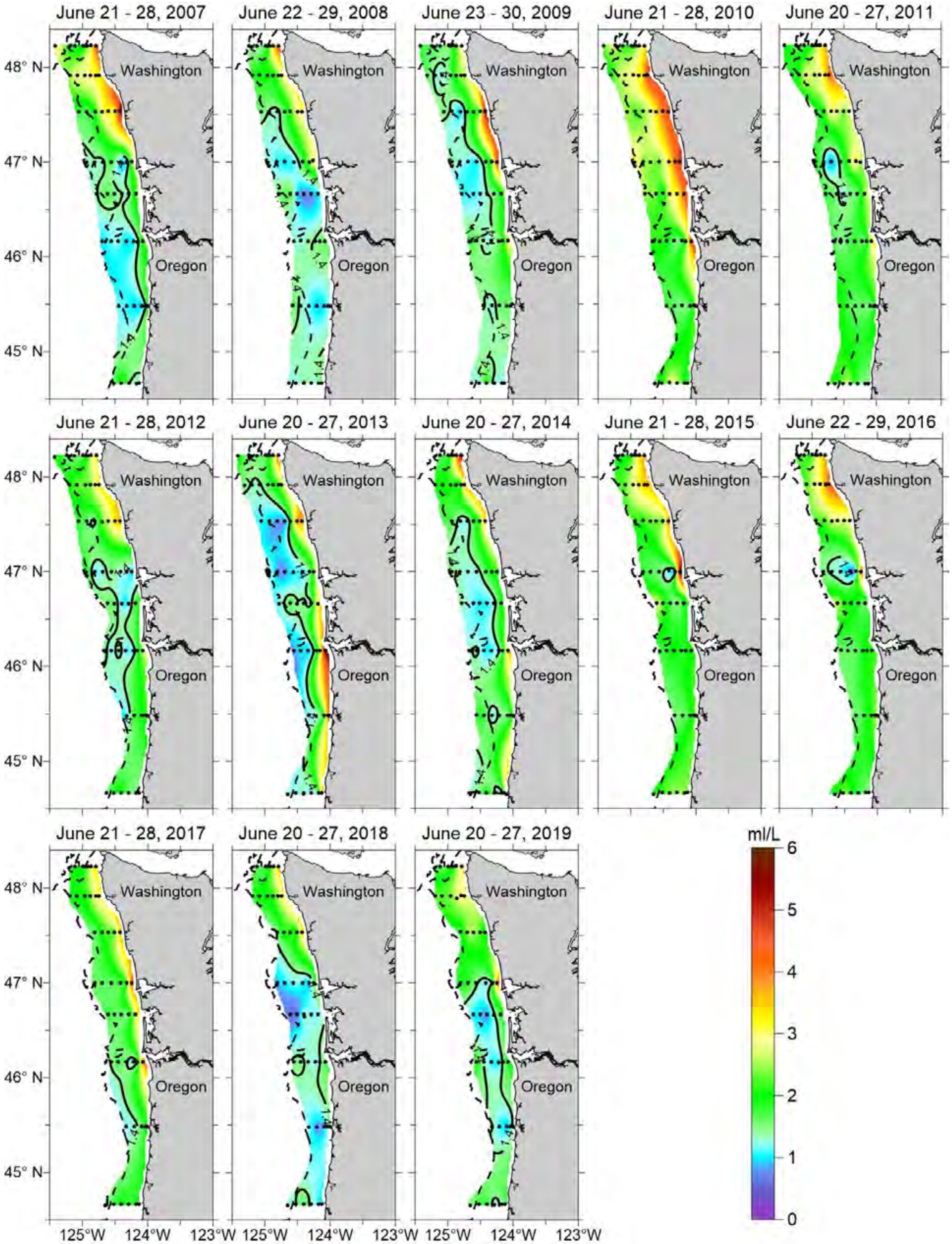


Figure S.WQ.8.6. Dissolved oxygen maps. Distribution of the minimum dissolved oxygen values (ml/L) during June from 2007 to present. A level of <1.4 ml/L (<2 mg/L) dissolved oxygen is generally used to identify hypoxic waters (outlined with bold contour line). Image: NOAA

Data from the sanctuary's long-term coastal oceanographic mooring array, which has been deployed at 10 locations seasonally for more than two decades (Figure S.WQ.8.7), provide a closer look at how ocean chemistry has changed in nearshore areas over time. The 2019 data show that hypoxia was detected at southern sites (i.e., Kalaloch and Cape Elizabeth) for most of summer 2019, and that dissolved oxygen continued to decrease over the summer (Figure S.WQ.8.8). In reviewing bottom oxygen conditions over the period of 2006–2017, Alin et al. (2022b) used calculated values from OCNMS moorings to identify a similar north-south gradient, contrasting conditions at the northern sites near Makah Bay and Cape Alava, which largely remained above the hypoxia threshold, with conditions at southern sites like Kalaloch and Cape Elizabeth, where hypoxia is often more persistent and pronounced (Figure S.WQ.8.9).

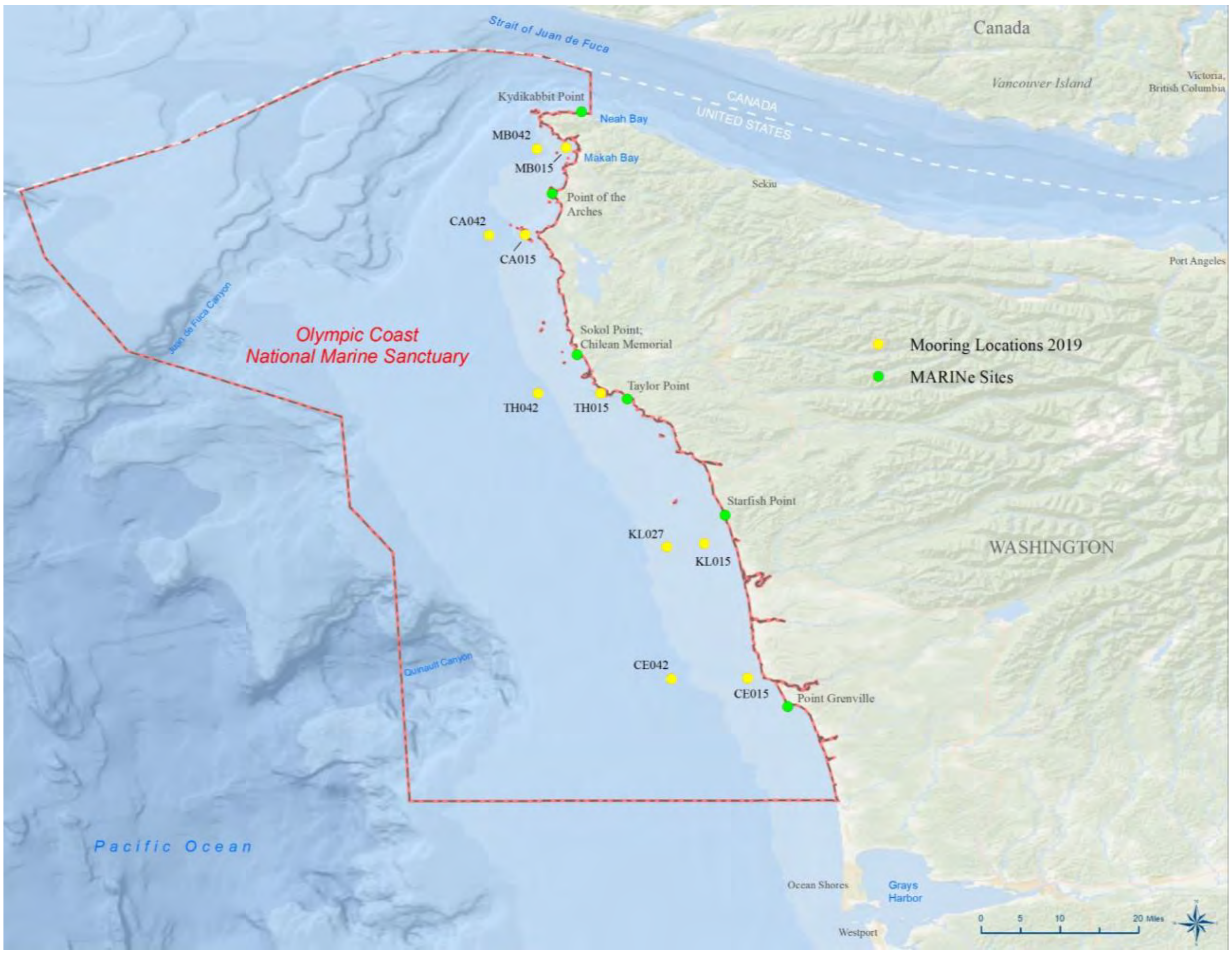


Figure S.WQ.8.7. The location of ten long-term coastal oceanographic moorings within OCNMS and six MARINe sites (long-term intertidal sites), which are monitored annually. Image: NOAA

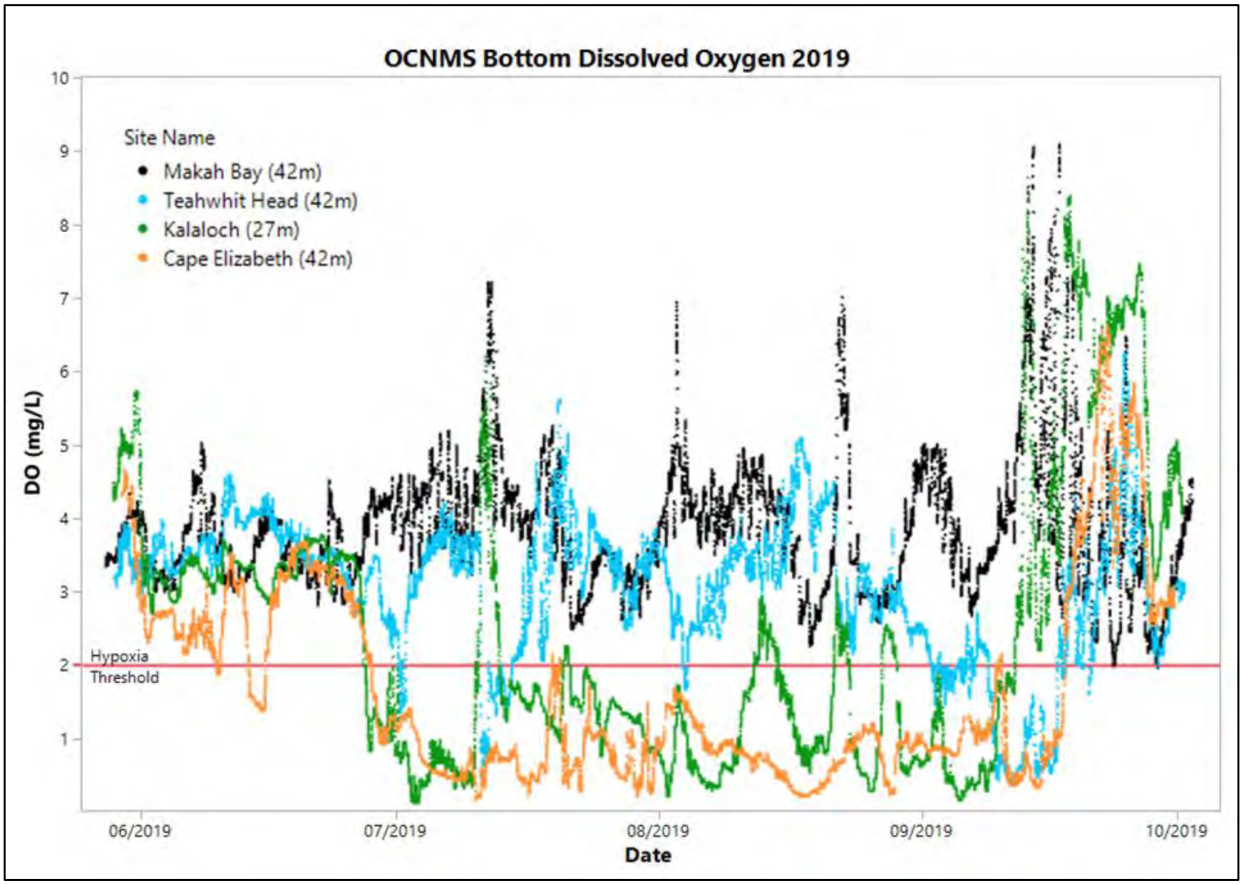


Figure S.WQ.8.8. OCNMS summer bottom dissolved oxygen in 2019 at four OCNMS mooring locations. These four locations span approximately 135 miles of coastline between Makah Bay in the north and Cape Elizabeth in the south. Horizontal line represents the hypoxia threshold (dissolved oxygen <2 mg/L or <1.4 ml/L). Source: NOAA; Image: A. Mabrouk/NOAA

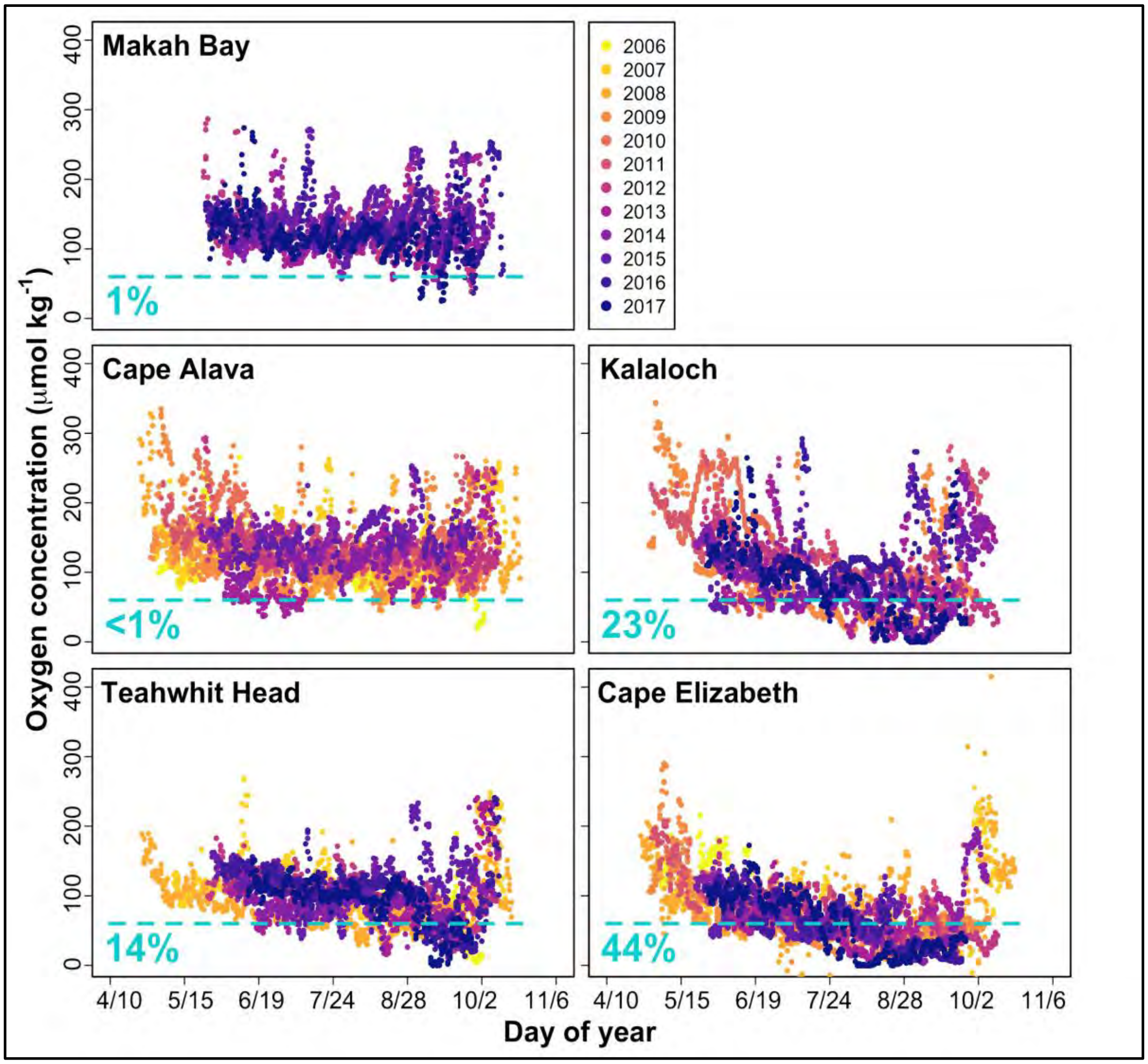


Figure S.WQ.8.9. Seasonal variability for near-bottom dissolved oxygen at locations spanning the Olympic Coast from Makah Bay in the north to Cape Elizabeth in the south (2006–2017). Results indicate a north-south gradient and seasonal progression of hypoxia, with greater frequency of hypoxic conditions at southern sites. Percentages estimate the proportion of the upwelling season when conditions are below the threshold for hypoxia. Source and image: Alin et al., 2022b

Ocean Acidification

Ocean acidification, resulting from the absorption of anthropogenic CO_2 from the atmosphere into the ocean, reduces pH and carbonate ion levels in seawater, increasing acidity and decreasing calcium carbonate saturation. Aragonite saturation is considered a key indicator of ocean acidification that reflects the availability of carbonate ions in seawater for synthesizing aragonite shells and skeletons. Aragonite is more soluble than other types of calcium carbonate (i.e., calcite), and thus, conditions can become corrosive to aragonite-producing organisms relatively quickly with increasing CO_2. California Current Ecosystem species, including oysters, crabs, and pteropods, have shells and carapaces containing calcium carbonate and are, thus, vulnerable to decreasing saturation states (and increasing corrosivity to calcium carbonate) (Feely et al., 2008; Barton et al., 2012; Bednaršek et al., 2014; Feely et al., 2016, 2018; Marshall et al., 2017; Hodgson et al., 2018).

To evaluate ocean acidification, we used the analysis of OCNMS benthic mooring data by Alin et al. (2022b). Three main ocean acidification indicators were evaluated for the period from 2006 to 2017: (1) pCO_2 (Figure S.WQ.8.10), (2) aragonite saturation state (Ω_{arag}; Figure S.WQ.8.11), and (3) pH (Figure S.WQ.8.12). Values were calculated based on *in situ* oxygen, temperature, and salinity data from OCNMS moorings (27–42 m depth). Analysis revealed a north-south gradient and seasonal progression to higher pCO_2 (and lower Ω_{arag} and pH values), and a greater frequency of high pCO_2, low Ω_{arag}, and low pH conditions affecting southern sites (Alin et al., 2022b). Aragonite saturation values show a greater frequency of corrosive conditions ($\Omega_{arag} < 1$) in the south, with data from the 42-m Cape Elizabeth mooring indicating nearly continuous aragonite undersaturation during the May to October time frame, when moorings are deployed. Average values for pH were between 7.5 and 7.7 across moorings (Alin et al., 2022b). Preliminary analysis of pCO_2 data from a NANOOS-University of Washington mooring near La Push and a specially instrumented NDBC mooring at Cape Elizabeth show that air pCO_2 is increasing annually. Seawater pCO_2 does not appear to be increasing; however, a longer time series is needed to detect the anthropogenic carbon signal in surface waters due to the high natural variability in surface pCO_2 based on mooring data (Alin et al., 2020; Sutton et al., 2019). Based on observations from NOAA's West Coast Ocean Acidification cruises from 2007 through 2013, seawater from 0 to 110 m over the northern California Current Ecosystem shelf has accumulated an average of 43–60 µmol/kg of anthropogenic carbon dioxide since the pre-industrial era, which is enough to increase pCO_2 and decrease pH and Ω_{arag} substantially (Feely et al., 2016; Alin et al., 2022b).

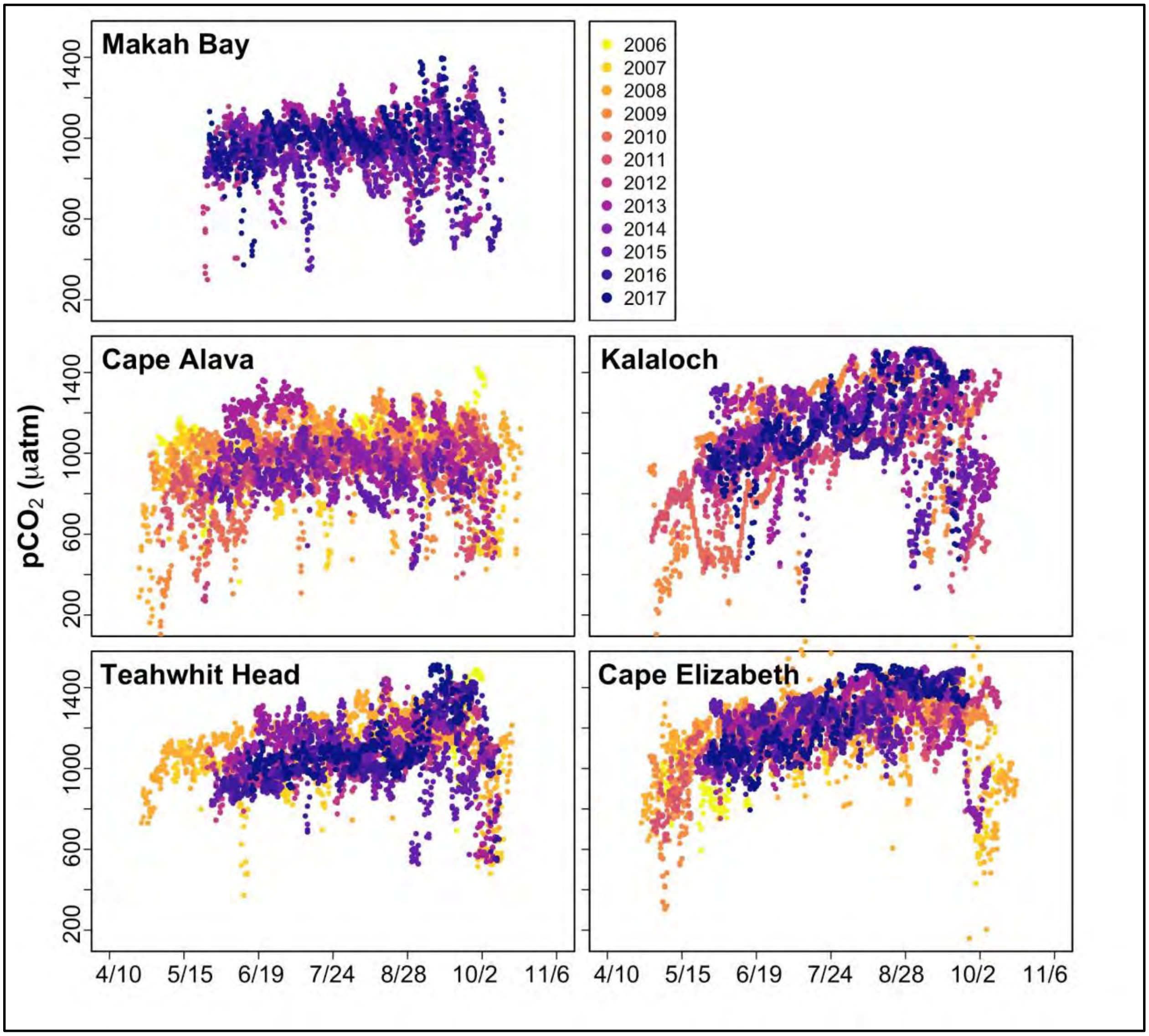


Figure S.WQ.8.10. Seasonal variability for pCO2 at locations spanning the Olympic Coast from Makah Bay in the north to Cape Elizabeth in the south (2006–2017), indicating a north-south gradient and seasonal progression. Source and image: Alin et al., 2022b

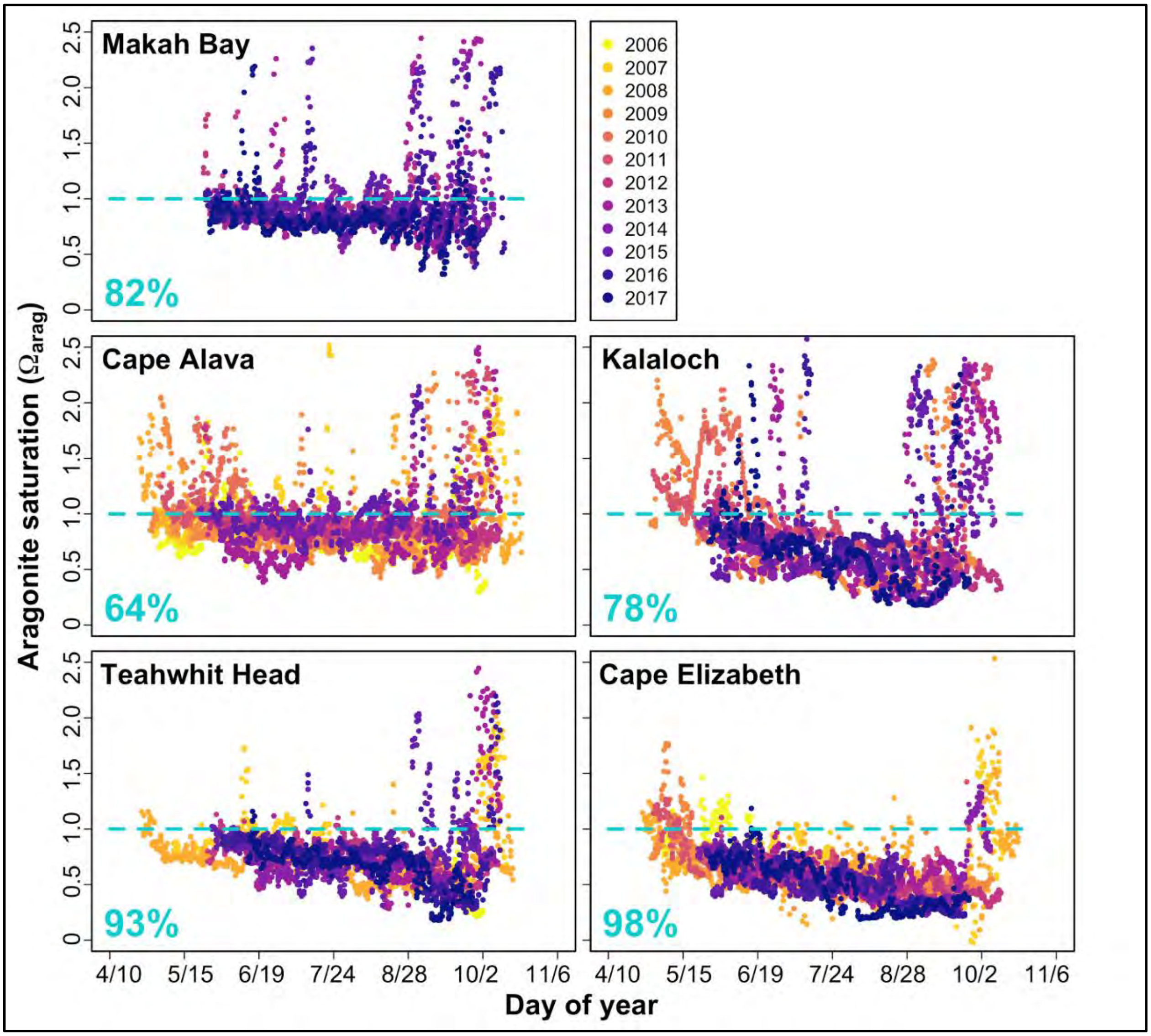


Figure S.WQ.8.11. Seasonal variability for aragonite saturation at locations spanning the Olympic Coast from Makah Bay in the north to Cape Elizabeth in the south (2006–2017). The dotted lines represent the saturation threshold; with values below 1 are undersaturated or “corrosive.” Percentages indicate the portion of the mooring record where values fell below the aragonite saturation threshold. Source and image: Alin et al., 2022b

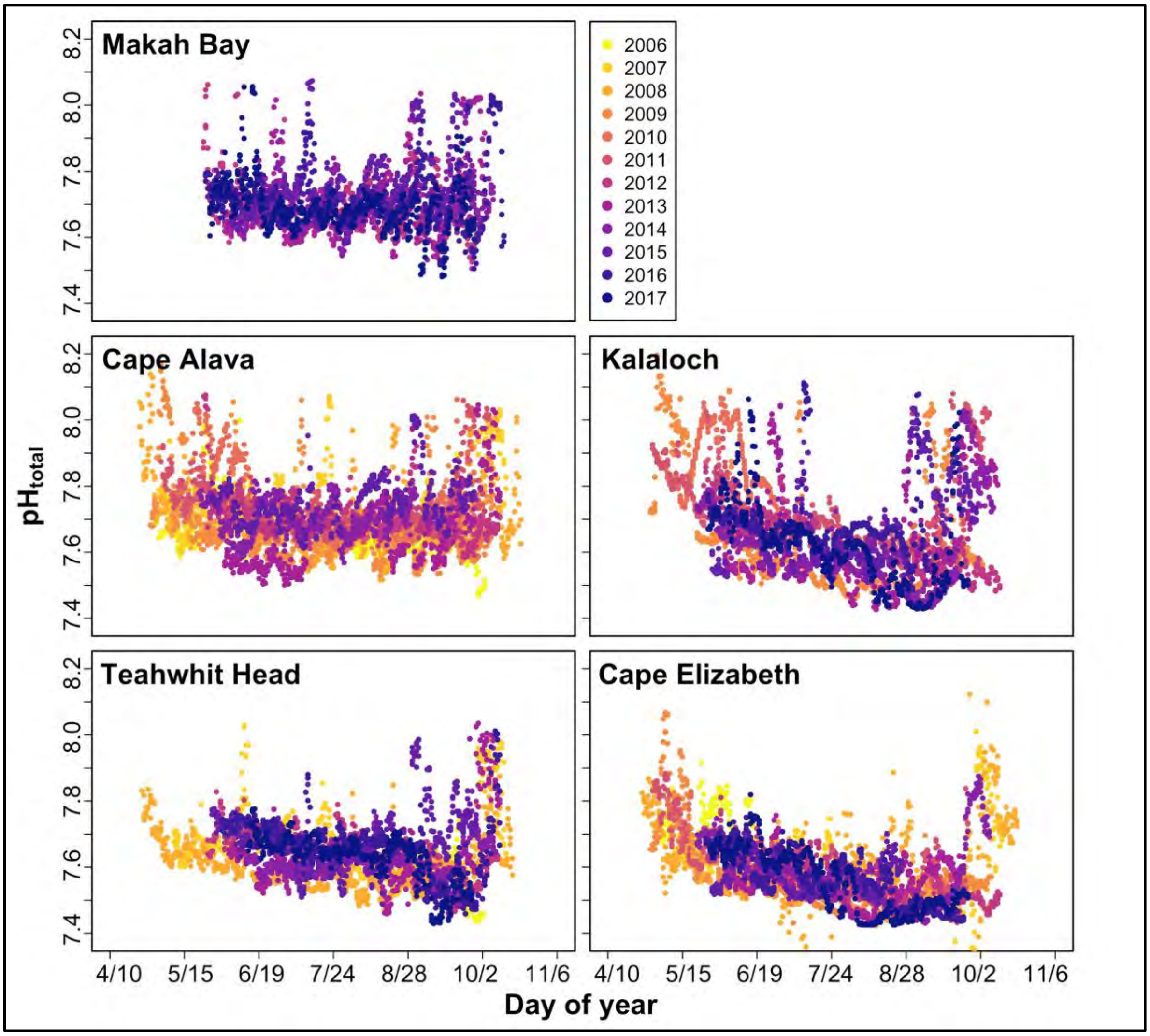


Figure S.WQ.8.12. Seasonal variability for pH, reported on the total scale, at locations spanning the Olympic Coast from Makah Bay in the north to Cape Elizabeth in the south (2006–2017). Calculated values and visualization: Alin et al., 2022b

Conclusion

For the 2008–2019 assessment, the status of climate-altered water conditions in OCNMS was fair/poor, and the trend was worsening, both with high confidence. While the availability of monitoring data helped increase confidence in these ratings, data and analysis gaps were also identified. Specifically, sea surface temperature and air temperature datasets from NDBC require additional trend analysis. Datasets for pCO_2 and pH from the Pacific Marine Environmental Laboratory for La Push and NDBC buoys for Cape Elizabeth need to incorporate new data and additional analyses. Additionally, pCO_2, Ω_{arag}, pH, and O_2 datasets for OCNMS moorings need trend analysis. Data describing thermoclines and pycnoclines, especially from the NANOOS Ćháʔba· buoy (see Box 3) and Northwest Enhanced Moored Observatory (NEMO) profiling mooring, also exist, but additional analysis is needed to estimate and track changes to these indicators over time. Table S.WQ.8.1 summarizes data gaps that would be beneficial to fill for the next condition report.

Box 3: NANOOS and Ćháʔba·

Composed of 73 members, NANOOS is a user-driven regional partnership, representing the Pacific Northwest as a regional association within the broader U.S. Integrated Ocean Observing System. The primary mission of NANOOS is to provide regional stakeholders with the ocean data, tools, and information they need to make responsive and responsible decisions, appropriate to their individual and collective societal roles. By coordinating existing assets and placing strategic focus on new investments, NANOOS has produced a distributed observing system that yields informative and decision-relevant data products. These products serve Pacific Northwest stakeholders and society by addressing five areas of concern (maritime operations, ecosystem assessment, coastal hazards, biodiversity, climate) across three spatial domains (coastal ocean, estuaries, shorelines). From this system, NANOOS provides significant societal benefits to a wide spectrum of users including federal, tribal, state, and local governments; industries; scientific researchers; non-governmental organizations; educators; and the public. NANOOS maintains essential subsystems (Governance and Management, Observing, Data Management and Cyberinfrastructure, Modeling and Analysis, and Engagement) in coordination with other regional associations, the U.S. Integrated Ocean Observing System, and Canadian counterparts. NANOOS products provide essential, management-relevant information that directly informs and supports OCNMS and other partner organizations. Products of particular relevance to the sanctuary include: the NANOOS Visualization System, which serves marine data and interpreted products; near- and mid-term forecasts of ocean conditions provided by LiveOcean and J-SCOPE models; and high-resolution, real-time data streams provided by the Ćháʔba· mooring and affiliated ocean profiling and HAB monitoring efforts, all of which collect data in the central portion of the sanctuary.

Table S.WQ.8.1. Status and trends for individual Question 8 indicators discussed at the January 2020 workshop.

Indicator	Source	Habitat	Data Summary	Figures
Climate and basin-scale indices	IEA/CCIEA	All habitats	Status: Recent (last 10 years) means for PDO, NPGO, and ONI were within 1 standard deviation of the long-term mean. Trend: PDO increased, NPGO decreased, and ONI increased.	S.WQ.8.1–S.WQ.8.3
Upwelling indices LUSI, TUMI, and STI	Jacox et al., 2018; IEA/CCIEA	All habitats	Status: Recent mean (last 10 years) for LUSI, TUMI, and STI are within 1 SD of the long-term mean Trend: LUSI, TUMI, and STI did not change during the study period.	S.WQ.6.3–S.WQ.6.4
Water temperature	NOAA Fisheries, 2020b; O'Brien & Oakes, 2020; NANOOS; Ian Miller/ Washington Sea Grant/University of Washington/ Peninsula College	All habitats	Status: More analysis required; multiple anomalously warm years occurred within the assessment period. Trend: SST data show repeated elevated temperature anomalies during the assessment period.	S.WQ.8.4–S.WQ.8.5; App.S.WQ.8.1–App.S.WQ.8.5
Air temperature	NANOOS	All habitats	Status: More analysis required for coastal sites; for inland stations, many of the warmest years occurred during the assessment period. Trend: More analysis required	App.S.WQ.8.3–App.S.WQ.8.5
Salinity	NOAA Fisheries, 2020d; O'Brien & Oakes, 2020; NOAA Pacific Marine Environmental Laboratory	All habitats	Status: Very few buoys collecting these data; outputs from COPEPODITE are suspect and conflict with data from OCNMS buoys; other sources of data exist but have not yet been analyzed Trend: Analysis required	
Dissolved oxygen and hypoxia (benthic)	OCNMS buoys; Alin et al., 2022b	All habitats	Status: Frequent hypoxic conditions at southern sites (Kalaloch and Cape Elizabeth) for most of the summer (July–September) Trend: Seasonal hypoxia tends to be more pronounced and persistent at southern sites (Kalaloch and Cape Elizabeth)	S.WQ.8.6–S.WQ.8.8; App.S.WQ.8.6
$p\mathrm{CO_2}$ (benthic)	Alin et al., 2022b; Sutton et al., 2019	All habitats	Status: North-south gradient and seasonal progression to higher $p\mathrm{CO_2}$ values at southern OCNMS benthic mooring sites (sensors at 42 m) Trend: need analysis	S.WQ.8.9

Indicator	Source	Habitat	Data Summary	Figures
Aragonite saturation (benthic)	Alin et al., 2022b	All habitats	Status: North-south gradient with greater frequency and severity of corrosive conditions at southern OCNMS benthic mooring sites Trend: Increasing frequency of corrosive conditions at 42 m depths	S.WQ.8.10
pH (benthic)	Alin et al., 2022b; Olympic National Park	All habitats	Status: North-south gradient with lower values toward southern sites Trend: Increasing frequency of low pH conditions at 42 m depths	S.WQ.8.11
Wind/wave	Ian Miller/ Washington Sea Grant/University of Washington/ Peninsula College	All habitats	Status: Analysis required Trend: No significant change in wind speed or wave height and power	
Thermocline depth	NANOOS; Palacios et al., 2004; OCNMS moorings	All habitats	Status: Analysis of NANOOS data required; historic, multi-decadal shift in regional thermocline depth from 1950 to 1993 (Palacios et al., 2004) Trend: Analysis of NANOOS data required; no consistent trend in 1998–2014 assessment (Andrews et al., 2015); analysis gap for 2015–2019	
Pycnocline depth	NANOOS; OCNMS moorings	All habitats	Status: Analysis of NANOOS data required Trend: Analysis of NANOOS data required; no consistent trend in 1998–2014 assessment (Andrews et al., 2015); analysis gap for 2015–2019	
Data gaps	Additional information required regarding decline in shell thickness, change in size of salmon, fish washing up on beaches/fish kills; severe degradation of ecological integrity has occurred in the southern area of OCNMS over the last 10 years, while the northern area may be less impacted (referencing north-south gradient of some indicators)			
Analysis gaps	Water temperature from OCNMS moorings, air temperature, salinity, pCO_2, wind/wave, thermocline depth, and pycnocline depth			

Question 9: Are other stressors, individually or in combination, affecting water quality, and how are they changing?

Status Description: Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.

Rationale: Persistent organic pollutants were present in some forage fish and gray whales, but below effects levels. Microplastics are likely present, based on data from Oregon. The worsening trend determination was based on global trends in these stressors.

Comparison to 2008 Condition Report

In the 2008 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 2008, that question received a good rating and an undetermined trend. The basis for judgment was hypoxic conditions that were described as potentially increasing in frequency and spatial extent in nearshore waters. 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 (see Table S.WQ.6.1 and Appendix H).

New Information in the 2008–2019 Condition Report

In addressing this question, we considered contaminants, microplastics, and pharmaceuticals as important indicators of other stressors in OCNMS. Limited data and no long-term monitoring studies were identified, but experts considered the low number of potential sources adjacent to the sanctuary and the low frequency of reports related to these problems and judged OCNMS water quality with regard to other stressors to be good/fair. Unfortunately, no data were identified that shed light on the compounding effects of multiple stressors (e.g., heavier precipitation and runoff or storm surge resuspending buried contaminants).

A 2014 study investigated persistent organic pollutants in forage fish and prey species of rhinoceros auklets in breeding colonies on Protection Island, Tatoosh Island, and Destruction Island (Good et al., 2014). Protection Island is in the eastern Strait of Juan de Fuca (Puget Sound), 70 nautical miles from the sanctuary boundary, and Tatoosh and Destruction islands are within the sanctuary. Overall, contaminant levels in fish from the outer coast were 25–50% of those in fish from Puget Sound, but they had similar contaminant profiles. High PCB and PBDE concentrations in Chinook salmon from the outer coast likely reflected Columbia River conditions (Good et al., 2014).

A 2018 study investigated persistent organic pollutants in eastern North Pacific gray whale blubber from samples collected in 2003, 2010–2012, and 2015–2017 and found that mean concentrations were lower, on average, than previously reported levels for gray whales and some other baleen whales (Hayes, 2018). PCBs had the highest concentration, followed by DDTs, chlordanes, and hexachlorocyclohexanes. However, the persistent organic pollutant contaminant concentrations detected were all below the health effects threshold for PCBs in aquatic mammals (Hayes, 2018).

Mercury concentrations were studied in harbor seals in British Columbia and Puget Sound between 2003 and 2010. While samples were not collected within OCNMS, one site was at Point Renfrew, British Columbia, just north of the sanctuary. Harbor seal pups at Port Renfrew had significantly higher concentrations of mercury compared to sites sampled inside Puget Sound, the Strait of Georgia, and other sites along Vancouver Island. The authors found this surprising and surmised that perhaps the high upwelling in the region may contribute to increased methylmercury concentrations at the bottom of the food chain, which then biomagnified up the food chain into adult seals and passed to the pups via placenta and milk (Noël et al., 2015).

Microplastics are an ecological stressor of emerging concern, with implications for ecosystem and human health when present in seafood. Microplastics may cause harm to humans via both physical and chemical pathways. They are found in nearly every environment on Earth (Thompson et al., 2004). Plastic debris in the marine environment contains organic contaminants, some of which are added during manufacturing, and some of which are absorbed from surrounding seawater (Teuten et al., 2009). A recent study quantified microplastic types, concentrations, anatomical burdens, geographic distribution, and temporal differences in Pacific oysters and Pacific razor clams from 15 Oregon coast sites. Microplastics were present in organisms from all sites and in 244 of 245 samples. The study notes that the degree to which microplastics pose a threat to coastal marine ecology or predators of bivalves (including humans) is still unclear (Baechler et al., 2019).

Over the last 15 years, increasing attention has been paid to understanding the presence and impacts of pharmaceuticals entering or detected in freshwater ecosystems. By contrast, significantly less attention has been paid to understanding releases of pharmaceuticals from sewage and other routes into coastal environments and their potential marine impacts (Gaw et al., 2014). Pharmaceuticals are present and may be affecting marine species in Puget Sound (Meador et al., 2016). No studies or data were found specific to the outer coast of Washington.

Conclusion

Persistent organic pollutants, microplastics, and pharmaceuticals are likely present in OCNMS. While these may degrade some attributes of ecological integrity, little information on this topic was available. What information was identified led to a rating of good/fair with a worsening trend. This was based on the presence of persistent organic pollutants in rhinoceros auklet prey fish and the widespread presence of microplastics in Pacific oysters and Pacific razor clams along the Oregon Coast. While pharmaceuticals were reviewed, no relevant studies were identified, so they were not considered in the final rating. Limited monitoring in the sanctuary for all of the contaminants considered is a significant data gap.

Status and Trends of Habitat (Questions 10–11)

Habitats within OCNMS extend from the intertidal to the depths of its submarine canyons, and range along a large proportion of Washington's outer Pacific coast. Information on these habitats comes from multiple sources, including long-term monitoring programs, discrete mapping surveys, and focused ecosystem research. The following sections provide an assessment of the status and trends of key habitat indicators in OCNMS for the period from 2008–2019.

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. 2008 (left) and 2008–2019 (right) status, trend, and confidence ratings for the habitat questions.

2008 Condition Report Questions	2008 Rating	2008–2019 Condition Report Questions	2008–2019 Condition Report Rating
5. Habitat abundance/distribution	–	10. Integrity of major habitats	Fair ▼
6. Condition of biologically structured habitat	?		
7. Contaminants	–	11. Contaminants	Good ?

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

Status Description: Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.

Rationale: Since 2008, the ecological integrity of major habitat types has been mixed. There was little evidence of major degradation in kelp forests and rocky coasts, but the dominant habitat, the pelagic zone, has been degraded by marine heatwaves, ocean acidification, and hypoxic events, and measurable declines in these indicators drove the ratings for this question. Data on the integrity of other habitat types in the sanctuary are lacking.

Definition and Description

This question is intended to address acute or chronic changes in both the extent of habitat available to organisms and the quality of that habitat, whether non-living or biogenic. Non-living habitats are physical structures, such as rocky coasts, sand flats, and the water column. Biogenic habitats are structure-forming species that create habitat, like kelp forests, deep-sea corals and sponges, and mussel beds. Biogenic habitats are layered on top of, and often form in association with, particular non-living habitat types. Change and loss of habitat is of paramount concern when it comes to protecting marine and terrestrial ecosystems. Of greatest concern to sanctuaries are changes to habitats caused, either directly or indirectly, by human activities.

In the 2008–2019 assessment, the integrity of major habitat types was rated fair with a worsening trend. This rating indicates that selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity. These ratings were supported by data showing that while kelp forests and rocky shores exhibited little degradation, pelagic and deep seafloor habitats on the continental shelf have been degraded by hypoxic events, ocean acidification, marine heatwaves, and other climate impacts. There is generally a lack of information describing changes in deep seafloor, shallow sandy seafloor, and beach habitats. In addition, experts acknowledged that the impacts of marine heatwaves in 2014–2016 and again in 2019–2020 are a concern. Confidence was medium for both the status and trend ratings because, despite mixed trends among habitats, robust evidence indicated that pelagic and seafloor habitats have been significantly altered in the past decade by hypoxia, ocean acidification, and marine heatwaves.

Comparison to 2008 Condition Report

This question was addressed differently in 2008, when abiotic and biotic habitat types were assessed separately. The statuses of major abiotic and biotic habitats were rated good/fair and fair, respectively, and corresponding trends were rated not changing and undetermined (Table S.H.10.1 and Appendix H). These previous ratings were based on observations that most habitats were undisturbed by human use and development, but were tempered by the acknowledgement that there was limited, localized habitat modification from disturbances such as trawling, cable installation, shoreline armoring, and human visitation.

Many of the habitats found in OCNMS are relatively undisturbed, and remain in a similar healthy condition as in 2008. The sanctuary's remote location and shorelines, buffered by the Olympic National Park and tribal reservations, offer protection from coastal development and other direct anthropogenic disturbances. However, more pervasive anthropogenic impacts to habitats from broadscale oceanographic hypoxia and impacts from recent marine heatwaves are a concern. It is also assumed that localized habitat modification from trawling the deep seafloor is an issue, but there were insufficient data to assess change in the condition of these habitats. Information on seafloor trawling in the sanctuary is provided in Question 3.

Much of the information on habitat integrity within the sanctuary comes from long-term monitoring of kelp forests, rocky shores, and pelagic habitats. Kelp forests and rocky shores have been well studied and support some of the most productive and diverse communities in the California Current Ecosystem. The integrity of these two habitats appeared to be in good and stable condition from 2008–2019. However, researchers are concerned about future impacts from climate change.

New Information in the 2008–2019 Condition Report

Kelps are foundational species in the Pacific Northwest, and there are extensive tracts of kelp forests within OCNMS (Van Wagenan, 2015), with many kelp forest canopies exhibiting a mix of giant kelp (*Macrocystis pyrifera)* and bull kelp (*Nereocystis luetkeana)*. Kelp forests provide food and shelter for many invertebrates and fishes (Teagle et al., 2017), are exceptionally efficient primary producers (Mann, 1973), and are well connected to adjacent ecosystems through energy and nutrient transfers (Hansell, 2013). The extent and integrity of kelp forests are intimately related to external ecosystem forces such as water temperature and upwelling regimes, and therefore kelp forests can vary substantially among years and are sensitive to changes in ocean climate (Pfister et al., 2017).

Pfister et al. (2017) analyzed aerial censuses of giant kelp and bull kelp in Washington state waters from 1989 to 2015 and compared these modern censuses with censuses in 1911 and 1912. They found kelp forests remained at historic high levels along the outer coast (Figure S.H.10.1) between 2008 and 2015 and detected no consistent change in kelp forest persistence during these years. The relative stability and persistence of kelp forests on the Olympic Coast is encouraging when compared to the declining trends in kelp forests located inside Puget Sound, and provides a sharp contrast to steep kelp forest declines experienced recently in parts of California (ONMS, 2019). Although the assessment by Pfister et al. (2017) was positive overall, localized areas of high variability and low abundance, as well as areas of extirpation, were documented. These losses align with kelp forest losses recorded by Quileute elders (Shaffer et al. 2004), and could be due in part to localized oil spills and intermittent influx of sediment from storms after timber harvest (Shannon et al., 2016). Pfister et al. (2017) concluded with a caution that kelp forest viability remains a concern for the future because of the strong relationship between kelp and ocean temperature, which is increasing.

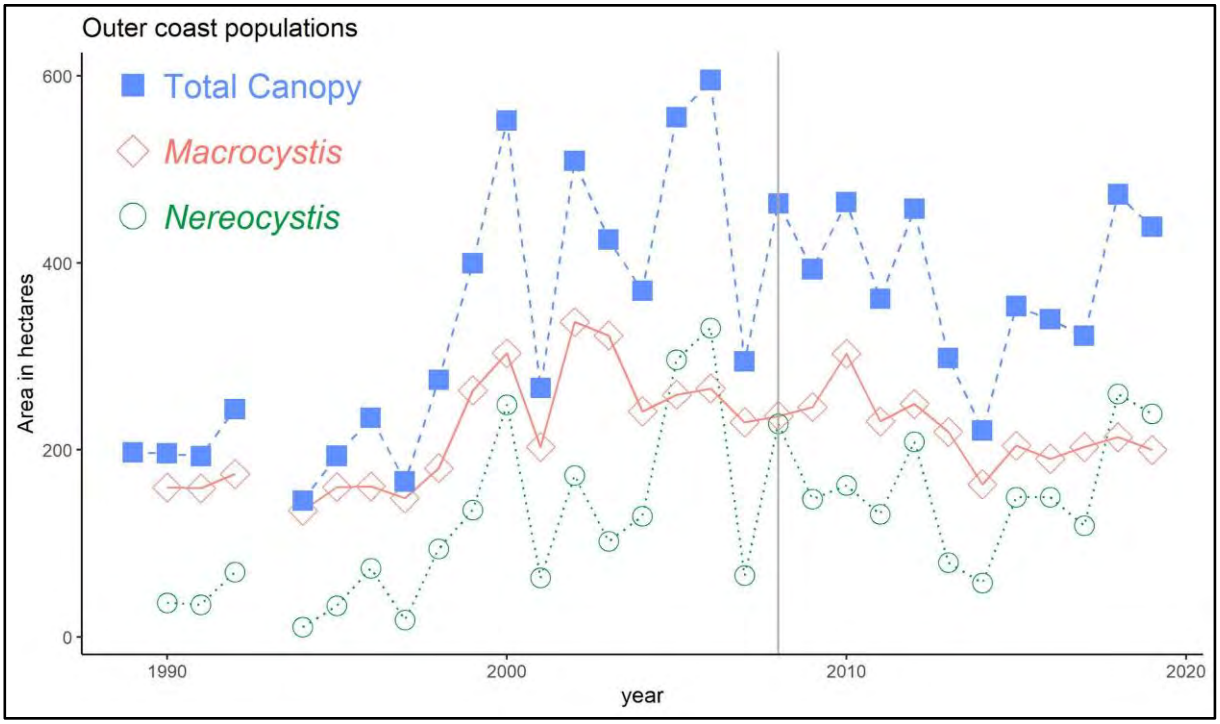
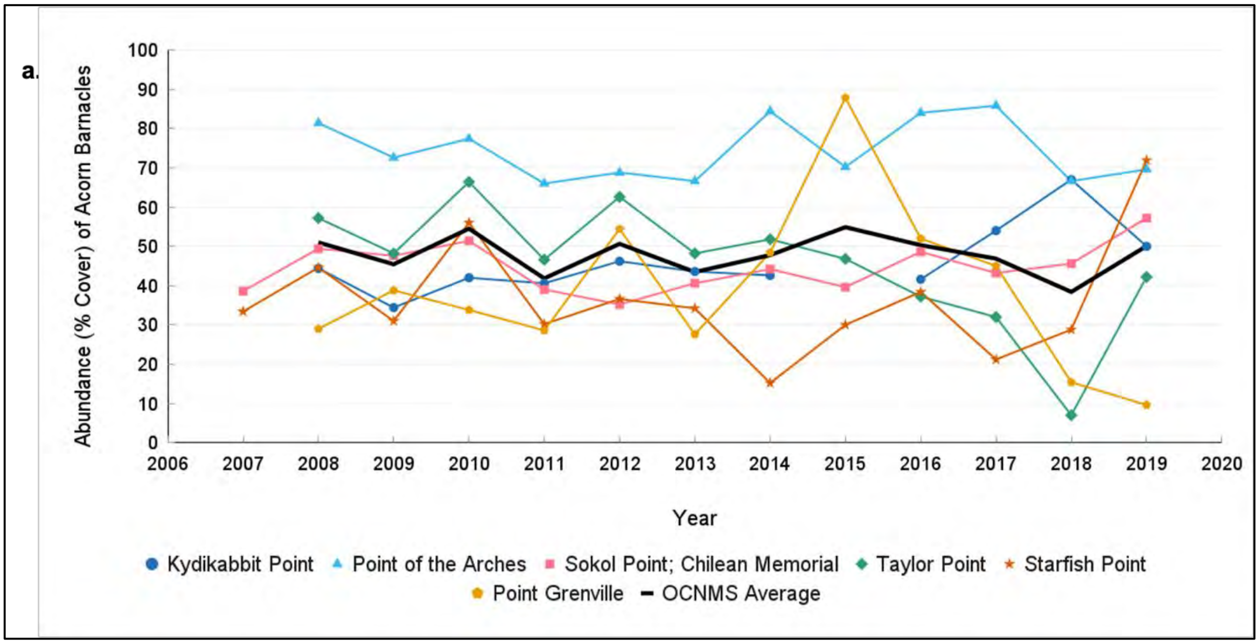


Figure S.H.10.1. The area (in hectares) of total kelp canopy, *Nereocystis* spp., and *Macrocystis* spp.from 1989 to 2019 on Washington's outer Pacific coast, based on aerial surveys. The vertical black line indicates the last condition report in 2008. Image: Modified from Pfister et al., 2017 by H. Berry/Washington State Department of Natural Resources

Rocky shores are one of the most iconic and conspicuous marine habitats for people visiting OCNMS because they occur at the dynamic interface between land and water and are relatively accessible. Tide pools, boulders, and rocky outcrops provide habitat for a wide variety of invertebrates, macroalgae, and intertidal fish, and these habitats are among the most diverse in the California Current Ecosystem (Suchanek, 1979; Multi-Agency Rocky Intertidal Network [MARINe], 2020). Rocky shores are monitored systematically by the Multi-Agency Rocky Intertidal Network (MARINe) at six permanent, long-term monitoring stations within the sanctuary. The network targets several species that are sensitive to degradation from human pressures like shoreline visitation or oil spills. Time series from long-term monitoring sites showed little change in the coverage of acorn barnacles (*Chthamalus fissus*, *C. dalli*, and *Balanus glandula*; Figure S.H.10.2a), California mussels (*Mytilus californianus*; Figure S.H.10.2b), and surfgrass (*Phyllospadix scouleri* and *P. torreyi*) between 2008 and 2019, despite interannual variability within stations. Prior to 2007, MARINe also conducted biodiversity surveys in the sanctuary, which collected more detailed information about species diversity, abundance, and distribution to assess influences of climate change and coastal development. This information would have been valuable for this assessment had sampling continued, and remains a clear data need.



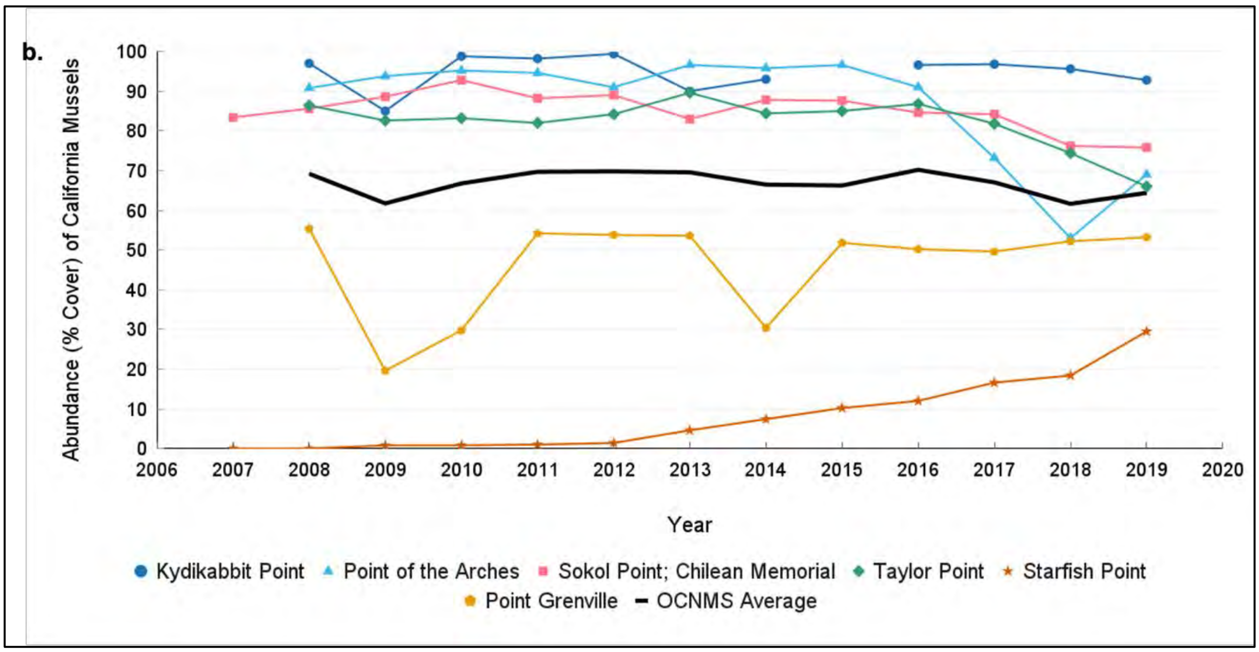


Figure S.H.10.2. Average abundance of (a) acorn barnacles (*Balanus glandula* and *Cthamalus dalli*) and (b) California mussels (*Mytilus californianus*) measured as percent cover in rocky intertidal monitoring plots at six locations adjacent to OCNMS from 2007 to 2019. The bold, black line indicates the sanctuary-wide annual abundance calculated by averaging across the six sites. Only data from permanent plots focused on (a) acorn barnacles and (b) mussels were used. Source: MARINe; Image: J. Brown/ECOS Consulting for NOAA

Additional data and TK offer different perspectives on rocky intertidal areas in the sanctuary. Pfister et al. (2016) found that shell thickness of California mussels collected from 2009–2011 was less than archival shells from the 1970s or midden shells from the sanctuary (radiocarbon dated to 1000–1340 years before present). Their results suggest changes in seawater pH and the availability of carbonate ions associated with anthropogenic carbon dioxide emissions pose a challenge for California mussels and other calcifying marine species. In addition, Quileute elders have reported lower abundance and smaller sizes of blue mussels over time (Shaffer et al., 2004).

The pelagic habitat supports a wide range of living marine resources (e.g., whales, fish, seabirds, plankton) and ecosystem services, and is inextricably linked to other habitats in the sanctuary. It is studied using moored instrument buoys, cross-shelf transects, and satellite sensors to measure physical parameters (e.g., temperature, salinity, turbidity) that determine the spatial and temporal distributions of organisms. Some of the parameters more commonly used to characterize water quality are addressed in Questions 6, 8, and 9.

Frequent hypoxic events, characterized by low oxygen concentrations, have been recorded at the seafloor over the continental shelf in the sanctuary by mooring stations (Alin et al., 2022b) and systematic oceanographic surveys (by NWFSC) dating back to 2006. These datasets recorded hypoxic events during mid- to late summer, with the lowest oxygen concentrations occurring offshore in the southern half of the sanctuary. Although there is substantial interannual variability, with some years showing little to no hypoxia, in other years hypoxic waters covered up to 62% of the continental shelf north of the Newport Hydrographic Line. At a broader scale, the last comprehensive temporal study of oxygen found persistently declining concentrations in the interior waters of the eastern subarctic Pacific over the last 50 years (Whitney et al., 2007). The specific impacts on species from these changes is under investigation, but presumably, hypoxia will compress benthic and pelagic habitats and cause a range of negative effects on plants and animals, including reduced growth rates, metabolic impairments, and, for some, death.

An emerging issue of concern in OCNMS is related to periods of extraordinarily warm ocean temperatures, known as marine heatwaves (Harvey et al., 2020). Marine heatwaves were observed in the Northeast Pacific in 2014–2016 and again in 2019–2020 (CCIEA, 2021) (Figure S.H.10.3). The 2014–2016 heatwave was the most extensive observed in the Northeast Pacific since at least the 1980s and possibly as early as 1900 (Bond et al., 2015). Although the documented marine heatwaves were most prominent in the Gulf of Alaska and north-central Pacific, their impacts extended into the sanctuary. They had profound impacts on weather patterns, oceanographic productivity, and mixing patterns, and caused major species distribution shifts (Whitney, 2015; Goddard, 2016; Santora, 2020). For example, a massive die-off of Cassin's auklets, a small pelagic seabird, was linked to warmer ocean temperatures from the 2014–2016 marine heatwave, which shrank their cold-water foraging habitat and reduced their prey (Jones et al., 2018b). Impacts from the 2019–2020 marine heatwave are currently being investigated (Harvey et al., 2020). Additional research is needed on marine heatwave impacts to pelagic habitats and ocean productivity, and how disruptions to the ocean food web may produce cascading negative impacts to adjacent habitats and species.

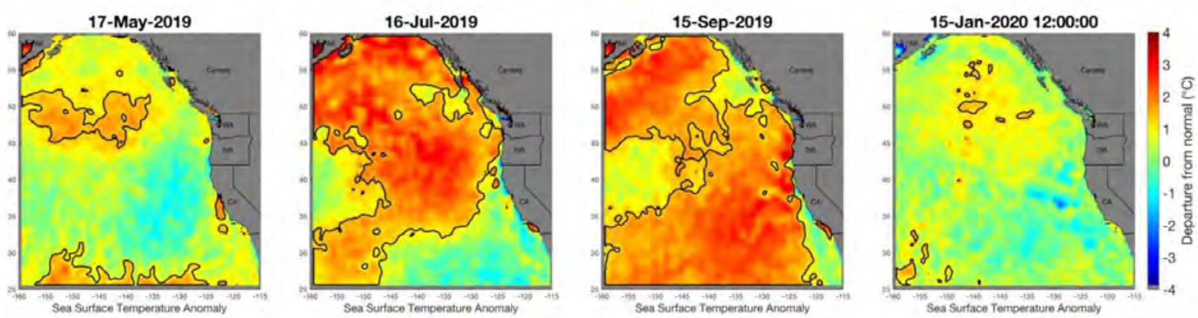


Figure S.H.10.3. Four maps showing standardized SST anomalies (SSTa) across the Northeast Pacific Ocean, including OCNMS, for May, July, and September 2019 and January 2020. Dark contours denote regions that meet the criteria of a marine heatwave (see Harvey et al., 2020). Standardized SSTa is defined as SSTa divided by the standard deviation of SSTa at each location calculated from 1982–2019, thus accounting for spatial variance in the normal fluctuation of SSTa. Image: CCIEA, 2021; Harvey et al., 2020

There are several habitats within the sanctuary where data were insufficient or unavailable to understand their integrity. Prominent, habitat-wide data gaps exist for deep seafloor and shallow sandy seafloor. Although data characterizing sediment size composition and beach slope have been collected at sites in Olympic National Park, such as Kalaloch and Rialto (Fradkin & Boetsch, 2012; Fradkin, 2014, 2015; Miller, 2019a, 2019b), they have not yet been interpreted to assess habitat integrity. Table S.H.10.2 summarizes data gaps that would be beneficial to fill for the next condition report. In addition, it would be useful to identify habitat indicators suitable for sandy seafloor habitat, as none were identified by experts.

Conclusion

In this assessment, the integrity of major habitat types was rated fair with a worsening trend. Although available data showed mixed signals for different habitats, the large area encompassed by pelagic and seafloor habitats, which have experienced habitat degradation since 2008, drove the rating for this question. Pelagic habitat, which is the dominant habitat type in OCNMS, has been compromised repeatedly by marine heatwaves, ocean acidification, and seasonal hypoxic events, all of which are ecosystem disruptions that may affect seafloor communities as well. Experts noted important data gaps for deep seafloor, shallow sandy seafloor, and beach habitats, but strong agreement and robust evidence about degradation within pelagic habitats resulted in the assignment of medium confidence scores for both habitat condition and trend.

Table S.H.10.2. Status and trends for individual Question 10 indicators discussed at the January 2020 workshop.

Indicator	Source	Habitat	Data Summary	Figures
Kelp canopy 2008–2019 (aerial extent)	WADNR surveys; Pfister et al., 2017; Shaffer et al., 2004	Kelp forest	Status: Kelp canopy from 2008 to 2019 remained at historic high levels along the outer coast. Sensitivity to changes in ocean climate and SST suggest concern into the future (Pfister et al., 2017). Trend: No trend ↔ between 2008 and 2015.	S.H.10.1
Barnacles 2008–2019 (% cover)	MARINe	Rocky shores	Status: There is no evidence of change in the percent cover of barnacles since 2008. Trend: No trend ↔ between 2008 and 2019, although there is interannual variability.	S.H.10.2
Mussels 2008–2019 (% cover)	MARINe; Shaffer et al., 2004	Rocky shores	Status: There is no evidence of change in the percent cover of California mussels since 2008. Quileute elders have observed lower abundance and smaller sizes of blue mussels over time (Shaffer et al., 2004). Trend: No trend ↔ between 2008 and 2019, although there is interannual variability.	S.H.10.2
Marine heatwaves (frequency and duration)	CCIEA, 2021; Bond et al., 2015	Pelagic	Status: The 2014–2016 heatwave was the most extensive observed in the Northeast Pacific since at least the 1980s and possibly as early as 1900 (Bond et al., 2015). Trend: Undetermined. Analysis gap.	S.H.10.3
Dissolved oxygen (frequency and duration of hypoxic events)	Alin et al., 2022b; Whitney et al., 2007	Pelagic	Status: Frequent summer hypoxic events in the southern part of the sanctuary; no evidence to show there has been a significant change in the frequency or duration of events compared to before the 2008–2019 assessment period (analysis gap). Trend: Undetermined. Analysis gap.	
Thermocline depth	Palacios et al., 2004; OCNMS moorings	Pelagic	Status: Historic multi-decadal shift in regional thermocline depth from 1950 to 1993 (Palacios et al., 2004). Analysis gap for 2015–2019. Trend: No consistent trend in 1998–2014 assessment (Andrews et al., 2015). Analysis gap for 2015–2019.	
Pycnocline depth	Columbia Plume; OCNMS moorings	Pelagic	Status: Analysis gap for 2015–2019. Trend: No trend in 1998–2014 (Andrews et al., 2015). Analysis gap for 2015–2019.	
Analysis gaps	Pelagic, beaches		Pelagic: Marine heatwaves, dissolved oxygen, thermocline depth, pycnocline depth Beaches: Beach position/slope, sediment size composition	
Data gaps	Beaches, deep seafloor, kelp forest		Beaches: Beach wrack/wood, phytoplankton abundance Deep seafloor: Extent of biogenic invertebrates, terrain complexity Kelp forest: Extent of bare rock, extent of understory kelp/algae	

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

Status Description: Contaminants have not been documented, or do not appear to have the potential to negatively affect ecological integrity.

Rationale: Contaminant concentrations are considered to be generally low in the sanctuary, and there is no evidence to suggest contaminant concentrations are increasing; however, most data and published information preceded the assessment period.

Definition and Description

This question focuses on contaminants commonly found in benthic habitats, but also includes contaminants in the pelagic habitat that have been resuspended. Contaminants of concern include heavy metals, pesticides, hydrocarbons, and other persistent organic pollutants. Some contaminants are also addressed in Question 9, and are important indicators for answers to both questions. Toxins and bacteria found in water, such as harmful algal toxins (e.g., domoic acid) and bacteria, are reviewed in Questions 7 and 8. Related impacts, such as commercial shellfish closures and beach closures, are also reviewed under Questions 7 and 8. Many consider noise a pollutant, but in the interest of focusing on more traditional forms of habitat degradation caused by harmful substances, the impacts of acoustic pollution are addressed within the Living Resources section.

In this assessment, contaminant concentrations were considered to be generally low in the sanctuary and there was no evidence to suggest concentrations are increasing; however, most data and published information preceded the assessment period. Experts rated contaminant concentrations in sanctuary habitats as good, and the trend undetermined.

Comparison to 2008 Condition Report

In 2008, the condition of contaminant concentrations in sanctuary habitats was rated as good and the corresponding trend was rated as not changing, as reports published before 2008 reported low levels of contaminants (see Table S.H.10.1 and Appendix H). This rating was selected because OCNMS is relatively remote and separated from major urban developments and areas of high population density, which are common sources of habitat contamination. Both the wilderness designation of Olympic National Park and restricted access to tribal reservations place controls on coastal development and separate the sanctuary from inland industrial, commercial, and population centers. Consequently, anthropogenic nonpoint sources are minor and contaminant concentrations in sanctuary habitats are considered low.

New Information in the 2008–2019 Condition Report

There are several legacy contaminants in the sanctuary from past human uses that have deleterious impacts to habitats, ecosystems, and humans. The most significant sources come from use of now-banned pesticides and PCBs, military use of the Quinault Range Site and bombing practice on offshore islands after World War II, and two oil spills that occurred off the

Washington coast, one in 1988 (*Nestucca*) and the other in 1991 (*Tenyo Maru*). These noted contamination events occurred before OCNMS was designated in 1994, but added enduring contaminants into sanctuary habitats. Pesticides such as DDT, PCBs, and oil naturally decrease over time, but the sanctuary is also part of efforts to restore degraded habitats and plans to prevent future contamination (e.g., The *Tenyo Maru* Oil Spill Natural Resource Trustees, 2000).

The most comprehensive survey of sediment contamination in OCNMS was part of the 2000–2003 EPA National Coastal Assessment (NCA) based on the Environmental Monitoring and Assessment Program. The NCA was focused on legacy contaminants such as DDTs, PCBs, and heavy metals within sediments and benthic fish tissue. Even though it preceded this assessment period, the NCA offers a sound contamination baseline for coastal habitats, particularly for deep and sandy seafloor. The NCA sampled approximately 30 sites inside the sanctuary and found no organic contaminants (i.e., polycyclic hydrocarbons, PCBs, DDT, pesticides), which contrasts with high levels found around urban areas of Puget Sound (Partridge, 2007). At several locations, the levels of silver and chromium exceeded toxicity thresholds, but anthropogenic sources for these metals are not known.

Another approach used to assess legacy contaminant concentrations in the sanctuary has been to test plant and animal tissues, because they provide an integrated measure of bioavailability of compounds that are present at low or variable levels in the marine system. Tests of fish, whale, mussel, and otter tissues collected in the sanctuary revealed a community with generally low levels of contaminants (Good et al., 2014; Brancato et al., 2009; Sato, 2018; Hayes, 2018). One exception was unexpectedly elevated levels of DDTs, PCBs, and PBDEs found in Chinook salmon collected off of Destruction Island (Figure S.H.11.1; Good et al., 2014). Two of the three individuals tested showed PBDE contaminant levels that fell in the range of increased disease susceptibility. One individual fell in the range for potential secondary poisoning related to DDT bioaccumulation and bioconcentration in estuarine systems (Good et al., 2014). These salmon are believed to have been exposed to the contaminants while in the Columbia River rather than in the sanctuary.

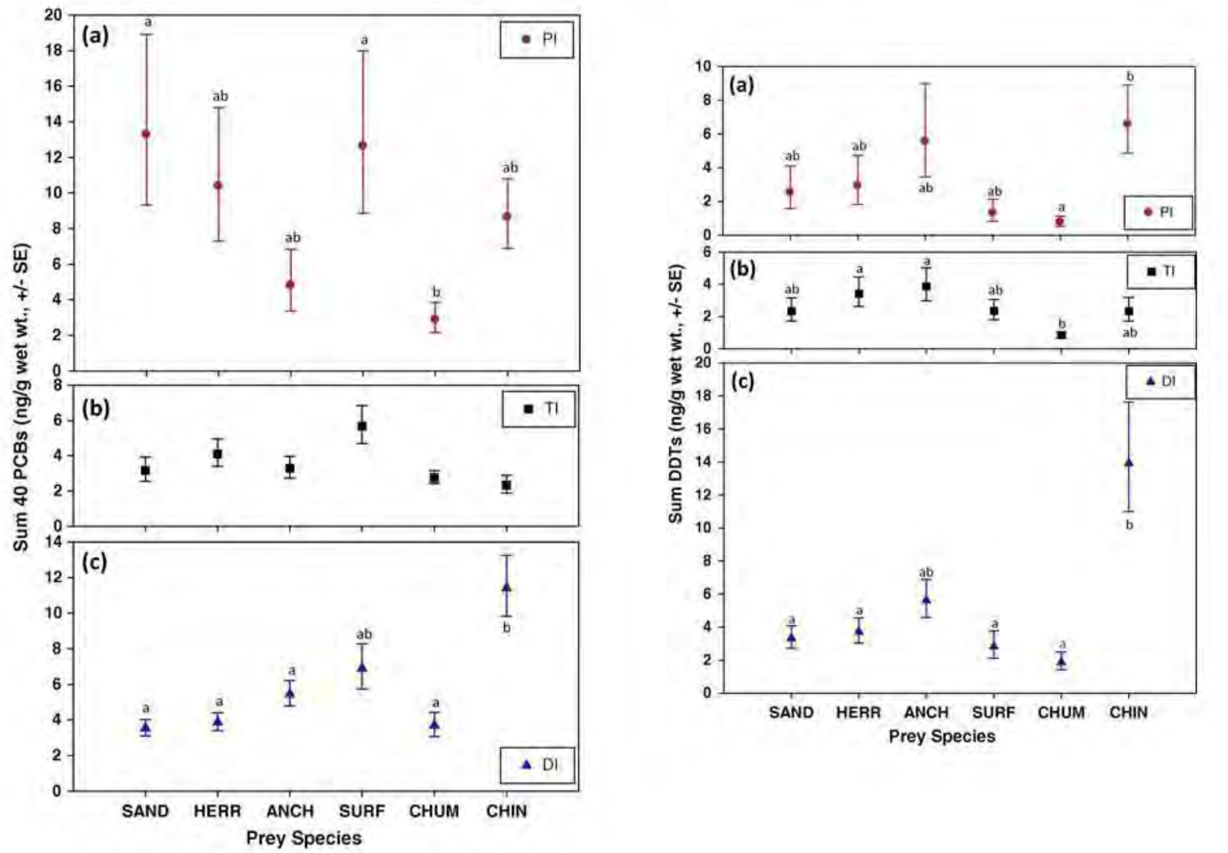


Figure S.H.11.1. Concentration of PCBs (left) and DDTs (dichloro-diphenyl-trichloroethane and five others; right) in fish collected from rhinoceros auklets on (a) Protection Island (PI), (b) Tatoosh Island (TI), and (c) Destruction Island (DI) breeding colonies. Prey fish include Pacific sand lance (SAND), Pacific herring (HERR), surf smelt (SURF), Northern anchovy (ANCH), chum salmon (CHUM), and Chinook salmon (CHIN). Letters above whiskers denote significant post hoc differences among species using Bonferroni tests. Image: Good et al., 2014

NOAA's Mussel Watch Program has monitored polycyclic aromatic hydrocarbons, DDTs, PCBs, and another 180 contaminants in coastal mussels nationwide. Because the program is focused on providing regional and nationwide assessments, there is only a single monitoring site within OCNMS. The site, located at Cape Flattery, offers a time series that should be interpreted with caution, as there is no spatial replication and the exact location sampled varied among years. Mussels collected at Cape Flattery showed very low levels of polycyclic aromatic hydrocarbons (Figure S.H.11.2), PCBs, and DDTs relative to other sites in Washington, and, after a steep decline in the mid-1980s, declined slowly to the end of the interpreted time series in 2010 (Lanksbury et al., 2010). In contrast, mussels collected from Puget Sound had polycyclic aromatic hydrocarbon, DDT, and PCB levels well above the national median (O'Connor & Lauenstein, 2006).

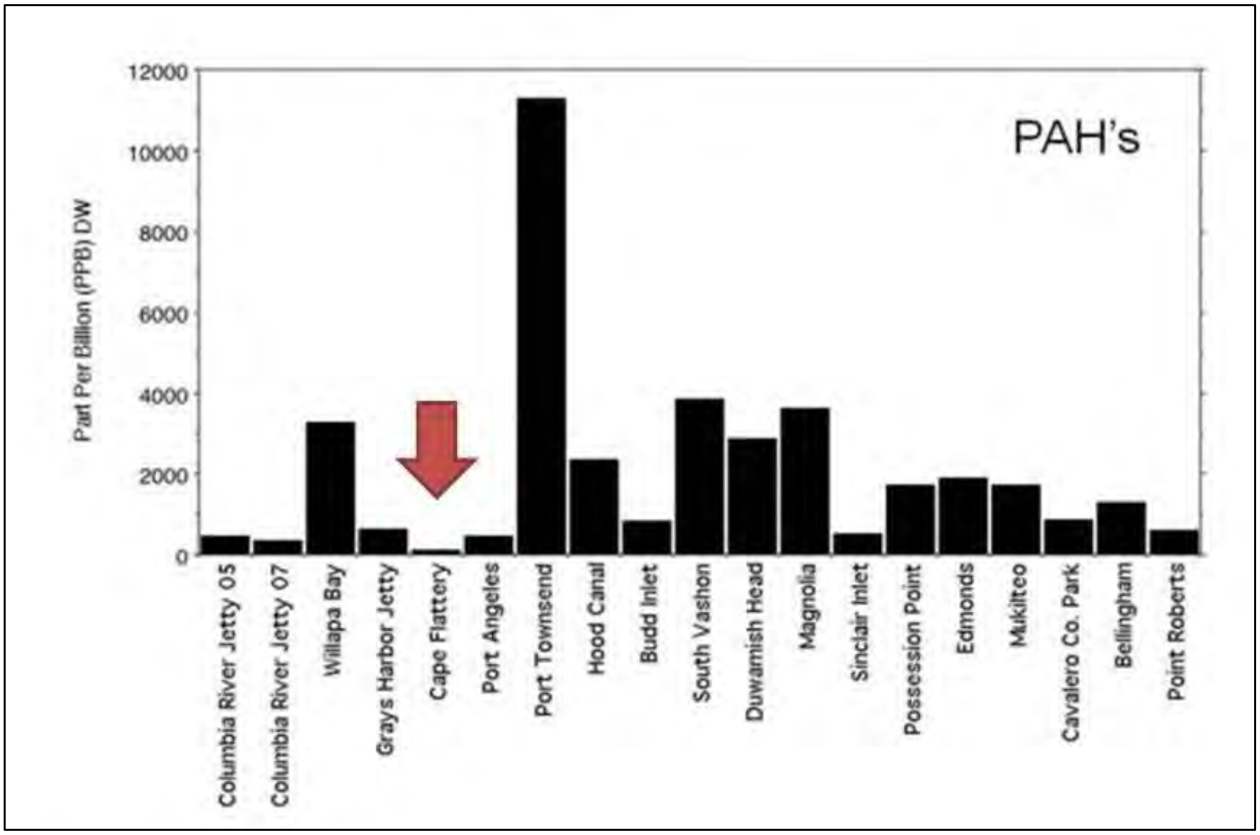


Figure S.H.11.2. Total polycyclic aromatic hydrocarbons (PAHs) from select NOAA Mussel Watch sites in Washington state in 2006. A red arrow points to Cape Flattery, the only mussel watch site in OCNMS. Source: NOAA; Image: A. Mearns/NOAA

Unlike species that migrate extensively, sea otters provide an unusual opportunity for study because both sea otters and their principal prey are relatively sedentary; thus, their contaminant burdens should reflect localized contamination. In the late 1990s, sea otter populations declined alarmingly along the California Coast and Aleutian Islands. Several reports at the time suggested increased disease susceptibility resulting from contaminant-induced immunosuppression. To assess the threat, OCNMS completed an assessment of contaminant levels in live captured sea otters and liver samples from beach-cast sea otter carcasses within the sanctuary (Brancato et al., 2009). They showed low levels of metals, butyltins, and organochlorine compounds in blood samples, with many organochlorines not detected (except PCBs), and a few aromatic hydrocarbons detected in the livers of live-captured animals. Aliphatic hydrocarbons were measurable in the liver among live-captured animals; however, some of these were likely from biogenic sources. A recent status review of sea otters in Washington state did not identify contaminants as a concern (Sato, 2018).

Contaminated sites upstream of OCNMS pose risks to habitats in the sanctuary. The EPA and Washington state compile lists of contaminated sites according to the Clean Water Act, the Superfund program, and Washington state surveys of legacy contaminants like PCBs and DDTs. There are two listed sites adjacent to the sanctuary. This number lies in stark contrast to the hundreds of sites located in Puget Sound or at the mouth of the Columbia River (Washington State Department of Ecology, 2020c). Lake Ozette, which lies upstream of the sanctuary, was listed because of unusually high mercury flux rates and fish tissue concentrations associated with logging within the catchment area (Van Furl et al., 2010). The lake lies about one mile inland from the Pacific coast and drains into the sanctuary via the Ozette River. The Warmhouse Beach Dump Site was added to the Superfund National Priorities List in December 2013 and is located at headwaters to two creeks that run into the sanctuary, as well as traditionally significant shellfish beaches. Elevated levels of metals, perchlorate, and PCBs have been found in soil at the dump and in sediment in both creeks (EPA, 2016). Mussels at the beach also contain elevated concentrations of lead; however, it has not been determined whether the lead originated from the dump or creeks. The EPA is in the early stages of the Superfund cleanup process, called the remedial investigation.

Two potential sources of contamination from distant sources are the Fukushima Daiichi nuclear disaster in 2011 (radionuclides) and atmospheric deposition of mercury from the burning of fossil fuels. From 2014 to 2016, Kelp Watch, a scientific monitoring campaign, sampled kelp forests along the U.S. West Coast, including within OCNMS, to determine the extent of expected contamination. There was no indication that radioactivity from Fukushima became incorporated in the coastal kelp beds sampled. The main source of mercury to the ocean and to habitats in the sanctuary is likely from marine traffic residual fuel oil, biomass combustion emissions, and sea salt (Hadley, 2017). It is estimated that peak emissions of mercury in the western U.S. occurred in the 1980s, but have since declined due to emission controls (Schuster et al., 2002); however, this trend is counteracted by increasing emissions from Asia (Pacyna et al., 2010). Surprisingly, an analysis of mercury wet deposition and mercury air concentrations on the Pacific coast from 1997 to 2013 found no trends in either metric (Weiss-Penzias et al., 2016). It is likely that the lack of change in mercury is a result of decreased local emissions counteracting the increase in mercury transported to the United States from Asia.

Conclusion

In this assessment, contaminant concentration in major habitat types was rated good with an undetermined trend. There are notable data gaps regarding contaminant concentrations in OCNMS habitats, including a paucity of data within the 2008–2019 assessment period. Much of the available data on contamination in the sanctuary were collected prior to 2003. In addition, there are numerous indicators that experts noted as important for assessing habitat contamination, but for which no data are available (Table S.H.11.1; data gaps for contaminant levels in krill and other zooplankton, algae, infauna, seabirds, and sediment in additional habitats were identified after the January 20, 2020 workshop).

Table S.H.11.1. Status and trends for individual Question 11 indicators discussed at the January 2020 workshop.

Indicator	Source	Habitat	Data Summary	Figures
Contaminant levels in sediment	NCA	Deep seafloor	Status: Very low levels of contamination in sediments and flatfishes from 2003. Data gap after 2003. Trend: Undetermined. Data gap.	
Contaminant levels in sediment	EPA; Washington State Department of Ecology	All habitats	Status: Several legacy military sites with localized impacts. Trend: Remediation underway at several degraded sites.	
Contaminant levels in pelagic fish	EPA; Washington State Department of Ecology	Pelagic	Status: PCB and DDT concentrations in fish are relatively low and typically below action levels. Trend: Undetermined. Data gap.	S.H.11.1
Contaminant levels in shellfish	NOAA Mussel Watch Program	Rocky shores	Status: DDT and PCBs levels are low in OCNMS shellfish. Trend: Regional DDT and PCBs levels are decreasing in shellfish.	S.H.11.2
Contaminant levels in sea otters	Brancato et al., 2009; Sato, 2018	Kelp forest	Status: Low levels of metals, butyltins, and organochlorine compounds in tissues collected in the early 2000s. Not a concern in a 2018 status review. Trend: Undetermined. Data gap.	
Data gaps	Kelp forests, sandy beaches, sandy seafloor, rocky shore, pelagic		Kelp forests: Contaminant levels in sea otters, kelp, kelp forest fish Sandy beaches: Contaminants in sediment Sandy seafloor: Contaminants in infauna Rocky shore: Contaminants in sediment Pelagic: Contaminant levels in water, seabirds, marine mammals	

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

The following information describes the status and trends of living marine resources inside OCNMS from 2008–2019. The term "living marine resources" encompasses a range of organisms in OCNMS, 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 over the last 10 years. Each of the living marine resource questions focus on specific groups of species in OCNMS.

Question 12 evaluates changes to keystone (e.g., sea stars, kelp, sea otters) and foundation (e.g., mussels, anchovies) species, which are critical to maintaining OCNMS's ecosystem structure, function, and stability over time. Question 13 is centered around focal species (e.g., razor clams, Dungeness crabs, groundfish, salmon, marine mammals, seabirds), which may not be abundant or be key to OCNMS'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., eulachon, Southern Resident killer whales) 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., European green crab), 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 OCNMS'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 species richness and diversity indices, and the abundance of species that influence the integrity of food webs and other aspects of ecosystem function. Non-indigenous species were not included in estimates of native biodiversity.

Table S.LR.12.1. 2008 (left) and 2008–2019 (right) status, trend, and confidence ratings for the living resources questions.

2008 Condition Report Questions	2008 Rating	2008–2019 Condition Report Questions	2008–2019 Condition Report Rating
12. Status of key species	?	12. Keystone & foundation species	Fair
13. Condition/health of key species	?	13. Other focal species	Fair
11. Non-indigenous species	▼	14. Non-indigenous species	Good/Fair
9. Biodiversity	?	15. Biodiversity	Good/Fair

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

Fair

Status Description: Selected focal species are at reduced levels, but recovery is possible.

Rationale: Since 2008, some populations of focal species (e.g., razor clams, groundfish) have remained stable or have increased while others (e.g., Dungeness crab, chinook salmon, steelhead) and state and/or federal species of concern (e.g., eulachon, Southern Resident killer whale, humpback whale, fin whale, marbled murrelet, tufted puffin) have declined or have remained critically endangered.

Keystone species are organisms on which a large number of other species in the ecosystem depend (Paine, 1969). Their contribution to ecosystem function is disproportionate to their abundance or biomass. They can be habitat creators (e.g., kelp, corals), predators that control food web structure (e.g., sea otters, certain sea stars), herbivores that regulate benthic recruitment (e.g., certain sea urchins), and species involved in critical symbiotic relationships (e.g., cleaning or cohabitating species). Foundation species are single species that create locally stable conditions for other species (Dayton, 1972). These are typically dominant biomass producers (e.g., mussels, hake, anchovy, krill) in an ecosystem and 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.

The discussion for Question 12 is limited to keystone and foundation species. In OCNMS, keystone species include the purple sea star (*Pisaster ochraceus*), sunflower sea star (*Pycnopodia helianthoides*), purple sea urchin (*Strongylocentrotus purpuratus*), giant kelp (*Nereocystis luetkeana*), bull kelp (*Macrocystis pyrifera*), and northern sea otter (*Enhydra lutris kenyoni*), because the contribution of these species to ecosystem function is disproportionate to their abundance. Foundation species or functional groups discussed here include phytoplankton, copepods, California mussel (*Mytilus californianus*), Pacific hake (*Merluccius productus*), northern anchovy (*Engraulis mordax*), and northern Pacific krill (*Euphausia pacifica*). Other species were also considered during the January 2020 workshop, including lanternfish (myctophids) and key forage fish (i.e., Pacific sardine [*Sardinops sagax caerulea*] and Pacific herring [*Clupea pallasii*]). However, a lack of readily available long-term data or analysis prevented them from being included in the rankings.

For the 2008–2019 study period, the status of keystone and foundation species in OCNMS was fair (with medium confidence) and the trend was mixed (with high confidence). The availability of monitoring data for the above indicators helped increase confidence in these ratings. These ratings indicate that keystone and foundation species have experienced measurable, but not severe, degradation in some attributes of ecological integrity. The trend was mixed because populations of some keystone (e.g., purple and sunflower sea stars) and foundation species (e.g., California mussel) have declined while populations of other keystone (e.g., giant and bull kelp, sea otters) and foundation species (e.g., northern anchovies, Pacific hake) have remained stable or increased since 2008. These declines and increases are likely to have changed community structure or ecosystem function.

Comparison to 2008 Condition Report

Because Question 12 was changed following the 2008 report, a direct comparison was not possible between the two condition report ratings. However, the indicators used to develop the 2008 ratings for Question 12 and 13 overlap with the indicators used to develop the rating for Question 12. Specifically, in 2008, the status and condition of focal species were rated as fair and good/fair, respectively, with undetermined trends. These ratings were based on prevalence of disease in sea otters and reduced abundances of selected focal species, including sea otters, common murres (*Uria aalge*), and rockfish (*Sebastes* spp.). The rating for this assessment accounted for the recovery of sea otter populations, which were at an all time high in Washington state since monitoring began in 1989. The status of rockfish and common murre populations were also evaluated in this assessment, but they were incorporated into the rating for Question 13 (other focal species) because they are important, but not considered keystone or foundation species (see Table S.LR.12.1 and Appendix H).

New Information in the 2008–2019 Condition Report

The status rating for this assessment was based primarily on new information and expert opinions about known changes in specific keystone and foundation species abundances since 2008 (Table S.LR.12.2). These declines and resurgences have likely impacted rocky shore, sandy seafloor, kelp forest, deep seafloor, and pelagic ecosystems. Species from sandy beaches were not evaluated in this question because no appropriate keystone or foundation species were identified by experts during the workshops. Key indicators considered for this question included phytoplankton, purple and sunflower sea stars, purple sea urchins, California mussels, giant and bull kelp, northern sea otters, northern Pacific krill, and Pacific hake. Although northern anchovies are included here, they represent only one of many important forage fish species; thus, their abundance may not provide a good indicator independent of complementary indicators for other forage fish—a critical data gap for the region. The overall trend for Question

12 was mixed because some keystone and foundation species declined while others were stable or increased. These trends are described in more detail below.

Keystone Species

For keystone species, some species populations were stable or increased, while others declined. One of the most notable declines has been in the abundance of sea stars, specifically purple and sunflower sea stars, which are among the populations monitored annually at six sites along the Olympic Coast (Figure S.WQ.8.7) using standardized protocols developed for the west coast by MARINe. The abundance of purple sea stars declined precipitously from 2013 through 2015 in rocky shore habitats and has since stabilized at a lower abundance than observed prior to 2013 (Figure S.LR.12.1). The decline in their abundance, coupled with recruitment of new individuals (in some areas), has caused the population size structure of purple sea stars to shift to many more small (<50 mm) and very few large (>100 mm) individuals (Figure App.S.LR.12.1).

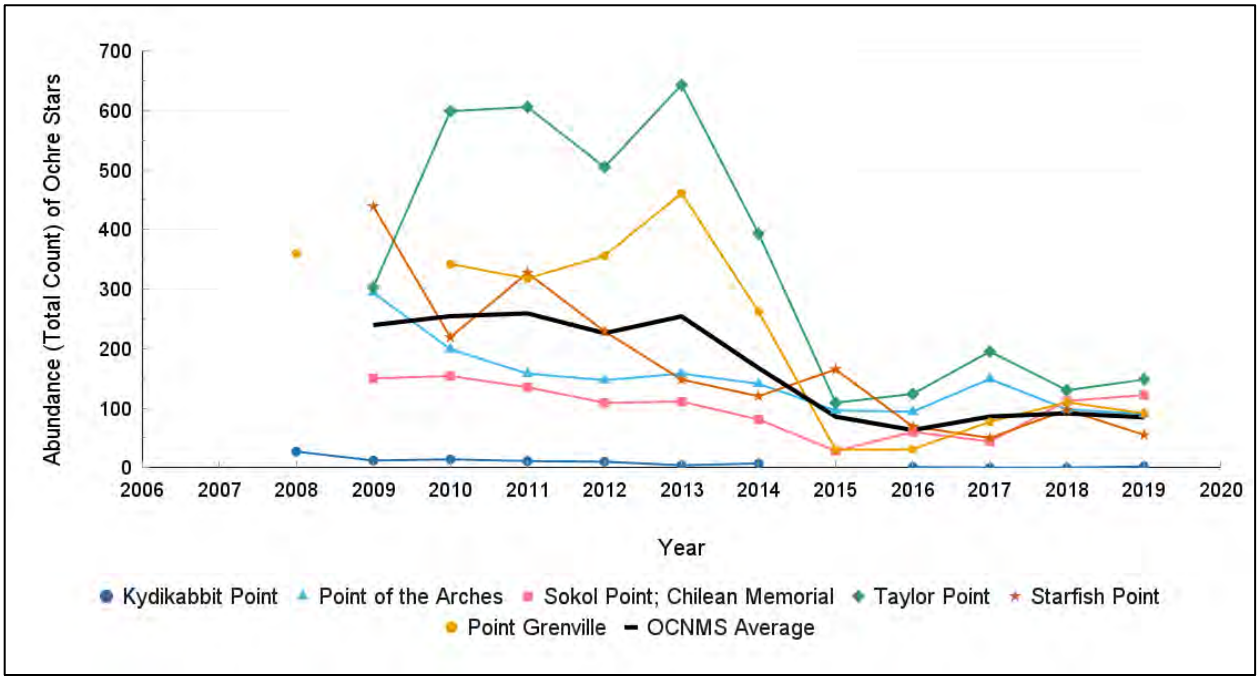


Figure S.LR.12.1. Abundance of purple sea star (*Pisaster ochraceus*) in rocky shore habitats within OCNMS from 2008–2019. Black line shows the average number of purple sea stars observed each year from 2009 through 2019. Source: MARINe, 2019; Image: J. Brown/ECOS Consulting for NOAA

Declines among purple sea stars have occurred largely due to an outbreak of sea star wasting disease that began in 2013 and continued (generally at low levels) through 2020 (Miner et al., 2018). The impacts of sea star wasting disease might have been exacerbated by the 2014–2016 marine heatwave (McCaffery et al., 2018; Miner et al., 2018). Some data exist for purple sea stars in kelp forests inside OCNMS, but monitoring began after their decline in 2015. Since 2015, the recovery of purple sea stars has been slow at these locations, with the most variability observed at 5-m depths at Destruction Island (Figure App.S.LR.12.2).

Similarly, in kelp forest and deep seafloor habitats, the abundance of sunflower sea stars has declined precipitously since 2013 (Figure S.LR.12.2; Figure App.S.LR.12.3a). As with the purple sea star, declines of this keystone species have impacted ecosystem integrity and occurred because of the 2013 outbreak of sea star wasting disease and the 2014–2016 marine heatwave (Montecino-Latorre et al., 2016; Harvell et al., 2019). NOAA Fisheries and its partners began collecting data on sunflower sea stars in 2015, which will help OCNMS track changes in this important subtidal predator (Figure App.S.LR.12.3b).

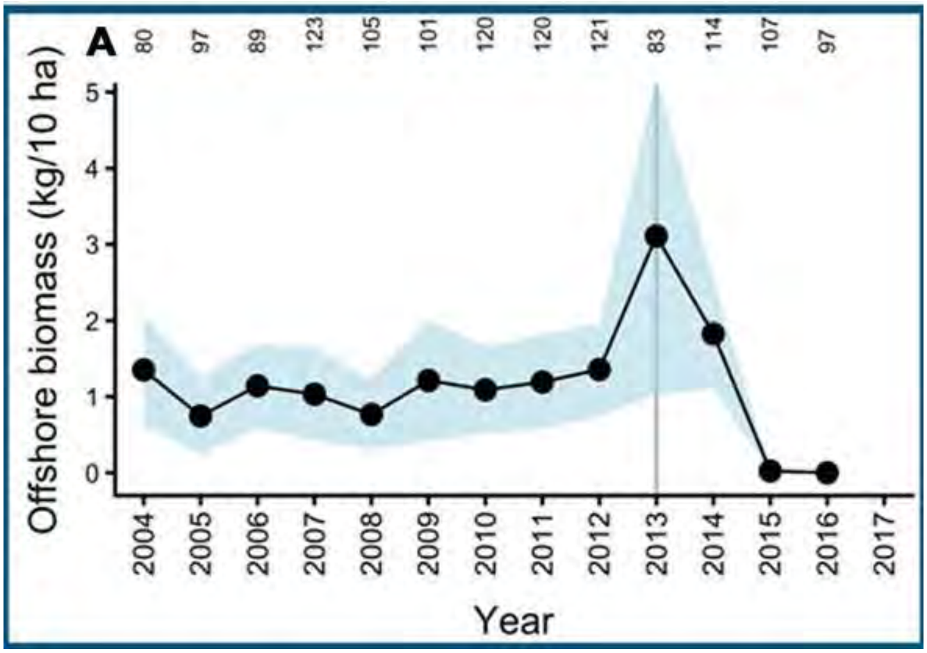


Figure S.LR.12.2. Mean biomass of sunflower sea star (*Pycnopodia helianthoides*) calculated from NOAA Fisheries deep trawls 55–1280 m offshore of the Washington coast. The shaded area indicates the 95% confidence interval and the vertical gray line marks the onset of sea star wasting disease in 2013. Image: Harvell et al., 2019

Other keystone species populations remained stable or increased. In particular, giant and bull kelp canopy cover has remained stable compared to pre-2008 levels (Figure S.H.10.1; Pfister et al., 2017). Kelp is also discussed in more detail in Question 10. Purple sea urchin abundances increased in kelp forest habitats at Destruction and Tatoosh Islands from 2016–2019, although their densities remained low at other sites in OCNMS (Figure App.S.LR.12.4). No readily available data exist for purple sea urchins in kelp forests before 2015. Northern sea otter populations also increased to their highest levels in kelp forest and sandy seafloor habitats since monitoring began in 1989 (Figure S.LR.12.3; Jeffries et al., 2019). The majority (~80%) of sea otters are located south of La Push. Recent sea otter mortality rates suggest that population growth may continue (White et al., 2018) unless populations become resource limited (Hale et al., 2019).

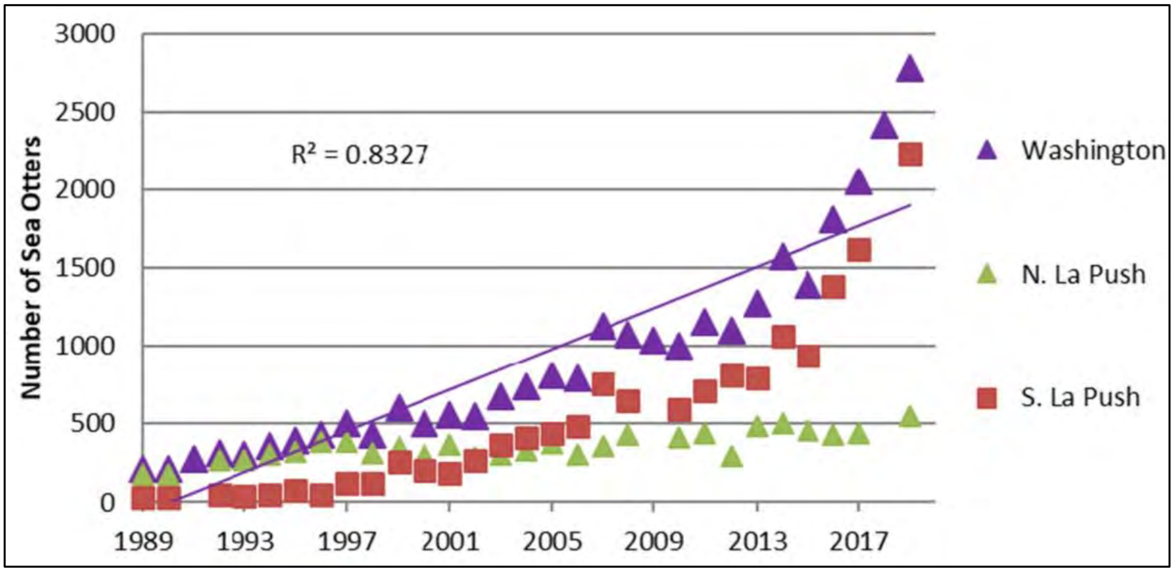


Figure S.LR.12.3. Uncorrected estimated minimum number of sea otters (from annual summer aerial surveys) in Washington, including areas north and south of La Push from 1989–2019. Line denotes the trend for Washington. Image: Jeffries et al., 2019

Foundation Species

For foundation species, most populations were stable or increased. In rocky shore habitats, California mussel populations have remained stable since 2008 (Figure S.H.10.3); however, it is important to note that their shells have become thinner at Tatoosh Island and Sand Point, Washington in recent times (2009–2011) compared to the past (i.e., in the 1970s and 1000–1340) (Figure S.LR.12.4; Pfister et al., 2016). Also, Quileute elders have noted a reduction in the abundance and individual size of blue mussels (*Mytilus trossulus*) along the northern Olympic Coast, making them too small to eat (Shaffer et al., 2004; Shannon et al., 2016). Mussels are discussed in more detail in Question 10.

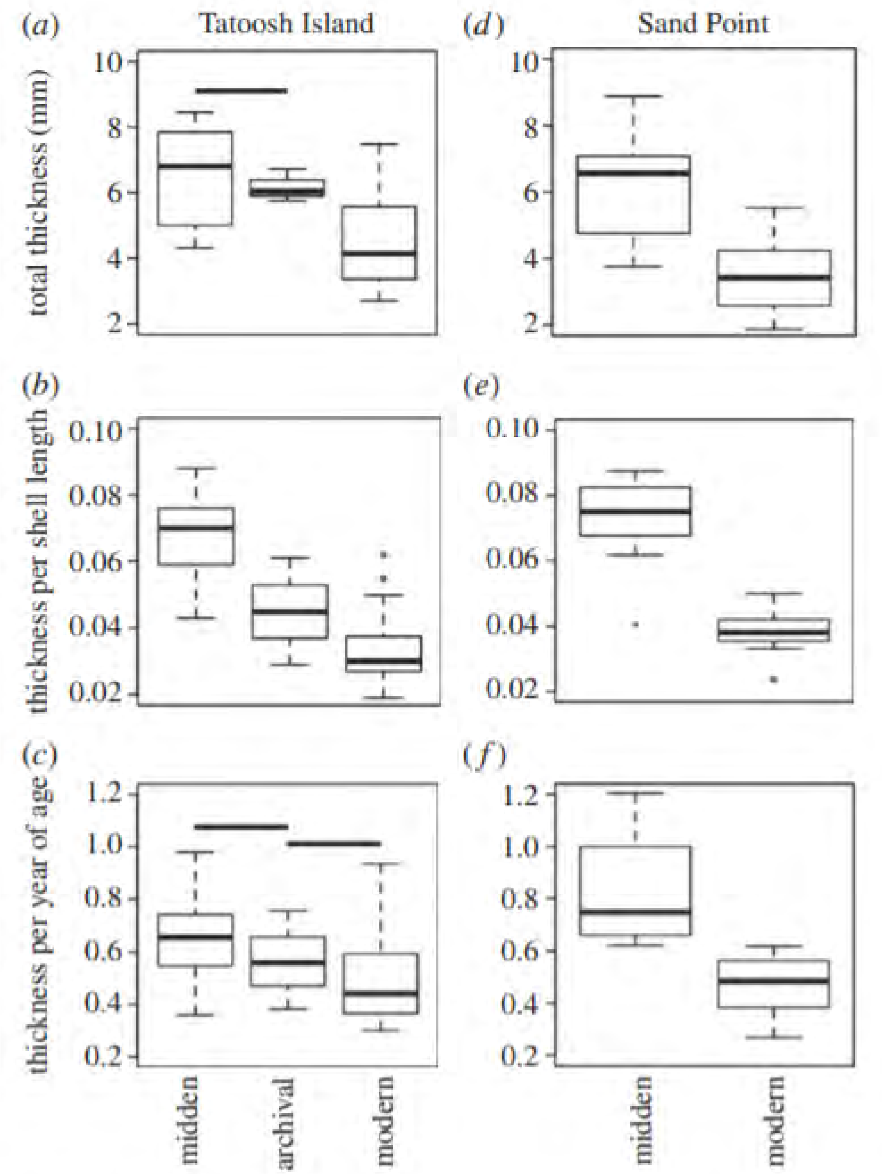


Figure S.LR.12.4. A comparison of California mussel relative shell thickness for modern (2009–2011), archival (1970s), and midden (radiocarbon dated 1000–1340) samples at two sites in Washington state: Tatoosh Island (a–c) and Sand Point (d–f); (a, d) total thickness, (b, e) thickness per shell length, and (c, f) thickness per year of age. Image: Pfister et al., 2016

In pelagic habitats, some foundation species, such as phytoplankton, copepods, northern anchovy, and Pacific hake populations, have remained similar to their long-term means. Copepod anomalies were similar to historical ranges of variation, with no trend observed during the 10-year study period (i.e., 2008–2019). Copepods are critical because they are the basis of the food web, converting plankton into food for higher trophic levels. Because copepods move with ocean currents, their community composition in any given location changes over time. In warm conditions, when water is transported from the south or offshore, abundances of less nutritious southern copepods increase and abundances of the more nutritious northern copepod (i.e., *Calanus marshallae* and *Pseudocalanus mimus*) decrease (NOAA Fisheries, 2020d). The reverse is true when water is transported from the subarctic Pacific. This change in community composition often leads to a cascade of effects, including unusual mortality events across multiple trophic groups (NOAA Fisheries, 2020d). It is worth noting that offshore of Washington, the copepod community remained in a warm state and never transitioned to a cold water (upwelling) community during the marine heatwave in 2015 and 2016 (NOAA Fisheries, 2020d; Figure S.LR.12.5).

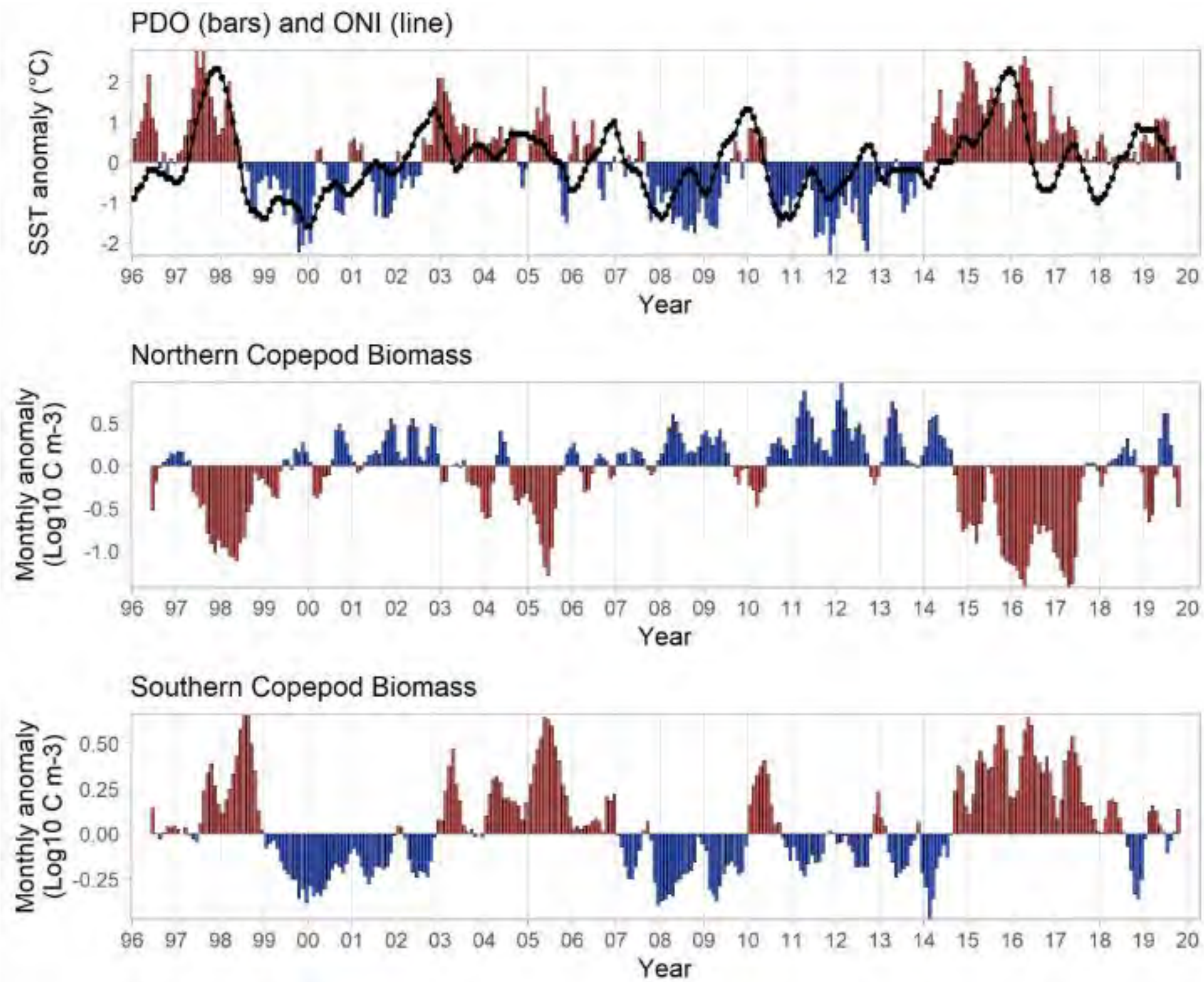


Figure S.LR.12.5. PDO and ONI (top) and monthly biomass anomalies of the northern (middle) and southern (bottom) copepod taxa from 1969 to 2020 offshore of Newport, Oregon. Note that when SST is anomalously warm (i.e., PDO is positive), northern copepod biomass is low (negative anomaly) and southern copepod biomass is high (positive anomaly). Image: NWFSC, 2020

Although abundance of northern anchovies is provided in Figure App.S.LR.12.5, experts agreed that additional work is needed to interpret anchovy "boom and bust" population cycles. Furthermore, experts questioned the use of northern anchovies as a foundation species and ecosystem indicator without considering this species in concert with information about the abundance and timing of krill and other forage species, including Pacific herring, Pacific sardine, eulachon, whitebait and surf smelt, and American shad, among others. An offshore forage indicator, such as the one proposed by Thompson et al. (2019), would likely provide a more comprehensive and representative indicator, despite likely undersampling species such as sardine and anchovy that undergo a diel vertical migration. What is abundantly clear is that forage fish are collectively an important indicator because of their critical importance to higher trophic levels, including fish, pinnipeds, whales, and seabirds. For example, Schrimpf et al. (2012) found that in some years, herring and surf smelt comprised more than 50% of the diet of common murres, followed by several other forage species, and that birds are able to shift among available species when provisioning their young. Forage fish ecology remains an important data and analysis gap for OCNMS.

Pacific hake biomass (offshore of California, Oregon, and Washington) has increased since 2008 by more than 1 standard deviation (Figure S.LR.12.6). Northern anchovy abundances were anomalous in 2008 and 2014 offshore of Washington and Oregon (Figure App.S.LR.12.5; Duguid et al., 2019). Phytoplankton abundances were also anomalously high in 2008 and 2014, although plankton anomalies have not increased in frequency since 2008. Conversely, northern Pacific krill densities offshore of southern Washington have been low since 2015, following the 2013–2014 marine heatwave. Densities prior to that were several orders of magnitude higher than at present (Figure App.S.LR.12.6; Harvey et al., 2020). Data on Pacific krill densities in OCNMS were not readily available.

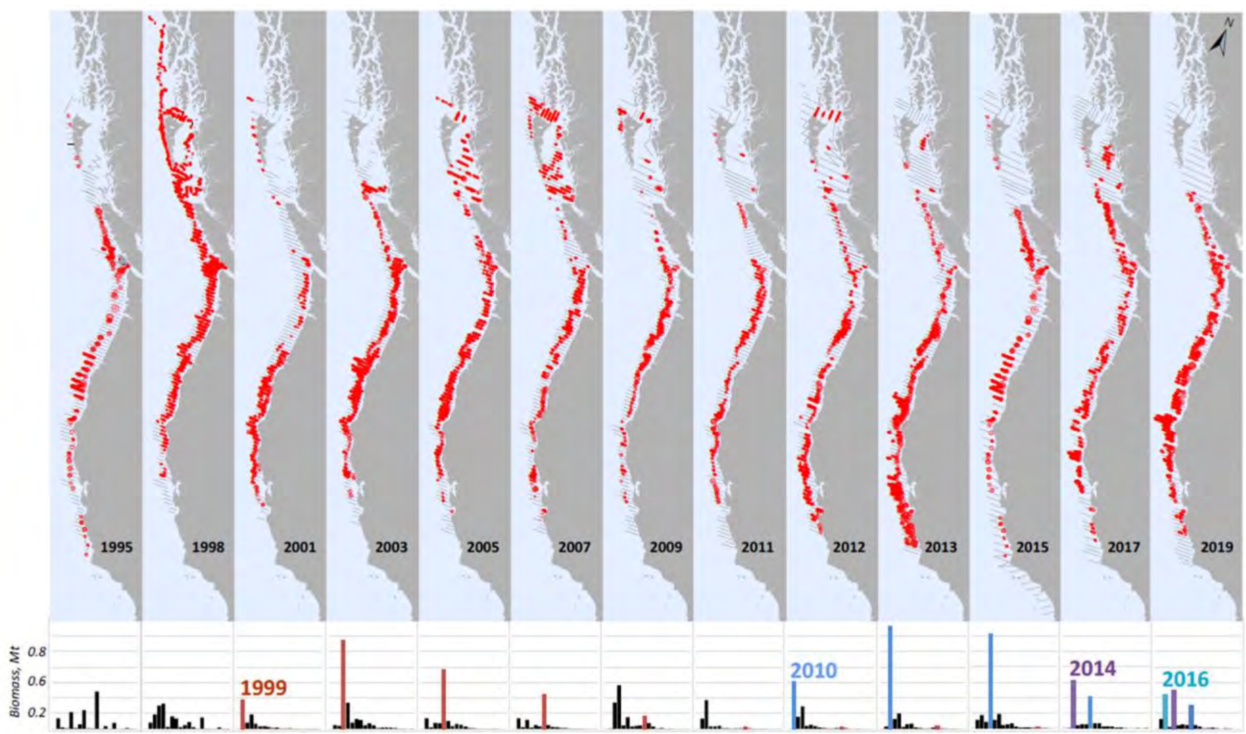


Figure S.LR.12.6. Spatial distribution of adult Pacific hake (>2 years old) based on acoustic backscatter data. Colors on the bar chart indicate specific year classes whose populations are tracked over time. Source: Grandin et al., 2020; Image: J. Clemons/NOAA

Conclusion

The status of keystone and foundation species was fair (with medium confidence) and the trend was mixed (with high confidence). While the availability of monitoring data helped increase confidence in these ratings, there are still data and analysis gaps inside OCNMS. Specifically, data gaps existed in the rocky shore habitat for black oystercatchers and in the sandy seafloor for key forage fish. Analysis gaps also existed in pelagic habitats related to northern Pacific krill, lanternfish (myctophids), and key forage fish (e.g., sardines, herring, smelt). No indicators were selected for the sandy beach habitat, largely due to a lack of available data.

For two declining species, purple and sunflower sea stars, there was not enough new information to predict if or when populations will recover to pre-2014 levels (Miner et al., 2018). Monitoring data are being collected for these species, but additional analyses are needed to understand temporal trends in OCNMS and the broader region (MARINe, 2019; Reef Environmental Education Foundation, 2020). In January 2020, neither sea star species was listed as threatened or endangered by Washington state, the U.S., or the International Union for Conservation of Nature.[16] Should their abundances continue to remain low, the loss of these species will likely change the community composition and shallow water seascape in some locations. In particular, the absence of the sunflower sea star may lead to an increase in red and green sea urchins (*Mesocentrotus franciscanus* and *Strongylocentrotus droebachiensis*), which could destroy existing kelp forests and threaten biodiversity (Montecino-Latorre et al., 2016; Harvell et al., 2019).

Climate change is also a major concern for the future of keystone and foundation species in OCNMS because its potential impact on these species (and the cascading effects of their loss) is unknown. Such synergistic effects could be ecologically devastating, pushing the system to a tipping point and leading to significant changes in biodiversity and ecosystem function in OCNMS, as well as the ecosystem services provided to coastal communities.

[16] In September 2021, *Pycnopodia helianthoides* was listed as critically endangered by the International Union for Conservation of Nature (Gravem et al., 2021).

Table S.LR.12.2. Status and trends for individual indicators discussed at the January 2020 workshop. There are no confidence scores for individual indicator status and trends.

Indicator	Source	Species Type & Habitat	Data Summary	Figures
Purple sea stars (abundance, size structure)	MARINe, 2019; NWFSC, 2019a; Shelton et al., 2018	Keystone; rocky shore, kelp forest	Status: Reduced abundance and altered size structure due to sea star wasting disease warrant significant concern. Trend: Abundances declined from 2013–2015 and have not recovered.	S.LR.12.1; App.S.LR.12.1–App.S.LR.12.2
Sunflower sea stars(biomass, density, counts)	Harvell et al., 2019; Montecino-Latorre et al., 2016; NWFSC, 2019a; Shelton et al., 2018	Keystone; kelp forest, deep seafloor	Status: Reduced abundance warrants significant concern. Trend: In kelp forests, *P. helianthoides* abundances decreased from 2013–2015. In the deep seafloor, *P. helianthoides* biomass decreased by 99.2%. No evidence of recovery.	S.LR.12.2; App.S.LR.12.3
Giant and bull kelp(aerial extent)	Pfister et al., 2017	Keystone; kelp forest	Status: Kelp canopy from 2008 to 2014 is similar to 1990s. Sensitivity to changes in ocean climate and SST suggest concern into the future (Pfister et al., 2017). Quileute elders have noticed the loss of kelp beds in recent history (Shaffer et al., 2004). Trend: No trend between 2008 and 2019.	S.H.10.1
Purple sea urchins (density)	NWFSC, 2019a; Shelton et al., 2018	Keystone; kelp forest	Status: Purple sea urchin densities low from 1999–2015. Trend: Densities increased from 2015–2019 at Destruction and Tatoosh Islands.	App.S.LR.12.4
Northern sea otter (abundance)	Jeffries et al., 2019	Keystone; kelp forest, sandy seafloor	Status: Population south of La Push and in all of Washington at all-time high since monitoring began in 1989. Sea otter population is concentrated south of La Push (80%). Trend: Mean annual increase = 9.81%; rate lower north of La Push (may be at carrying capacity). Densities are increasing (range not expanding).	S.LR.12.3
California mussels (shell thickness, percent cover)	Pfister et al., 2016; MARINe, 2019; Shaffer et al., 2004	Foundational; rocky shores	Status: California mussel shell size thinner now than in the past (Pfister et al., 2016). Quileute elders have observed lower abundance and smaller sizes of blue mussels over time (Shaffer et al., 2004). Trend: No trend between 2008 and 2019.	S.H.10.3; S.LR.12.4

Indicator	Source	Species Type & Habitat	Data Summary	Figures
Zooplankton (copepod biomass anomaly)	NOAA Fisheries, 2020d	Foundational; all	Status: Recent mean similar to long-term mean. Trend: No trend.	S.LR.12.5
Pacific hake (biomass)	Grandin et al., 2020	Foundational; deep seafloor, pelagic	Status: Recent mean similar to long-term mean. Trend: Increasing biomass. Need analysis inside OCNMS.	S.LR.12.6
Key forage fish (northern anchovy, Pacific krill) (abundance anomalies, catch per unit effort)	Duguid et al., 2019; Harvey et al., 2020	Foundational; pelagic	Status: Elevated abundances for anchovy observed in 2004, 2009, 2015, and 2016. Limited data for anchovy in Washington. No data for krill in OCNMS. Trend: No clear trend for northern anchovy. No data for krill in OCNMS.	App.S.LR.12.5–App.S.LR.12.6
Phytoplankton (chlorophyll *a* abundance anomalies)	National Marine Fisheries Service, 2020	Foundational; all	Status: More positive chlorophyll *a* anomalies compared to the last assessment period. Trend: Increased in the last 10 years.	S.WQ.6.2
Data gaps	Kelp forest, sandy seafloor		Sandy seafloor: Key forage fish (see below), copepods, and zooplankton	
Analysis gaps	Pelagic		Pelagic: Key forage fish (e.g., Pacific sardines, Pacific herring, eulachon, smelt species, krill, lanternfish [myctophids])	

Question 13: What is the status of other focal species and how is it changing?

Status Description: Selected focal species are at reduced levels, but recovery is possible.

Rationale: Since 2008, some populations of focal species (e.g., razor clams, groundfish) have remained stable or have increased while others (e.g., Dungeness crab, chinook salmon, steelhead) and state and/or federal species of concern (e.g., eulachon, Southern Resident killer whale, humpback whale, fin whale, marbled murrelet, tufted puffin) have declined or have remained critically endangered.

This question targets other species of particular interest from the perspective of OCNMS sanctuary management, Coastal Treaty Tribes, local partners, and experts (Table S.LR.13.1). These "focal species" (e.g., razor clam, Dungeness crab, salmon, groundfish, marine mammals, seabirds) may not be abundant or control ecosystem function, but their presence and health is important for the provision of economic, cultural, spiritual, 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. These species include: green sturgeon (*Acipenser medirostris*), eulachon (*Thaleichthys pacificus*), Southern Resident killer whales (*Orcinus orca*), humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*), marbled murrelets (*Brachyramphus marmoratus*), and tufted puffins (*Fratercula cirrhata*).

In this assessment, the status of other focal species in OCNMS was fair and the trend was mixed, both with high confidence. These ratings indicate that selected focal species are at reduced levels, but recovery is possible. The trend is mixed due to variation among species; some populations of focal species (e.g., razor clams, groundfish) are stable or have increased, while other focal species (e.g., Dungeness crab, chinook salmon, steelhead, Southern Resident killer whale, marbled murrelet) have declined or remained critically threatened or endangered since 2008. Many of these species were also potentially impacted by the 2013–2014 marine heatwave, which is believed to have caused or contributed to persistent and widespread HABs and anoxic events offshore of Washington state. In some cases, population declines negatively impacted coastal communities and Coastal Treaty Tribes and were recognized as fisheries disasters.

Comparison to 2008 Condition Report

Since Question 12 changed between 2008 and this assessment, a direct comparison is not possible between the two condition report ratings. However, the indicators used to develop the 2008 ratings for Question 12 and 13 overlap with the indicators used to develop the rating for this new Question 13. Specifically, in 2008, the status and condition of focal species were rated as fair and good/fair, respectively, with undetermined trends. These ratings were based on prevalence of disease in sea otters and reduced abundances of selected focal species, including sea otters, common murres, and rockfish. The status of sea otter populations was also evaluated in this assessment, but they were considered a keystone species and incorporated into the status for Question 12. Question 13 focused on several focal species, including rockfish and common murres, as well as other species of interest across all six habitats in OCNMS (see Table S.LR.12.1 and Appendix H). Expert agreement was high for this question, and the availability of monitoring data helped increase expert confidence.

New Information in the 2008–2019 Condition Report

The 2008–2019 status rating was based primarily on new information and expert opinions about known abundance changes among focal species since 2008. These changes occurred in all six habitats in OCNMS and are summarized in Table S.LR.13.2.

In pelagic habitats, important focal species include many wide-ranging marine animals such as seabirds—both residents that nest nearshore and forage in the pelagic zone and seasonal visitors to the Olympic Coast—as well as salmonids, forage fish, and marine mammals. Data and information are introduced below to describe both positive (i.e., gray, fin, and humpback whales) and negative (i.e., Southern Resident killer whales) changes in the abundance of focal species in the pelagic zone, as well as highlight recent ecosystem perturbations that have resulted in unusual mortality events and increasing threats to animals that depend on the abundance and timing of the region's pelagic productivity.

In sandy beach habitats, the Pacific razor clam is an important focal species because it is harvested for subsistence, commercial, and recreational purposes. Razor clams are divided into pre-recruit (<76 mm, below the preferable catch size) and recruit (≥76 mm above the preferable catch size) populations. In OCNMS, razor clam populations have remained stable or have increased since 2008, with variability observed among years and sites. At Point Grenville and Mocrocks Beach, densities of recruits have been near the long-term mean since 2008. Razor clam densities vary annually for both size classes, including large razor clam pre-recruit and recruit densities in 2010, 2014, and 2015 (Figure S.LR.13.1; Figure App.S.LR.13.1). At Kalaloch Beach, pre-recruit razor clams were abundant in 2015, 2017, and 2019 (Figure S.LR.13.2). Another sandy beach shellfish, the purple olive snail (*Olivella biplicata*), is important to the Makah Tribe for cultural and ceremonial reasons. In Makah Bay, purple olive snail populations have remained stable since 2008, despite a mass mortality event in June 2014 (Akmajian et al., 2017). Although the cause of this mortality event is still unknown, subsequent field surveys have shown that the Makah Bay olive snail population recovered from the event (Figure App.S.LR.13.2; Akmajian et al., 2017).

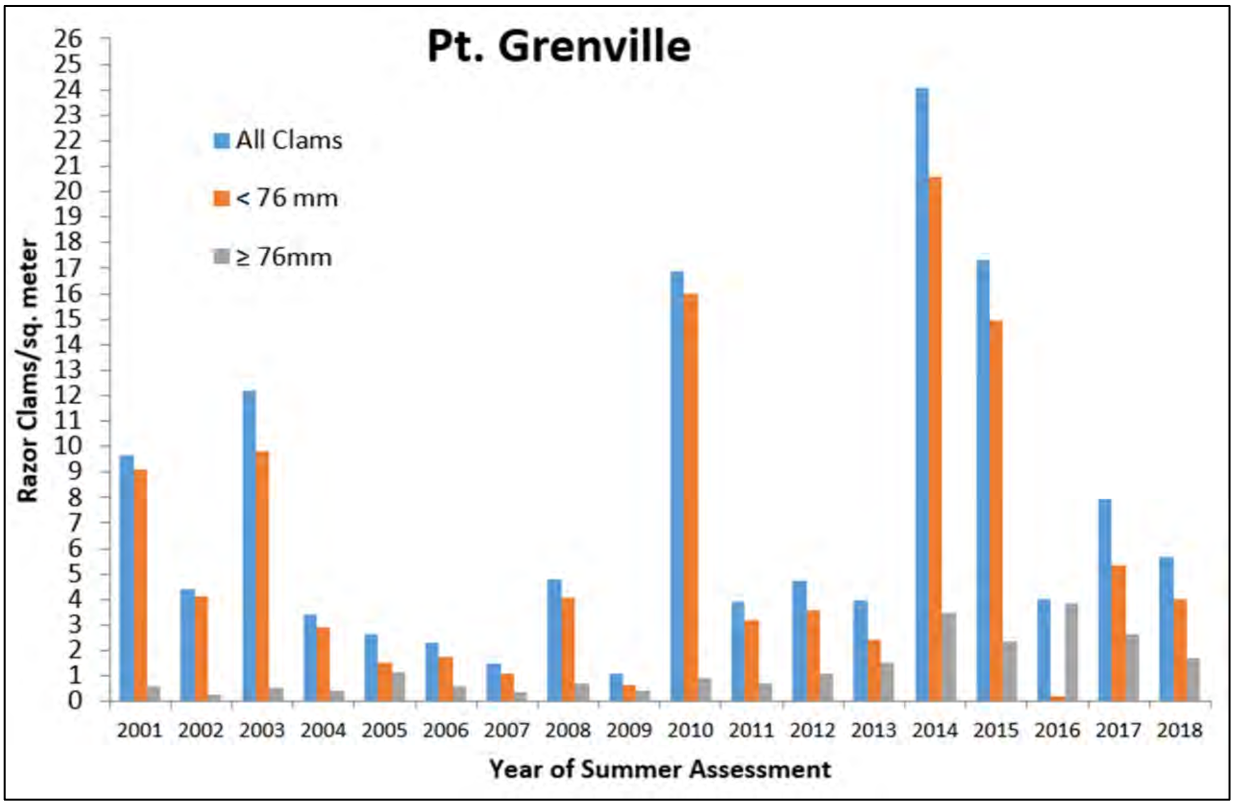


Figure S.LR.13.1. Average estimated summer density (clams per m^2) of razor clam recruits (≥76 mm) and pre-recruits (<76 mm) from 2001–2018 for Point Grenville, an important tribal harvest area within the 23 miles of coastline encompassed by the reservation of the Quinault Indian Nation. Population estimates are based on transect densities that are averaged and then expanded across the estimated habitat available on each beach; error estimates have not been calculated. Source: Quinault Indian Nation, 2019; Image: J. Schumacker/Quinault Indian Nation

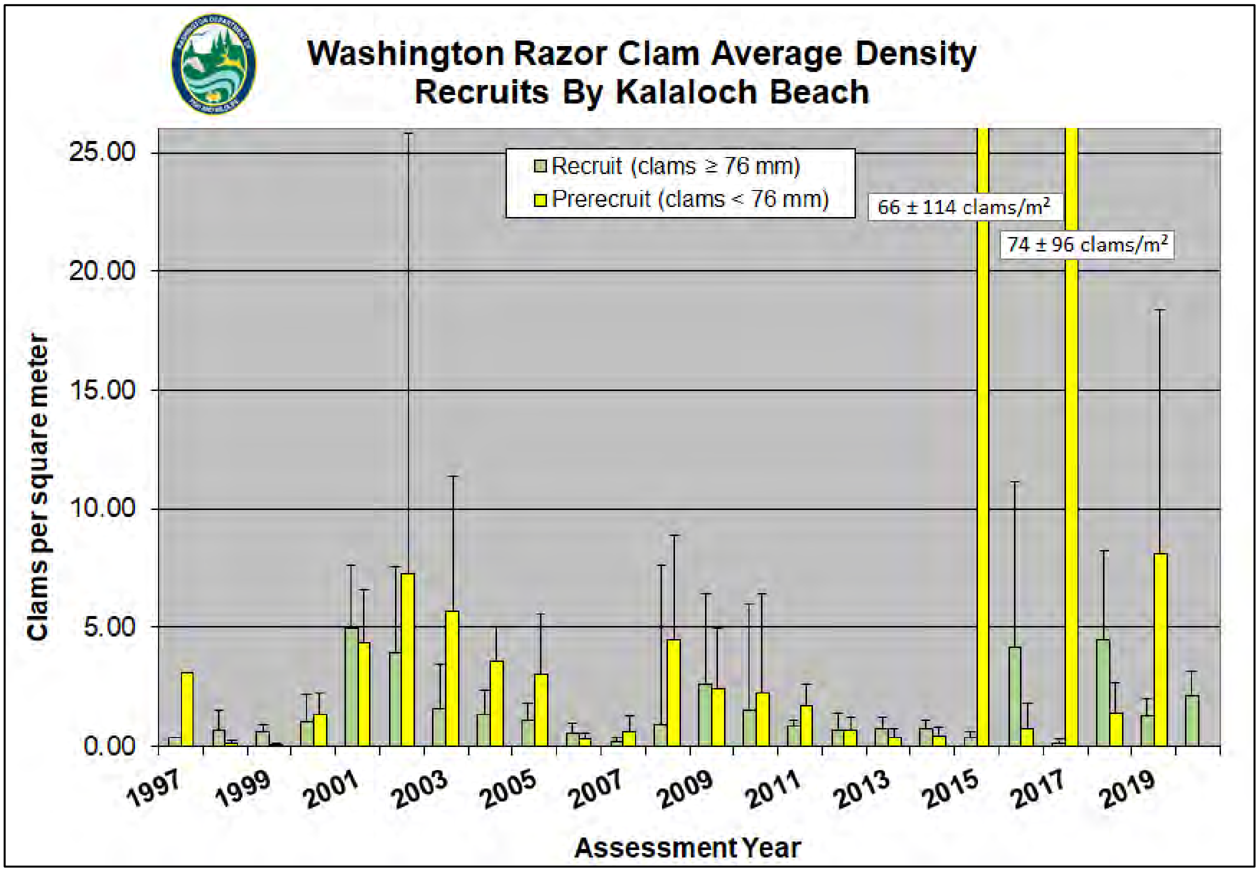


Figure S.LR.13.2. Average density (clams per m2) of razor clam recruits (≥76 mm) and pre-recruits (<76 mm) at Kalaloch Beach from 1997–2019. The Kalaloch razor clam management beach lies between Olympic National Park South Beach Campground and Brown's Point. Pre-recruits are below the preferable catch size and recruits are above the preferable catch size. Source: WDFW; Fradkin, 2019; Image: D. Ayres/WDFW

In sandy seafloor and deep seafloor habitats, Dungeness crabs (*Cancer magister*) support an important fishery on the northern Washington coast. In deep seafloor habitats (55 to 1280 m), Dungeness crab stocks (catch per unit effort) have not changed (compared to their long-term means) and are increasing inside OCNMS (Figure S.LR.13.3). However, these deeper, offshore areas are not routinely fished by coastal tribal communities. Tribal fishing grounds are generally closer to shore and in shallower (<55 m) habitats. Since 2008, Dungeness crab harvests in these shallow, sandy seafloor habitats have not changed south of Point Grenville, but have declined significantly to the north. Recent harvests (2014–2019) north of Point Grenville were lower than from 2000–2013 (Figure S.LR.13.4) because of persistent seasonal hypoxic conditions and a large and persistent toxic HAB. This bloom closed the Dungeness crab fishery in order to protect human health. Consequently, a fisheries disaster was declared by the Department of Commerce in 2017 at the request of the Quileute Tribal Council (NOAA Fisheries, 2021b). Please see Question 7 for more detail.

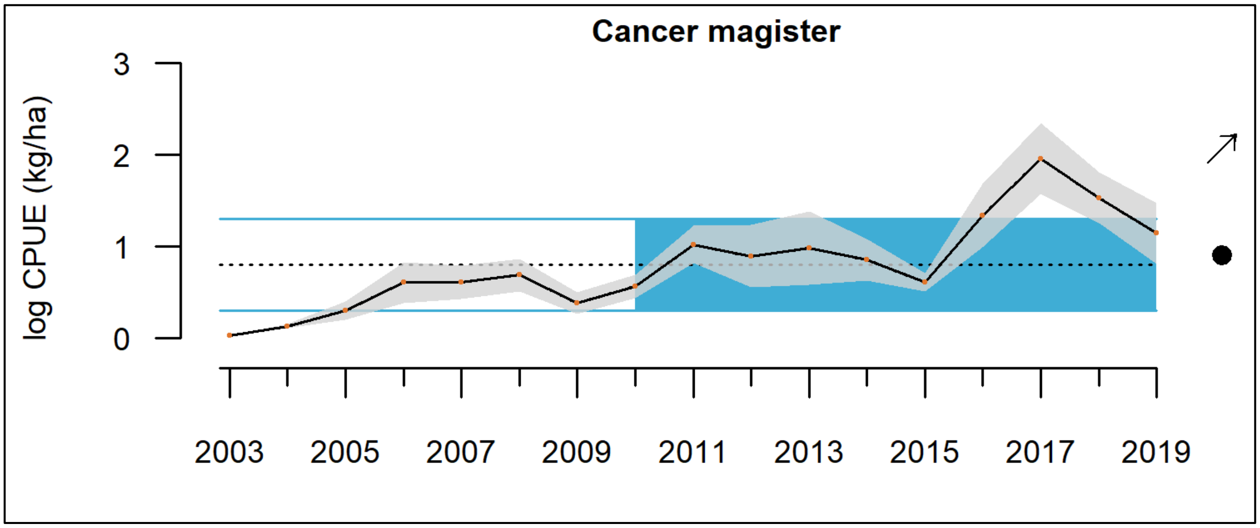


Figure S.LR.13.3. Log catch per unit effort for Dungeness crab (Cancer magister) from scientific surveys from 2003–2019 in OCNMS at 55–1280 m depths (offshore). The black dot (●) indicates that the 10-year mean (2010–2019) is within one standard deviation of the long-term mean, and there was an increasing trend (indicated by arrow ↗) for the last 10 years. The dashed line is the long-term mean and solid blue lines are ±1 standard deviation. Because NOAA Fisheries sampling is conducted offshore, it does not provide abundance estimates for the nearshore Dungeness crab populations frequently targeted by tribal fishers. For this reason, companion data describing nearshore catch <55 m are provided in Figure S.LR.13.4. Source: CCIEA, 2021; Image: G. Williams/NOAA

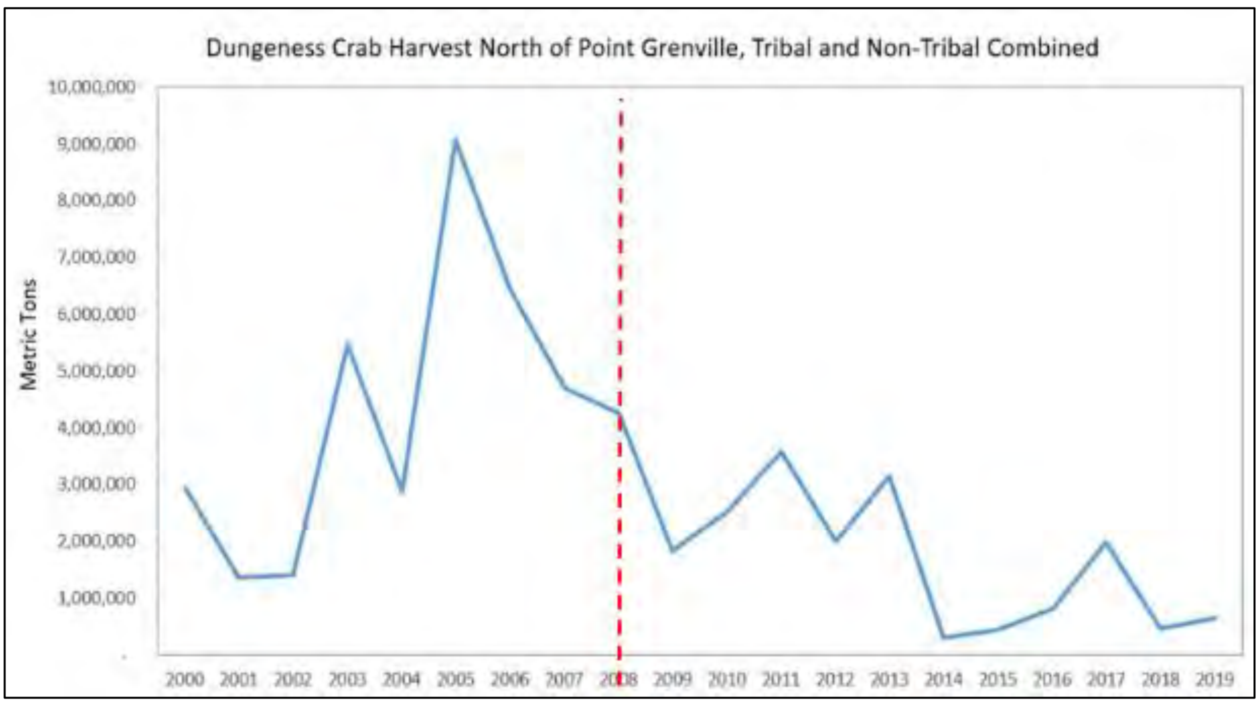


Figure S.LR.13.4. Dungeness crab harvest (in metric tons) from 2000–2019 from Point Grenville to Cape Flattery in <55 m depths. Counts reflect tribal and non-tribal harvest data combined. The vertical line at 2008 marks the beginning of the assessment period for this report. Source: WDFW; J. Schumacker/Quinault Indian Nation; Quinault Indian Nation, 2019; Image: J. Schumacker/Quinault Indian Nation

In addition to Dungeness crab, groundfish are an important fishery in sandy and deep seafloor habitats on the northern Washington coast. Some groundfish stocks were overfished pre-2008, but they have since been largely rebuilt (Table S.LR.13.1). Groundfish catch per unit effort has remained stable since 2008, with recent means within one standard deviation of long-term means (Figure S.LR.13.5). The 10-year trend is flat for groundfish catch per unit effort. The status is the same for specific key groups of groundfish, including rockfish (Figure S.LR.13.6), flatfish (Figure App.S.LR.13.3), roundfish (Figure App.S.LR.13.4), and sharks and skates (Figure App.S.LR.13.5) in OCNMS. Expert opinion is that groundfish stocks are sustainably managed by the Pacific Fishery Management Council and its partner entities. This opinion is supported by status and trends for individual species, including lingcod (*Ophiodon elongatus*), bocaccio (*Sebastes paucispinis*), and yelloweye rockfish (*Sebastes ruberrimus*). Specifically, recent mean abundances for these groundfish species have been within one standard deviation of their long-term means. Their 10-year trends vary, with lingcod showing a decreasing trend (Sampson et al., 2017), yelloweye rockfish showing no trend (Gertevesa & Cope, 2017), and bocaccio showing an increasing trend (Figures App.S.LR.13.6–App.S.LR.13.8). Bocaccio, while less common in Washington coastal waters, is included here because it is a conservation success story and an example of how some groundfish stocks are rebounding from overfishing.

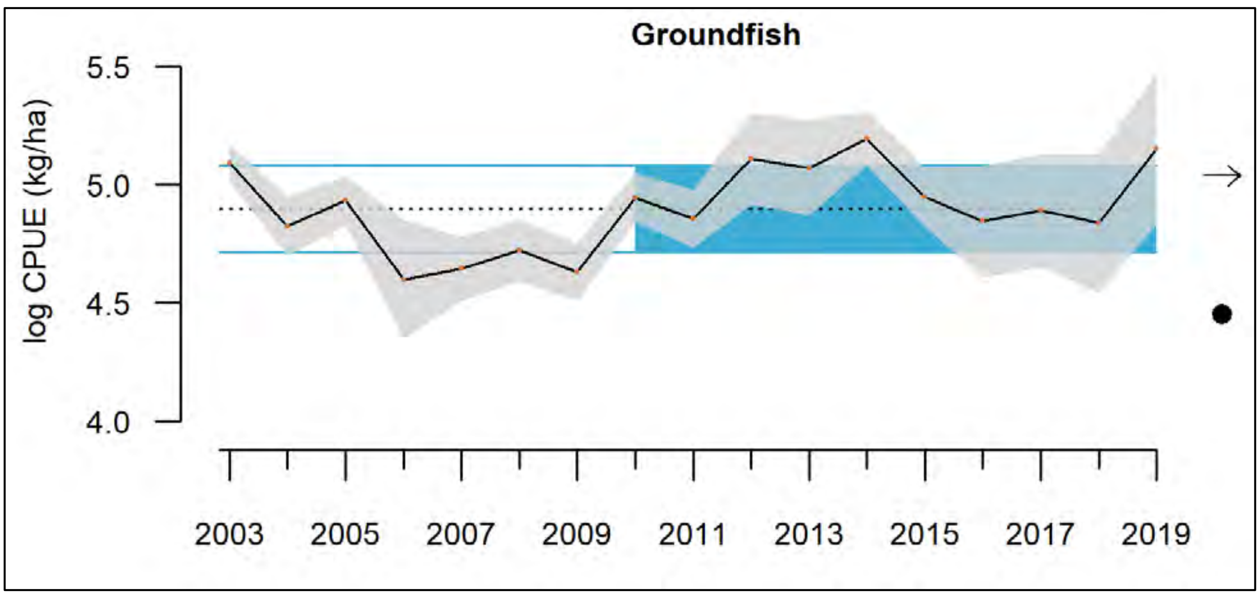


Figure S.LR.13.5. Log catch per unit effort for groundfish, including rockfish, flatfish, roundfish, and sharks/skates, from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean, and the horizontal arrow (→) indicates no change in the 10-year trend. The dashed line is the long-term mean and solid blue lines are ±1 standard deviation. Source: CCIEA, 2021; Image: G. Williams/NOAA

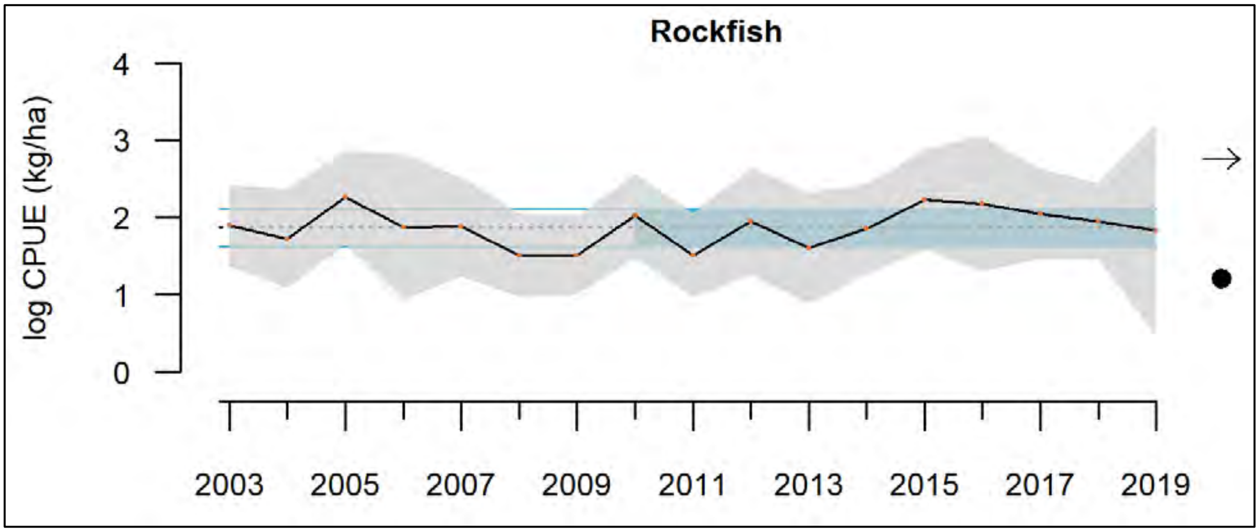


Figure S.LR.13.6. Log catch per unit effort for rockfish inside OCNMS from 2003–2019. Data from from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (shaded in blue) is within 1 standard deviation of the long term mean. The horizontal arrow (→) indicates no change in the 10-year trend. The dashed line is the long-term mean and solid blue lines are ±1 standard deviation. Source: NWFSC, 2018; CCIEA, 2021; Image: G. Williams/NOAA.

Steller sea lions (*Eumetopias jubatus*) and California sea lions (*Zalophus californianus*) are present in OCNMS. The focus here is on Steller sea lions because they are present and breed in Washington state year round, unlike California sea lions. Since 1989, Steller sea lion populations have increased in Washington state (Pitcher et al., 2007). Protections implemented during and after the 1970s have resulted in a period of sustained population growth in the eastern portion of their range, including the Washington coast (Wiles, 2015). As of 2019, Steller sea lion abundances were at an all time high in OCNMS since monitoring began in 1989, and their abundances continue to increase (Figure S.LR.13.7; Wiles, 2015). Nine haulouts are located inside the sanctuary; however, OCNMS does not support any recognized rookeries (i.e., >50 pups born per year) (Wiles, 2015).

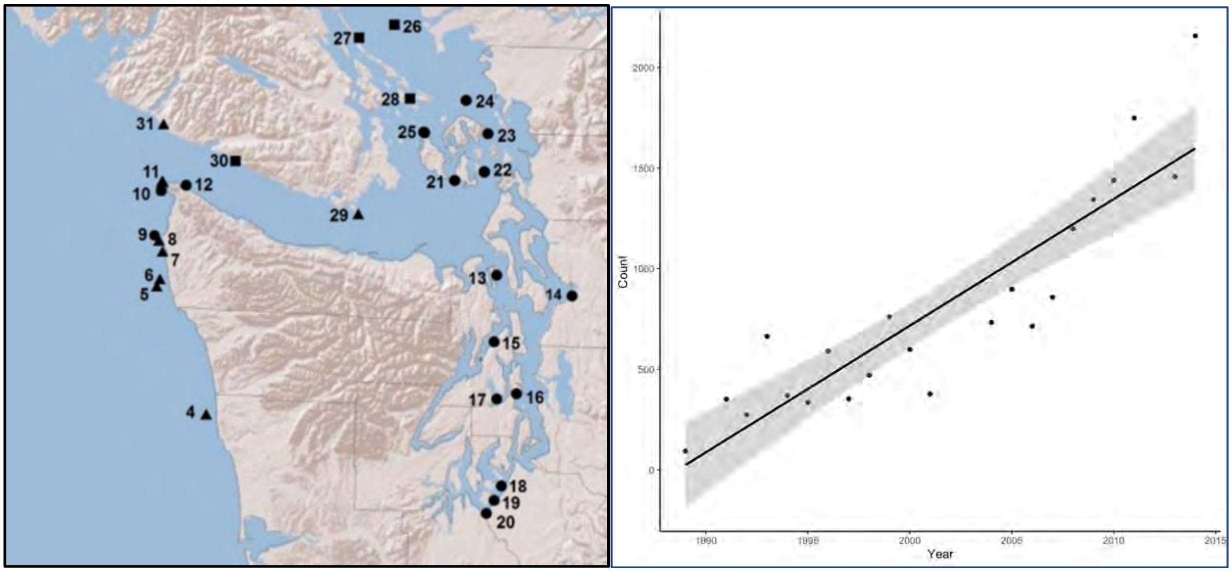


Figure S.LR.13.7. (Left) Location of Steller sea lion haulouts on the Olympic peninsula. Sites 4–12 are located inside OCNMS. Symbols denote haulouts with annual maximum numbers of >100 animals (triangles), ≤100 animals (circles), and no information (squares). (Right) Number of Steller sea lions counted during breeding season (June–July surveys) in OCNMS, 1989–2013. An overall increasing trend during this period is shown by the black line, while variability around that trend is shown by grey shading. Image: S. Colosimo and S. Jeffries/WDFW

Also in rocky shore habitats, seabird populations are considered indicators of ecosystem health because they connect the land and ocean. The common murre (*Uria aalge*) is one such seabird species that nests on coasts and islands and favors cool ocean waters for foraging. Since 2008, common murre abundance has increased, but remained below historical levels. From 1996–2015, common murre abundance at Washington colonies has increased by 8.8% annually. Northern colonies (White Rock to Quillayute Needles) increased by 11% per year, and are now larger than southern Washington colonies. Varying rates of increase have been observed at sites inside OCNMS, with the highest rates observed at sites from White Rock to the Bodelteh Islands (Figure S.LR.13.8; Thomas & Lyons, 2017). The common murre nesting aggregation on Tatoosh Island has also grown since 1998, and is one of the larger nesting aggregations in Washington state (Thomas & Lyons, 2017). Although common murre abundance is increasing, an unusual mortality event occurred in 2015–2016, potentially due to the 2014–2016 marine heatwave (Figure App.S.LR.13.9; Gibble et al., 2018; Piatt et al., 2020). Over 62,000 common murres washed ashore from California to Alaska during this unusual mortality event. Roughly 900 (mainly newly fledged) birds washed up on the shores of northern Washington (Piatt et al., 2020), and it is likely many more died but their carcasses did not come ashore. Although many birds died, this unusual mortality event did not appear to significantly impact the size of breeding colonies, which continued to increase during this time period.

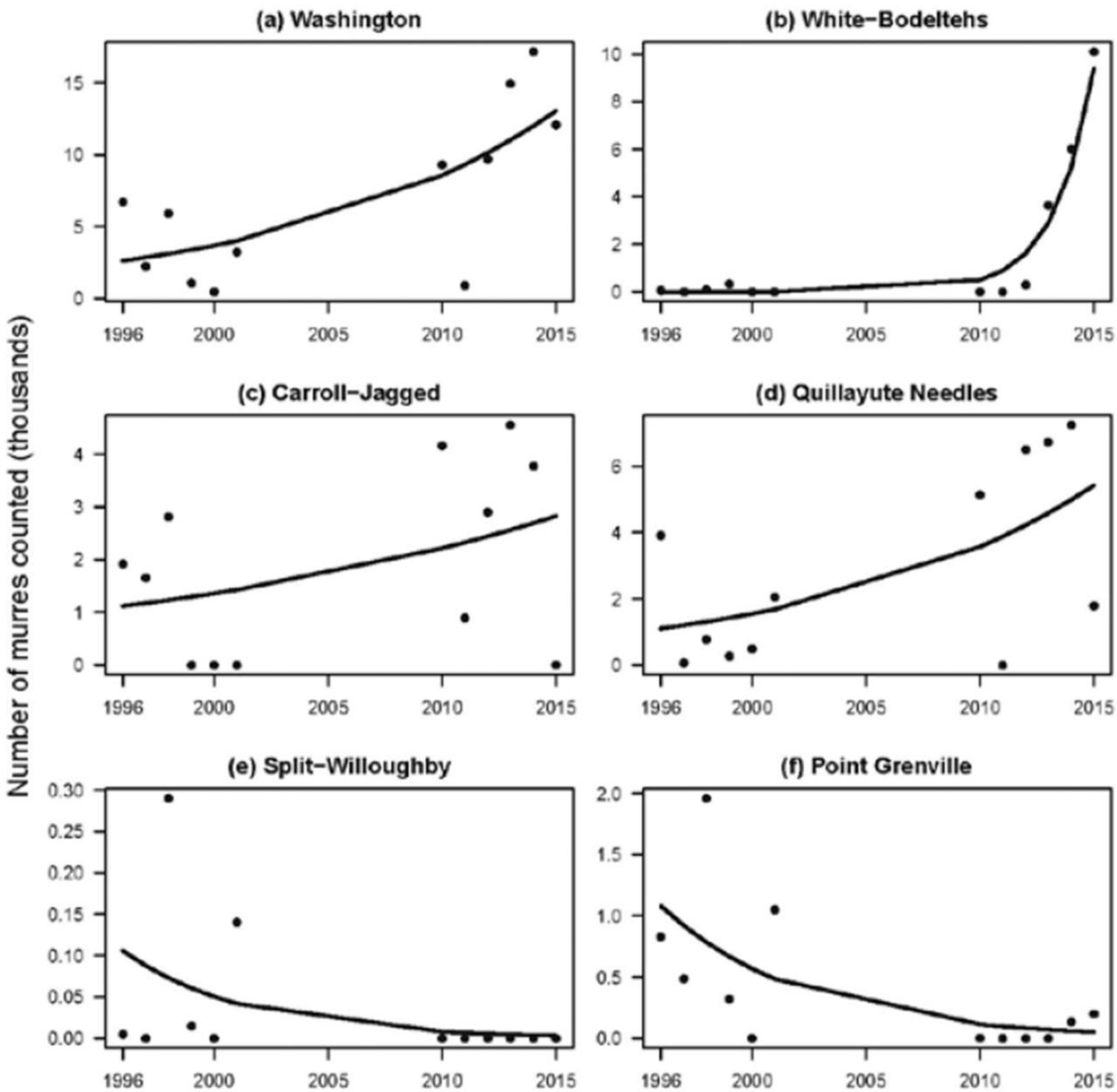


Figure S.LR.13.8. Whole-colony counts for common murres from 1996–2015 (except Tatoosh Island) in (a) Washington state and (b–d) northern Washington state (i.e., White-Bodeltehs, Carroll-Jagged, and Quillayute Needles). Solid line in each panel is the trend in colony counts. Image: Thomas & Lyons, 2017

In pelagic habitats, the abundance and mortality of other focal seabird species have remained stable or declined since 2008. Populations of Cassin's auklet have remained stable since 2008 compared to their long-term mean (Figure App.S.LR.13.10). While their abundance is stable and there is no 10-year trend, Cassin's auklets did experience an unusual mortality event in 2014 (Figure App.S.LR.13.11; Jones et al., 2017). Abundances of other focal seabird species, like the tufted puffin (*Fratercula cirrhata*) and marbled murrelet (*Brachyramphus marmoratus*), have decreased compared to long-term means in northern Washington (Figures S.LR.13.9–S.LR.13.10). Both species are of particular concern; marbled murrelets are federally threatened (McIver et al., 2019) and tufted puffin populations fell below the threshold for long-term viability (Hanson et al., 2019), prompting Washington state to list them as endangered in 2015.

These focal seabird species also still face a range of threats and challenges to their recovery in northern Washington (Washington State Department of Natural Resources, 2020b; Hanson et al., 2019).

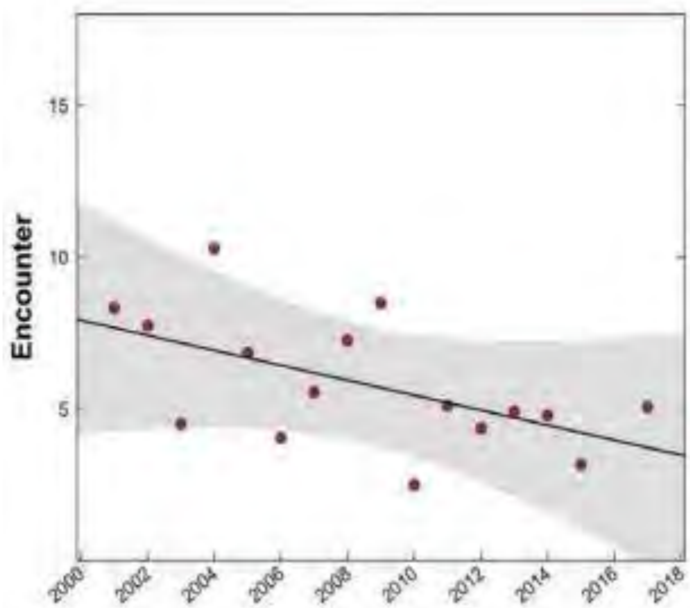


Figure S.LR.13.9. Encounters (birds/km) of tufted puffins during summer (May–July) at-sea surveys between Cape Flattery and Point Grenville from 2001–2017. Image: Hanson et al., 2019

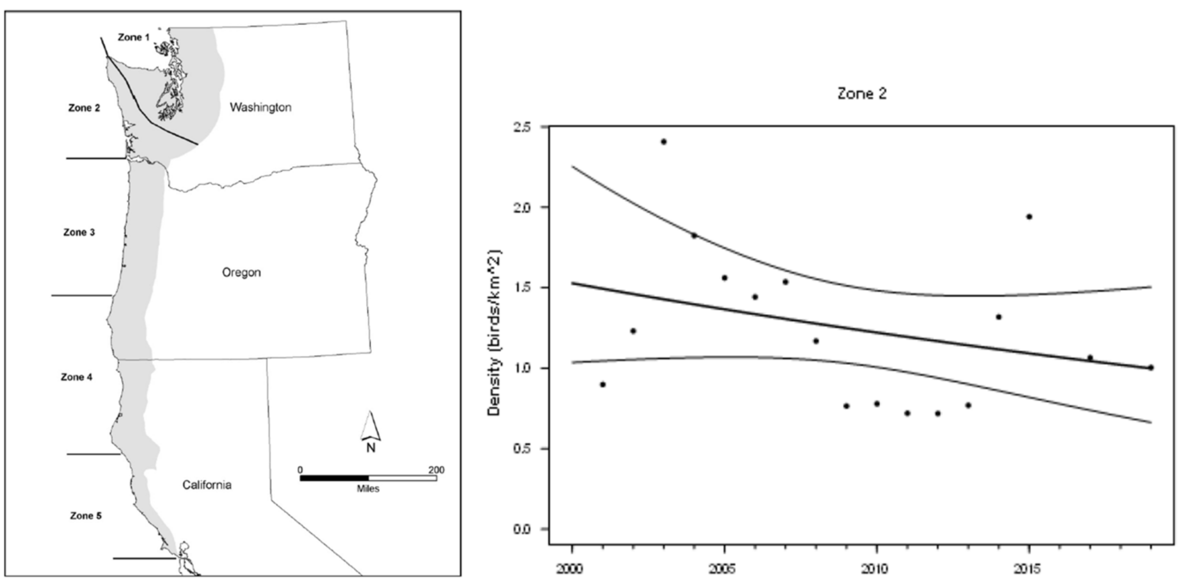


Figure S.LR.13.10. Marbled murrelet densities (birds/km2) along the Washington coast (Zone 2 on map) from 2000–2019. Image: McIver et al., 2019

Pacific salmon and steelhead stocks also face a range of threats. These fish are critically important species for subsistence, recreational, and cultural purposes in Washington. Their stocks are managed individually, run by run and river by river, by state and tribal agencies. Since 2008, some salmon and steelhead stocks have declined in pelagic habitats along the northern Washington coast. In 2015 and 2016, disasters were declared for ocean salmon fisheries at the request of the state of Washington and the Makah, Hoh, Quileute, Stillaguamish, Nooksack, Muckleshoot, Upper Skagit, and Suquamish Tribes and the Quinault Indian Nation (NOAA Fisheries, 2021b). These fisheries disasters resulted in millions of dollars in lost income for local communities. As of 2018, six stocks of Chinook and chum salmon were trending upwards; 56 stocks of Chinook, chum, sockeye, coho, and steelhead were stable; and 19 stocks of Chinook, coho, and steelhead were trending downwards (Washington State Recreation and Conservation Office, 2018a). Population data for these 81 stocks can be viewed online (Washington State Recreation and Conservation Office, 2018b) to better understand unique temporal trends and challenges for each stock river by river and run by run. One stock important to note here is the Quinault blueback (sockeye) salmon. This stock is critical to the Quinault Indian Nation, and run sizes have decreased compared to pre-2008 levels (Figure S.LR.13.11; Quinault Indian Nation, 2019; L. Gilbertson, personal communication, January 8, 2021). In 2019, the Quinault Department of Fisheries closed the blueback fishery because of two years of consecutive, historically low returns of spawning adults to the Quinault River (Bruscas, 2019). Overall, Chinook salmon abundance on the Washington coast (north of Cape Falcon, Oregon) increased from 2008–2016 (with a decline in 2016 likely linked to the marine heatwave); this includes runs from the Columbia River, Puget Sound, and other rivers in Oregon and California (Figure S.LR.13.12; Pacific Fishery Management Council, 2020).

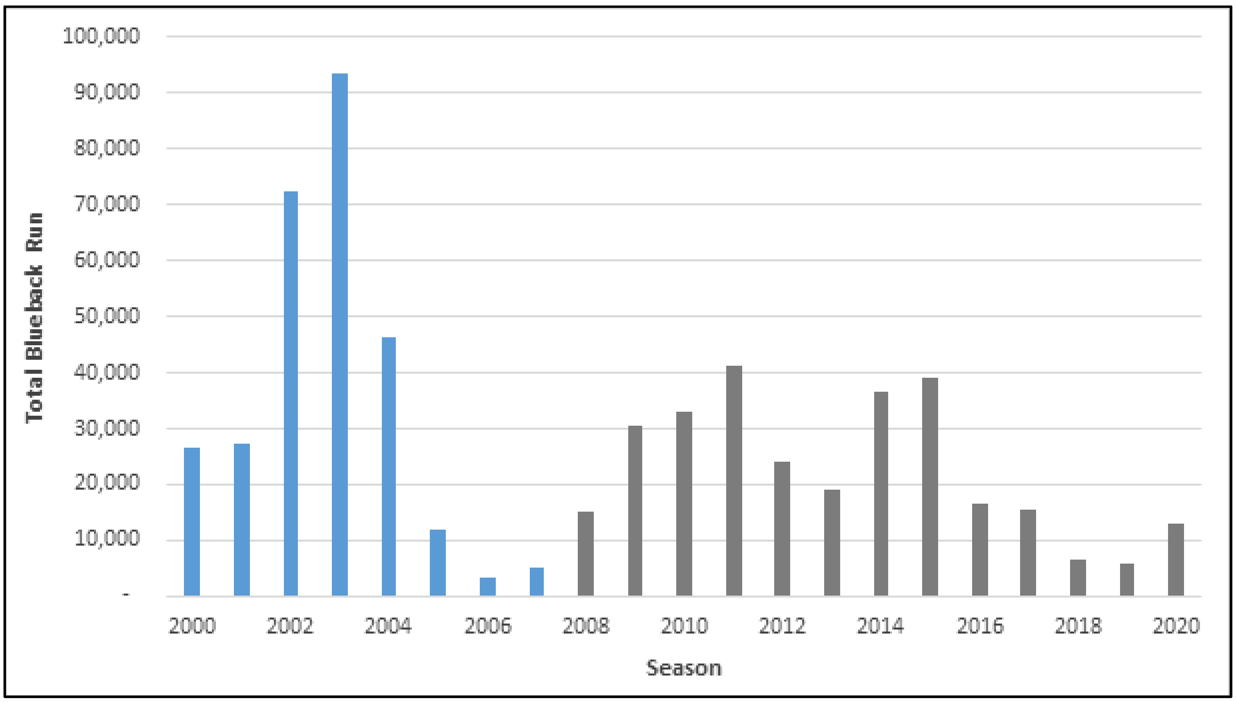


Figure S.LR.13.11. Estimated Quinault blueback (sockeye) salmon run sizes from 2000–2020, including the 2008–2020 assessment period for this report indicated by grey bars. The Quinault blueback salmon fishery was closed prior to each season in 2018, 2019, and 2020 because of historically low returns of wild adult salmon to the Quinault River following extremely poor ocean conditions beginning in 2014. Source: L. Gilbertson/Quinault Indian Nation, personal communication, January 8, 2021

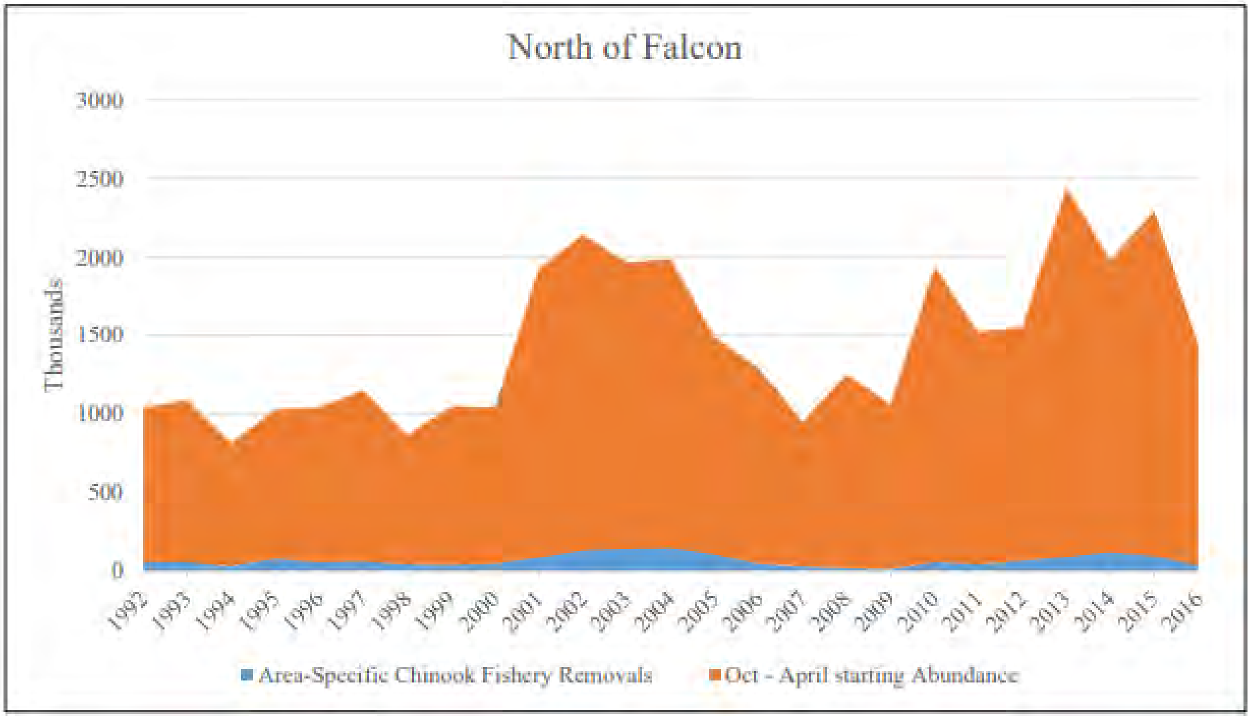


Figure S.LR.13.12. Annual trends in adult Chinook abundance north of Cape Falcon, Oregon and area-specific reduction in adult Chinook salmon abundance modeled to result from all Pacific Fishery Management Council salmon fisheries (from October through the following September). Image: Pacific Fishery Management Council, 2020

Another focal fish species, eulachon (*Thaleichthys pacificus*), has declined since 2008 and was listed as threatened under the ESA in 2010. Eulachon are anadromous species that return to rivers in schools to spawn. They have been traditionally harvested by the Coastal Treaty Tribes and are a prized recreational species. Since its listing, eulachon abundances vary by year and among rivers. In 2007–2012, eulachon densities (and bycatch by the pink shrimp fishery) increased (Ward et al., 2015); however from 2011–2018, the estimated number of spawning eulachon has not changed, and there is no consistent trend on the Washington coast (Figure App.S.LR.13.13; Langness et al., 2018). Environmental DNA or “eDNA,” which analyzes genetic material present in water samples, is beginning to be used to assess and monitor upriver spawning of eulachon.

Although some focal species are depleted or in decline, other focal species in pelagic habitats in OCNMS have remained stable or increased since 2008. In particular, all marine mammal species that use OCNMS, with the exception of Southern Resident killer whales, had either positive growth or stable population sizes since 2008 (Figures App.S.LR.13.13–App.S.LR.13.17; Nadeem et al., 2016; Becker et al., 2019). These include gray whales, fin whales, and humpback whales. Some feed in OCNMS, while others transit through the sanctuary during their north- and southbound migrations. Although these populations were stable or increasing, they still face multiple threats ranging from ship strikes to changing environmental conditions. Notably, gray whales are currently experiencing an unusual mortality event throughout their range (Figure App.S.LR.13.18; NOAA Fisheries, 2019b). The Pacific Coast Feeding Group is a small subset of gray whales that do not make the full migration to feeding grounds in Alaska and instead feed along the Pacific coast between northern California and northern British Columbia. Body conditions of the Pacific Coast Feeding Group were assessed using photographs from 1996–2013 from northern Washington (Akmajian et al., 2020). Their body condition reflects reproductive status, food availability, and ecosystem productivity over their feeding range. The previous 10 years (1998–2008) had a similar mean condition to more recent years (2009–2013), although there were a few years in which condition was lower than normal (Akmajian et al., 2020). The recovery of Southern Resident killer whales remains a concern in northern Washington since their designation as endangered in 2005. Their abundance has remained stable compared to the long-term mean, but their 10-year population trend indicates declining abundance (Figure S.LR.13.13; Ruggerone et al., 2019). This species also faces several threats, including environmental contaminants, low prey abundance, sound pollution, and vessel disturbance, and remains in danger of extinction (NOAA Fisheries, 2020e). Southern Resident killer whales have been increasingly observed along the coasts of Washington and Vancouver Island in recent years.

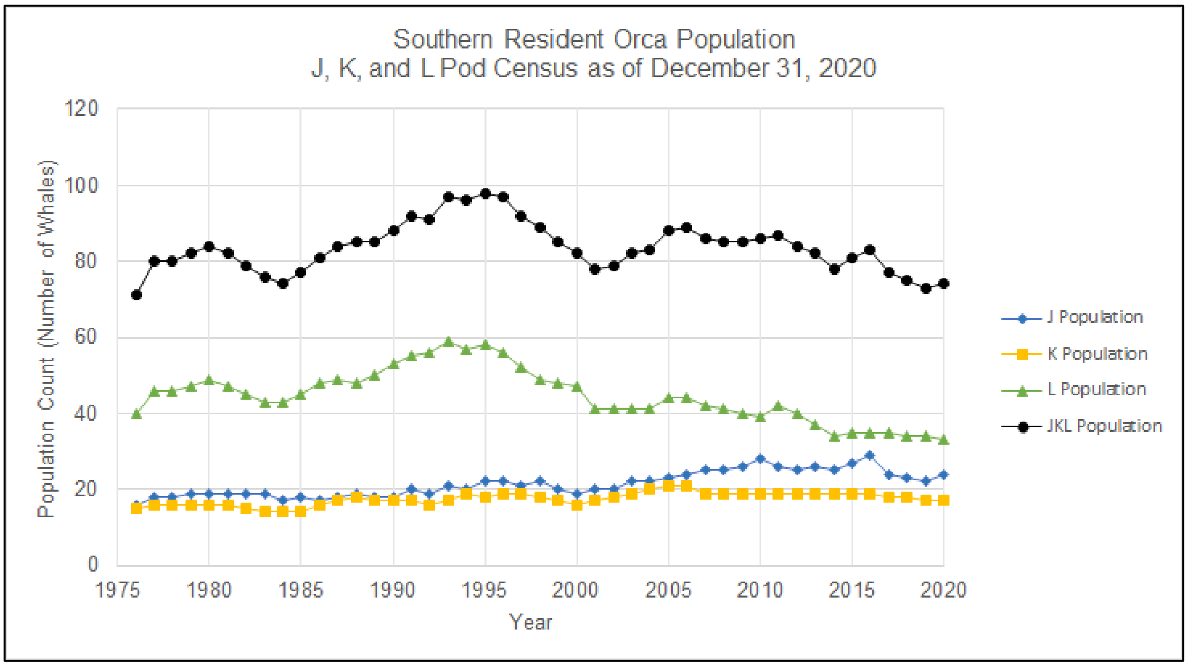


Figure S.LR.13.13. Abundance for Southern Resident killer whales in the Northeast Pacific, by pod, from 1975–2020 as of December 31, 2020. Southern Resident killer whale numbers have continued to decline during the assessment period for this report (2008–2020). Source: Center for Whale Research

Conclusion

The 2008–2019 status of focal species is fair and the trend is mixed, both with high confidence. The stability, recovery, or increases in razor clams, groundfish, and specific marine mammal populations were positive signs for focal species in and around OCNMS. Declines in the Dungeness crab catch north of Point Grenville and several salmonid stocks, including the Quinault blueback, are cause for concern. Fisheries disasters associated with these declines caused millions of dollars in lost revenue for Coastal Treaty Tribes and other Washington coastal communities.

While the availability of monitoring data helped increase confidence in these ratings, data and analysis gaps were identified during the expert workshop. Specifically, analysis gaps existed in the deep seafloor habitat (>30 m depth) for biogenic invertebrates, green sturgeon, Pacific cod, and Pacific hake, as well as in the pelagic habitat for mid-water rockfish, other marine mammals, and other seabirds. Data gaps also existed for focal species in the sandy beach habitat (i.e., decapods, isopods, amphipods, shorebirds), in the rocky shore habitat (i.e., black oystercatchers, Pacific harbor seals, resident colonial seabirds), in the sandy seafloor habitat (i.e., flatfish, benthic invertebrates), in the deep (>30 m) seafloor habitat (i.e., benthic invertebrates, shrimp, shad), and in the pelagic habitat (i.e., sea turtles). In kelp forest habitats, there was more monitoring data available compared to other habitats, although data were limited to recent years (2015–2019). Longer-term data are needed to establish trends for focal species like red sea urchins, black rockfish (*Sebastes melanops*), and striped surfperch (*Embiotoca lateralis*) (Figures App.S.LR.13.19–App.S.LR.13.21).

Climate change, including marine heatwaves, poses a major concern for many focal species. Dramatic changes in organism abundances were documented during the 2014 marine heatwave (Morgan et al., 2019). These changes in abundance were due to organisms moving from south to north or from east to west. While these shifts were temporary, longer-term distribution shifts may result in novel trophic interactions with unpredictable ecological results (Naiman et al., 2012). Changes in animal distributions also pose challenges for living marine resource managers in particular, including at OCNMS. Consequently, there is a strong need for projections of how species might be impacted by and respond to future environmental changes during the 21st century (Morley et al., 2018).

Table S.LR.13.1. Rebuilt groundfish and salmon stocks offshore of the continental U.S. West Coast as of December 2019. Image: NOAA Fisheries, 2020f

Rebuilt Stocks	**Year Rebuilt**
Pacific whiting	2004
Lingcod	2005
Chinook salmon, Klamath (fall)	2011
Widow rockfish	2011
Coho salmon, Queets	2011
Coho salmon, W. Strait of Juan de Fuca	2012
Chinook salmon, Sacramento (fall)	2013
Canary rockfish	2015
Petrale sole	2015
Bocaccio	2017
Darkblotched rockfish	2017
Pacific Ocean Perch	2017
Cowcod	2019

Table S.LR.13.2. Status and trends for individual Question 13 indicators discussed at the January 2020 workshop. There are no confidence scores for individual indicator status and trends. Asterisks indicate that the indicator was added after the January 2020 workshop.

Indicator	Source	Habitat	Data Summary	Figures
Razor clams (density, recruitment)	Quinault Indian Nation, 2019; D. Ayres/WDFW; Fradkin, 2019	Sandy beach	(Point Grenville) Status: Interannual variability for both size classes. Recent densities of large size class at or above long-term mean. Trend: No clear recent trend. (Kalaloch) Status: Interannual variability in densities of both size classes. Trend: No trend. (Mocrocks) Status: Razor clam densities in 2008–2019 were at or above densities observed in 1997–2007. Trend: No clear recent trend.	S.LR.13.1 (Point Grenville); S.LR.13.2 (Kalaloch); App.S.LR.13.1(Mocrocks)
Olive snails (density)	Akmajian et al., 2017	Sandy beach	Status: Mass mortality in June of 2014 in Makah Bay. Subsequent surveys (2015 to 2017) indicated apparent recovery of the population. Trend: Recent increase/recovery.	App.S.LR.13.2
Dungeness crabs (catch per unit effort, 55–1280 m depths)**	NWFSC, 2018; CCIEA, 2021	Deep seafloor	Status: Recent mean was similar to long-term mean in 55–1280 m depths. Trend: Dungeness crab catch per unit effort increased in 55–1280 m depths.	S.LR.13.3
Dungeness crabs (metric tons, <55 m depths)	Quinault Indian Nation, 2019; WDFW; J. Schumacker/ Quinault Indian Nation	Sandy seafloor, deep seafloor	Status: Dungeness crab harvests 2014–2019 lower than 2000-2013 in depths <55 m. Trend: Dungeness crab harvests declined since 2005 north of Point Grenville in depths <55 m. Harvests south of Point Grenville were unchanged in depths <55 m. Fishery disasters were declared in recent years and the fishery was affected by domoic acid.	S.LR.13.4
Groundfish (rockfish, flatfish, foundfish, sharks/skate; catch per unit effort)	NWFSC, 2018; CCIEA, 2021	Deep seafloor	Status: Recent mean similar to long-term mean for all groups. Generally noted that groundfish are sustainably managed. Trend: No trend in catch per unit effort.	S.LR.13.5–S.LR.13.6, App.S.LR.13.3–App.S.LR.13.5; Table S.LR.13.1
Roundfish/ rockfish (lingcod, bocaccio, yelloweye; catch per unit effort)	NWFSC, 2018; CCIEA, 2021	Deep seafloor	Status: Variable levels observed (data from yelloweye may be suspect because of low sample size). Trend: Decreasing trend for lingcod. Increasing trend for bocaccio. No clear trend for yelloweye.	App.S.LR.13.6–App.S.LR.13.8

Indicator	Source	Habitat	Data Summary	Figures
Pinnipeds (Steller sea lions, California sea lions*, harbor seals; counts)	S. Colosimo & S. Jeffries/WDFW	Pelagic, sandy beach, rocky shore	Status: *Steller sea lions:* Abundances at all time high in OCNMS since 1989. *Pacific harbor seals*: 2014 count similar to long-term mean. Northern elephant seals and Guadalupe fur seals also increased, although the latter experienced an unusual mortality event in 2019. Trend: *Steller sea lions:* Increasing abundances in OCNMS. *Pacific harbor seals*: No 10-year trend.	S.LR.13.7 (Steller sea lions); App.S.LR.13.13 (harbor seals)
Common murres (abundance, encounter rates)	Thomas & Lyons, 2017; Coastal Observation and Seabird Survey Team (COASST), 2020	Rocky shore	Status: Increased abundance at breeding colonies, but still below historic levels. Trend: Increasing from 2008–2015. Unusual mortality events in 2015 and 2019.	S.LR.13.8; App.S.LR.13.9
Seabirds (tufted puffin, marbled murrelet, Cassin's auklet, pink-footed shearwater*; density, encounter rates)	Hanson et al., 2019; McIver et al., 2019; COASST, 2020; CCIEA, 2021	Pelagic	Status: *Tufted puffin*: Listed as endangered by state. Populations below threshold for long term viability. *Marbled murrelet*: Listed as endangered by state and threatened federally. Reduced densities at sea. *Cassin's auklet*: Mean density/mortality similar to long-term means. Trend: *Tufted puffin:* Decreasing trend in sightings. *Marbled murrelet:* Decreasing trend in densities. *Cassin's auklet*: No trend in density or encounter rates (unusual mortality event in 2014). *Rhinoceros auklet* also experienced unusual mortality events in 2012, 2017, and 2020.	S.LR.13.9, S.LR.13.10, App.S.LR.13.10–App.S.LR.13.11
Salmonids (salmon, steelhead, blueback; condition, status, run size)	Washington State Recreation and Conservation Office, 2018a, 2018b; Quinault Indian Nation, 2019; L. Gilbertson, personal communication, January 8, 2021	Pelagic	Status: Overall, 56 stocks stable, six stocks increasing, and 19 stocks decreasing. Trends: Salmonid stocks managed river by river, run by run. Overall, no trend. Blueback run size is decreasing and the fishery closed early in 2019. Chinook populations north of Cape Falcon have increased since 2008.	S.LR.13.11; S.LR.13.13
Eulachon (spawning numbers)	Langness et al., 2018	Pelagic	Status: Federally listed as threatened in 2010. No change. Trend: Abundances vary river by river and year by year. No trend.	App.S.LR.13.13

Indicator	Source	Habitat	Data Summary	Figures
Cetaceans (Southern Resident killer whale, gray whale, humpback whale, fin whale; abundance)	CCIEA, 2021; Scordino et al., 2017; Carretta et al., 2020; Nadeem et al., 2016; Calambokidis et al., 2017; Becker et al., 2019	Pelagic	Status: Southern Resident killer whale, humpback whale, and fin whale listed as endangered at the state and federal level. *Southern Resident killer whale*: Recent mean similar to long-term mean. *Gray whale:* Above long-term mean. *Humpback whale*: Above long-term mean. *Fin whale*: Above long-term mean. Trend: *Southern Resident killer whale*: decreasing. *Gray whale*: stable (although unusual mortality event beginning in 2019). *Humpback whale:* stable. *Fin whale*: stable.	S.LR.13.13 (Southern Resident killer whale), App.S.LR.13.14–App.S.LR.13.18 (gray, fin, and humpback whales)
Red sea urchins (density)	NWFSC, 2019a	Kelp forest	Status: Undetermined. No data available prior to 2015 for comparison. Trend: Same as above.	App.S.LR.13.19
Kelp fish assemblage (black rockfish, striped surfperch; abundance)	NWFSC, 2019a	Kelp forest	Status: *All:* Undetermined. No data available prior to 2015 for comparison. Trend: *All:* Same as above. However, important to note that black rockfish are in low abundance in southern region (J. Schumacker/Quinault Indian Nation, personal communication, January 20, 2020)	App.S.LR.13.20–App.S.LR.13.21
Data gaps	Sandy beach, rocky shore, sandy seafloor, deep seafloor, pelagic		Sandy beach: decapods, isopods, amphipods, shorebirds Rocky shore: pinnipeds, black oystercatcher, colonial seabirds Sandy seafloor: flatfish, benthic invertebrates Deep seafloor (>30 m): shelled benthos, shrimp, shad Pelagic: sea turtles	-
Analysis gaps	Deep seafloor, pelagic		Deep seafloor (>30 m): biogenic invertebrates, green sturgeon (listed as federally threatened), Pacific cod, Pacific hake Pelagic: mid-water rockfish, other marine mammals, pink-footed shearwater, other seabirds	-

*Indicates species were not discussed at the January 2020 workshop. These species were suggested by experts during the June 2020 review period and were added after additional consultations with OCNMS.

**Because NOAA Fisheries sampling is conducted in waters deeper than 55 m, it does not provide abundance estimates for the nearshore populations frequently targeted by tribal and non-tribal fishers. For this reason, companion data describing nearshore catch in <55 m is provided in Figure S.LR.13.4.

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

Status Description: Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.

Rationale: Non-indigenous species (e.g., *Sargassum muticum* and *Caulacanthus okamurae*) have existed at low abundances in OCNMS for decades; however, a greater number of non-indigenous species have been identified as a concern in or adjacent to OCNMS boundaries in the last 10 years. These include the European green crab, 289 non-indigenous species introduced to the U.S. West Coast by the 2011 tsunami, and farmed Atlantic salmon that escape from net pens in Puget Sound.

Non-indigenous species (also called alien, exotic, non-native, or introduced species) are organisms living outside their native distributional range, having arrived there by deliberate or accidental human activity. Those that cause ecological or economic harm in the new environment are called invasive species. In this assessment, the status of non-indigenous species in OCNMS was good/fair and the trend was worsening, with high confidence. This means that non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.

The rating for this question was based on current information and trends for non-indigenous species from 2008–2019 (Table S.LR.14.1). Non-indigenous species (e.g., *Sargassum muticum* and *Caulacanthus okamurae*) have existed at low abundances inside OCNMS for decades; however, an increasing number of these species have been identified as a concern in or adjacent to OCNMS boundaries in the last 10 years. These include the first reported detection in 2017 and increasing abundance of European green crab (*Carcinus maenus*) (Akmajian & Halttunen, 2019), the introduction of 289 non-indigenous species to the U.S. West Coast by the 2011 tsunami in Japan (Carlton et al., 2017), and farmed Atlantic salmon (*Salmo salar*) that have escaped from net pens into Puget Sound. An especially large event occurred in 2017, when over 250,000 fish spilled out of a failing net pen near Cypress Island in northern Puget Sound (WDFW, 2017). The ecological impacts of these introductions are not fully understood. Non-indigenous species that do not directly impact species inside OCNMS (e.g., *Spartina alterniflora*; Civille et al., 2005) were not considered here.

Comparison to 2008 Condition Report

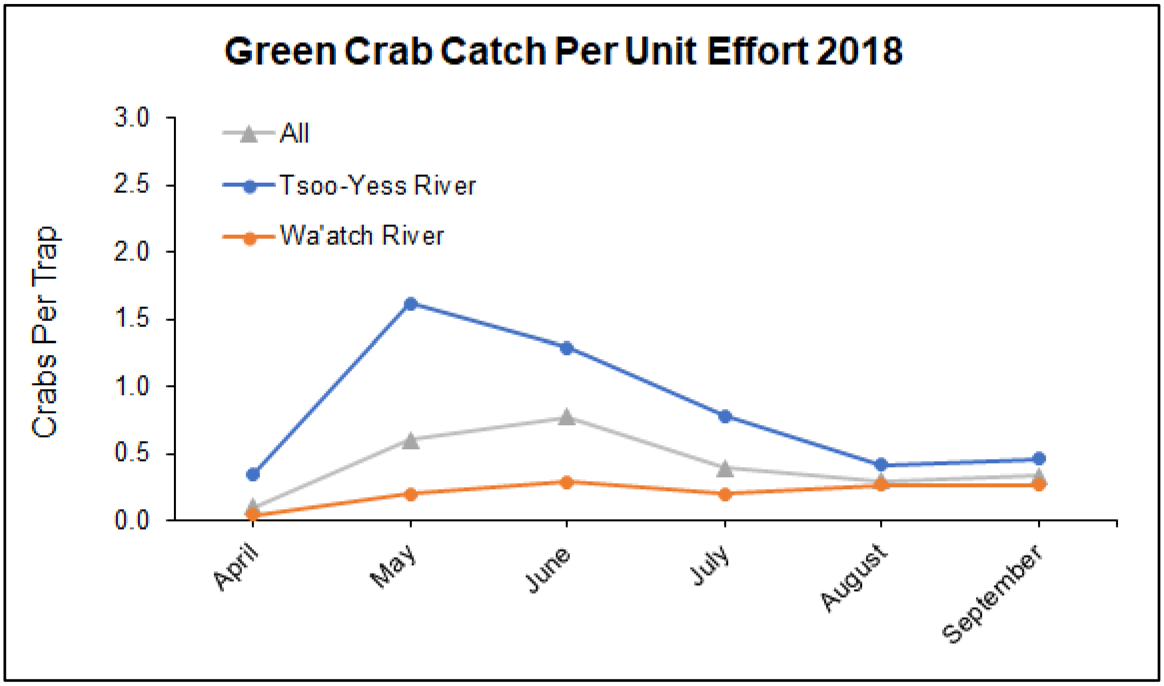
While there were more non-indigenous species of concern at the time of this assessment, the status and trend ratings were the same in both the 2008 and 2008–2019 condition reports (Table S.LR.12.1 and Appendix H). Specifically, the 2008 status was good/fair and the trend was worsening because the distributions of invasive *Sargassum muticum* and tunicates were expanding at sites inside OCNMS (ONMS, 2008). The present ratings were not based on expanding *Sargassum* distributions, but rather on the first recorded presence and increasing abundances of European green crab (Akmajian & Halttunen, 2019) and the occurrence of non-indigenous species in OCNMS due to the 2011 tsunami in Japan (Carlton et al., 2017). While the

2008 rating focused on pelagic habitats, the 2008–2019 status and trend looked across rocky shore and pelagic habitats, as well as at estuaries and river mouths adjacent to the OCNMS boundary. While better monitoring data were available for rocky shore habitats, minimal monitoring data on non-indigenous species were available for sandy beach, kelp forest, and deep-sea habitats. Currently, there are no known non-indigenous species of concern in these habitats.

New Information in the 2008–2019 Condition Report

As noted above, new information about European green crab and the influx of non-indigenous species as a result of the 2011 tsunami were the primary drivers of the ratings. European green crabs (Figure S.LR.14.1) were first reported in Washington in 1998 in Willapa Bay and Grays Harbor (Figlar-Barnes et al., 2002; Yamada & Gillespie, 2008). They were originally introduced by humans to California and then their larvae spread northward. Nineteen years later, the species was documented in estuaries and river mouths (i.e., Wa'atch and Tsoo-Yess River estuaries on the Makah Reservation) adjacent to OCNMS in late 2017. Since 2017, more than 2,500 European green crabs have been captured in the two estuaries during aggressive trapping efforts. Catch per unit effort appears to be increasing, likely due to both increasing abundance and improved capture methods (Figure S.LR.14.2; Akmajian & Halttunen, 2019; Yamada et al., 2019; Akmajian, 2020). Although little is known about the long-term impacts of this species inside OCNMS, European green crabs in British Columbia were found to reduce densities of eelgrass (Howard et al., 2019), which creates important habitat for Pacific salmon and Pacific herring populations (Hosack et al., 2006; Kennedy et al., 2018).

Figure S.LR.14.1. European green crabs captured in a shrimp pot in the Tsoo-Yess River in 2019. Photo: Akmajian, 2020



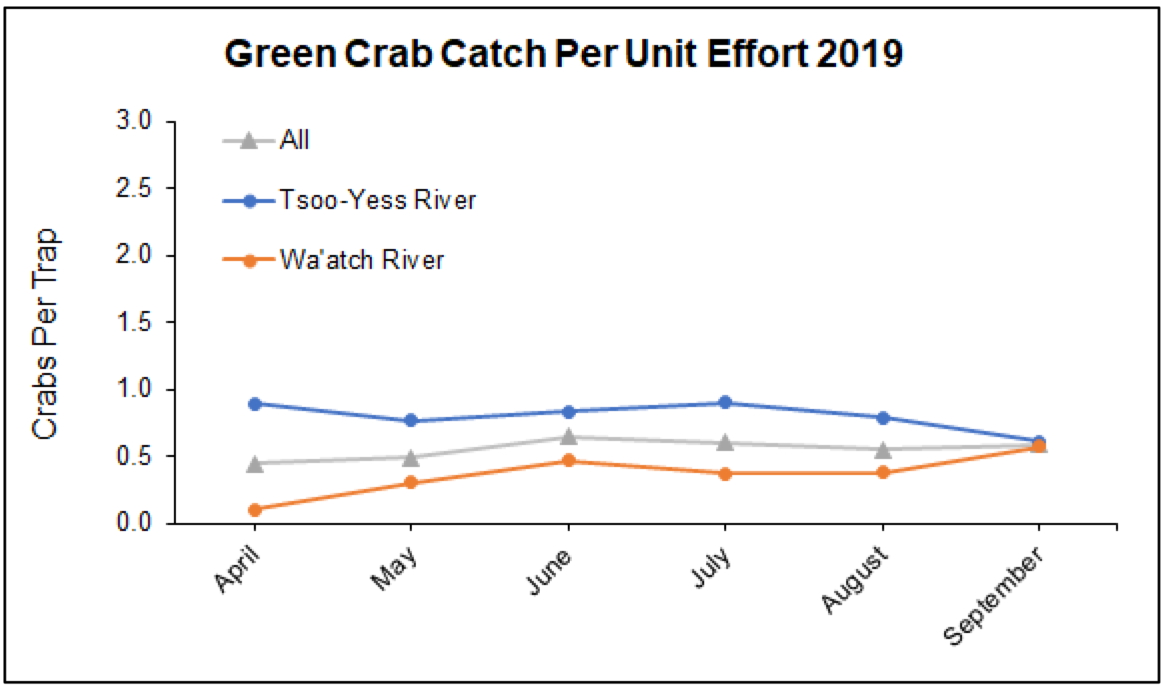


Figure S.LR.14.2. Catch per unit effort for European green crab from trapping in coastal rivers adjacent to Makah Bay in 2018 (top) and 2019 (bottom). Image: Akmajian & Halttunen, 2019

Around the same time that European green crabs were discovered adjacent to the sanctuary, there was an accidental release of farmed Atlantic salmon inside Puget Sound. Some of these farmed salmon were later caught in waters adjacent to and inside OCNMS (Figure S.LR.14.3; WDFW, 2017). In response to this release, Washington state banned new non-native fish pens in 2018; however, only new pens are prohibited, and it may be several years before existing leases expire and facilities are removed. This accidental release was not the first such introduction of Atlantic salmon into Pacific Northwest waters, but it was the first that resulted in detection of this species in OCNMS.

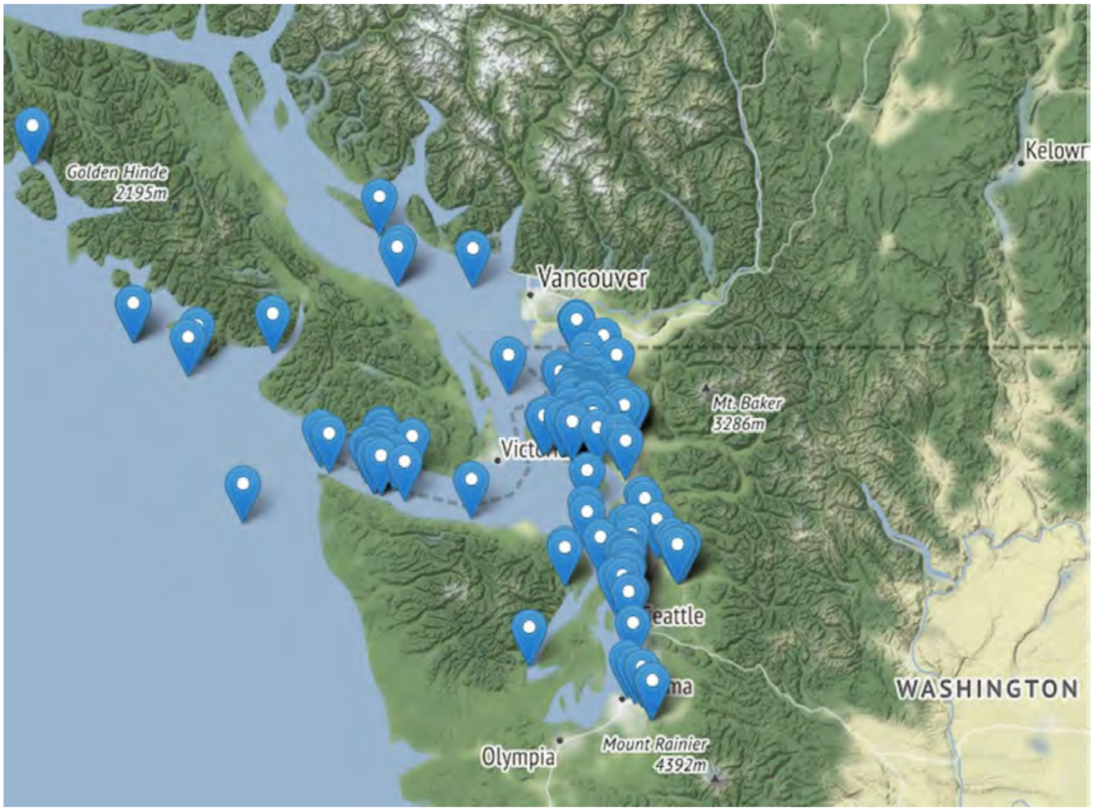


Figure S.LR.14.3. Locations where Atlantic salmon have been caught since their accidental release from a failing net pen near Cypress Island in 2017. Atlantic salmon have been caught in water adjacent to and inside OCNMS. Image: WDFW, 2017

In addition to European green crabs and Atlantic salmon, several species that were transported from Japan to OCNMS as a result of the 2011 tsunami are of concern. This tsunami was estimated to have introduced at least 289 non-indigenous species to West Coast waters and shorelines (Figure S.LR.14.4, Carlton et al., 2017). Non-indigenous biota included macroinvertebrates (235 taxa), fish (2 taxa), microinvertebrates (33 taxa), and protists (19 taxa). The majority of these organisms rafted on debris and landed in Washington and Oregon between 2012 and 2014 (Figure S.LR.14.5). Ninety percent of larger debris items (e.g., boats and docks; Figure S.LR.14.6) were removed from beaches. These removal efforts appear to have been effective in preventing non-indigenous species from becoming established (Hansen et al., 2018; Clarke Murray et al., 2019); however, a long-term monitoring site has been set up in Grays Harbor to track whether any Japanese species become established (Clarke Murray et al., 2019).

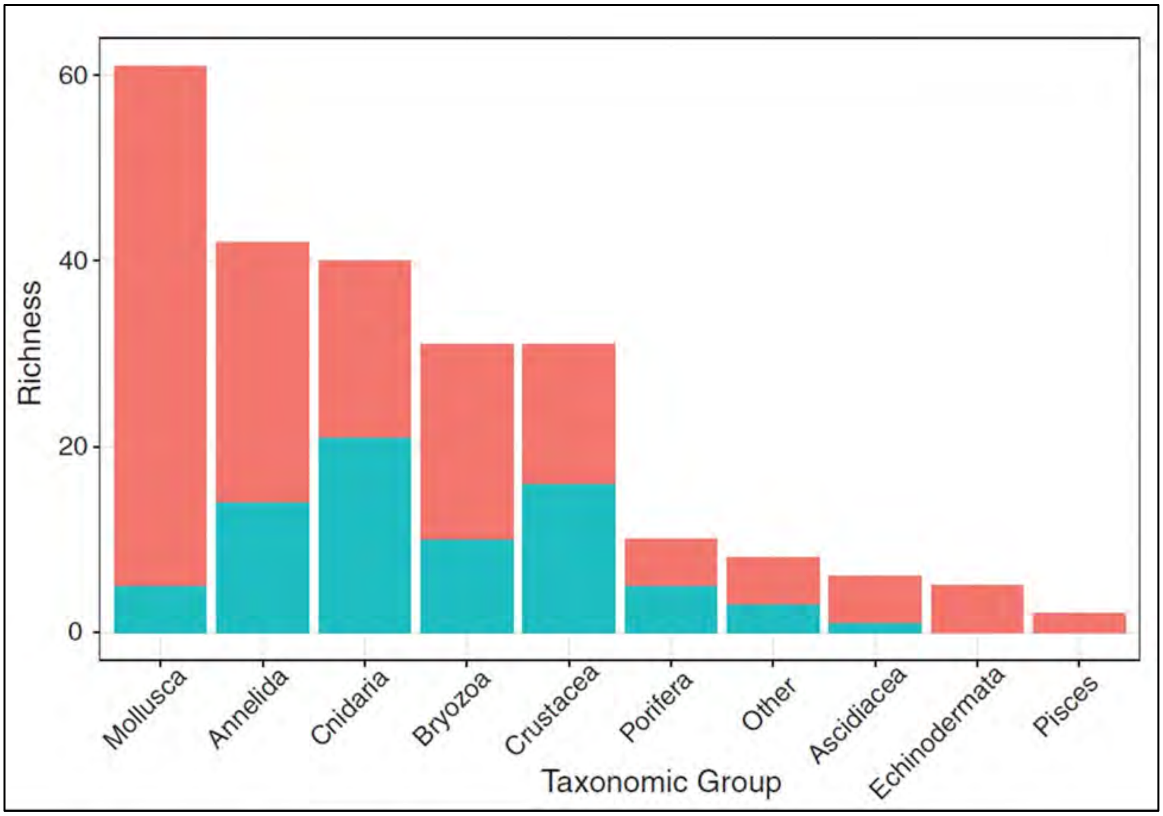


Figure S.LR.14.4. Living, non-indigenous species (by taxonomic group) introduced to the U.S. West Coast as a result of the 2011 tsunami in Japan. The turquoise shading denotes the number of non-indigenous species present before the tsunami. The coral bars denote the number of non-indigenous species introduced as a result of the tsunami. Image: Carlton et al., 2017

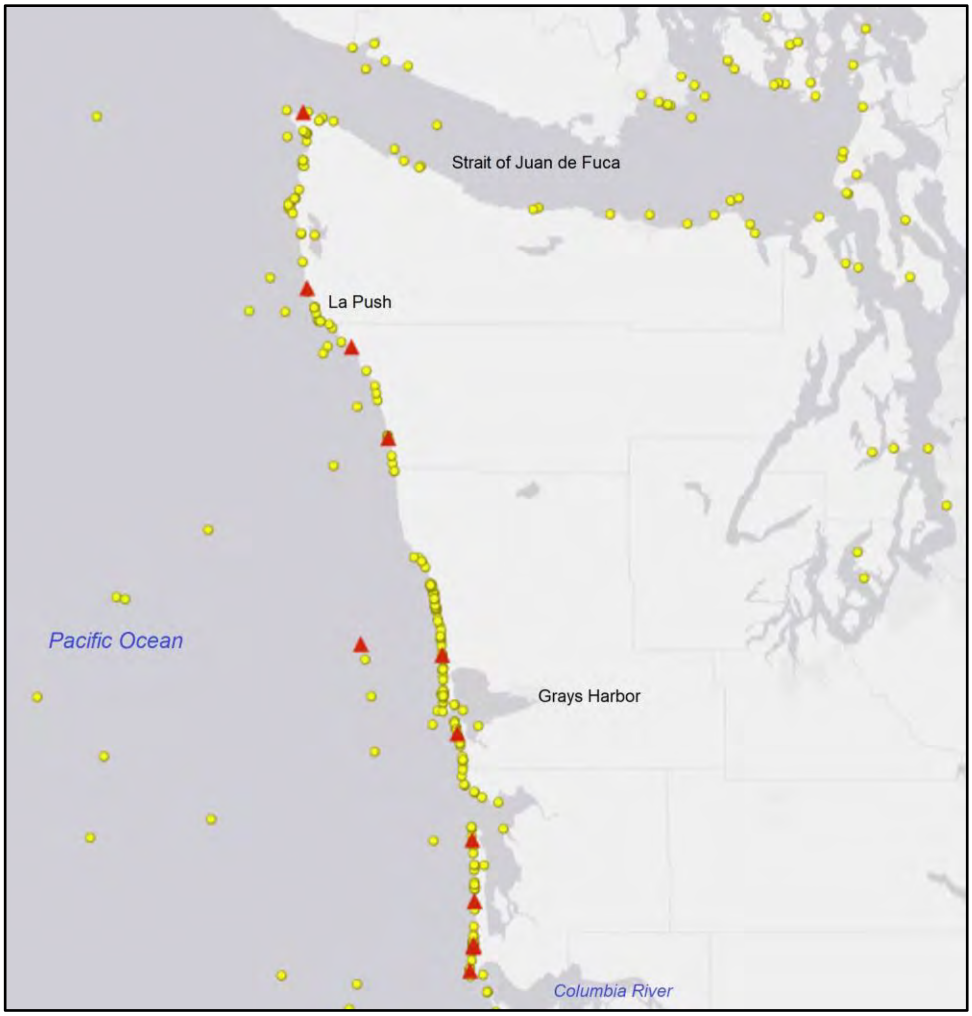


Figure S.LR.14.5. Confirmed (triangles) and potential (circles) marine debris from the 2011 tsunami reported from December 2011 to February 2016 in OCNMS. Image: Office of Response and Restoration, 2016

Figure S.LR.14.6. In December 2012, a 66-ft floating dock, dislodged from Misawa, Japan during the 2011 tsunami, washed up on the Olympic Coast of Washington near Mosquito Creek. Photo: Marine Debris Program, 2012

While European green crabs, Atlantic salmon, and tsunami-introduced species were of the highest concern, there are other known non-indigenous species inside OCNMS, including the algae *Sargassum muticum* and *Caulacanthus okamurae*. These two species are less of a concern than European green crab because their densities have remained low at specific sites since 2008 compared to pre-2008 levels (MARINe, 2019). Specifically, MARINe biodiversity surveys showed that *S. muticum* and *C. okamurae* were present at Cannonball Island before 2008. MARINe long-term monitoring surveys found that *C. okamurae* was also present at low levels (< 6% cover) at Point of the Arches every year between 2013 and 2018 (MARINe, 2019). Survey data from the Makah Reservation also documented the presence and low abundance of *S. muticum* in 2017, although it is unknown when it arrived (Akmajian, 2017).

Conclusion

In OCNMS, there is high confidence that the status of non-indigenous species was good/fair and the trend was worsening in 2008–2019. This indicates that non-indigenous species are present and may preclude full community development and function in OCNMS, but have not yet caused measurable degradation. However, there were clear data gaps inside OCNMS, including understanding the presence and abundance of: (1) non-indigenous species in rocky shore habitats (including *Mytilus galloprovincialis*) from monitoring datasets other than MARINe; (2) tropical and subtropical gelatinous pyrosomes in deep seafloor habitats; and (3) Humboldt squid in pelagic habitats. There was also inadequate information to determine whether some species (e.g., European green crabs) are permanently displacing or otherwise negatively affecting native species and whether some species (e.g., subtropical and tropical pyrosomes) are temporarily present due to the 2013–2014 marine heatwave or are permanently present due to range expansions associated with changing climate and oceanic conditions.

Table S.LR.14.1. Status and trends for individual Question 14 indicators discussed at January 2020 workshop.There are no confidence scores for individual indicator status and trends.

Indicator	Source	Habitat	Data Summary	Figures
European green crab 2018–2019 (catch per unit effort)	Akmajian, 2020; Akmajian & Halttunen, 2019	Estuary	Status: In 1998, European green crab was first reported in Washington, including in Willapa Bay and Grays Harbor. In 2017, European green crabs were first observed near OCNMS in Wa'atch and Tsoo-Yess Rivers. Trend: Increasing trend.	S.LR.14.1–S.LR.14.2
Atlantic salmon (presence)	WDFW, 2017	Pelagic	Status: In 2017, 250,000 farmed Atlantic salmon escaped into Puget Sound. Trend: Undetermined. Data gap.	S.LR.14.3
Tsunami-introduced non-indigenous species (species richness)	Carlton et al., 2017; Office of Response and Restoration, 2016; Marine Debris Program, 2012	All	Status: The 2011 tsunami introduced at least 289 non-indigenous species to the U.S. West Coast, and the majority landed in Washington and Oregon between 2012–2014. Trend: Undetermined. Data gap.	S.LR.14.4–S.LR.14.6
Sargassum muticum (presence/ absence)	MARINe, 2019; Akmajian, 2017	All, rocky shore	Status: *S. muticum* present in OCNMS pre-2007. Not observed in MARINe long-term monitoring plots to date. Observed on Makah Reservation in 2017. Trend: Undetermined. Data gap.	
Caulacanthus okamurae (presence/ absence)	MARINe, 2019	Rocky shore	Status: Low abundance in plots at Point of the Arches every year between 2013–2018. Trend: Undetermined. Data gap.	
Data gaps	Rocky shore, deep seafloor, pelagic		Rocky shore: Non-indigenous species in rocky intertidal not well surveyed (including *Mytilus galloprovincialis*) Deep seafloor: Tropical and subtropical pyrosomes (species that are problematic in Puget Sound) Pelagic: Humboldt squid	

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

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: Some keystone and foundation species experienced significant declines after 2013, which may have altered biodiversity and community structure and function. A worsening trend was determined based on changes to keystone and foundation species and declining diversity metrics over the last several years for groundfish; however, variable results for some other groups suggest that more comprehensive biodiversity assessments are needed.

Biodiversity assessment in national marine sanctuaries considers not only direct measures of community structure, which are calculated using numbers of species and their relative abundances (e.g., richness, evenness, Simpson's diversity index), but also the status of functional interactions among species. This may include the impacts of changing relative abundances on trophic relationships, competition, or symbioses. The objective is to ascertain whether observed conditions are within the expected range of natural variation of the ecosystem. In this assessment, the status of biodiversity in OCNMS was good/fair (with low confidence) and the trend was worsening (with low confidence). This rating suggests that selected biodiversity loss or change is suspected and may preclude full community development and function, but has not yet caused measurable degradation. The rating for this question was based on current information and trends for biodiversity from 2008–2019 (Table S.LR.15.1). Over the last decade, though no species are known to have been extirpated in OCNMS, some foundation and keystone species (e.g., purple and sunflower sea stars) experienced significant declines after 2013, which may have changed community structure, function, or biodiversity (see Question 12). Unfortunately, no data are available to quantify community impacts.

Comparison to 2008 Condition Report

In 2008, the status for biodiversity was fair and the trend was undetermined (confidence was not recorded) (Table S.LR.12.1 and Appendix H). In this assessment, the status improved to good/fair (with low confidence), but the trend was worsening (with low confidence). The low confidence scores resulted from data and analysis gaps for a number of species groups, including shorebirds, benthic invertebrates, flatfish, cetaceans, and seabirds. The higher status rating reflects the recovery of several groundfish stocks over the last 10 years, which resulted in fairly high abundance of these species in most years since 2009. The historical depletion of groundfish was an influential driver of the status rating in 2008. Since then, many groundfish stocks have recovered in response to fisheries management actions. These recoveries are juxtaposed with severe declines in certain keystone species abundances (e.g., purple and sunflower sea stars) over the last 10 years. Declines in sea star populations have, or likely will, negatively impact biodiversity in rocky shore and kelp forest ecosystems inside OCNMS; however, these impacts have not been well quantified due to insufficient monitoring data in these key habitats.

New Information in the 2008–2019 Condition Report

The good/fair rating was primarily driven by information about groundfish and, to some extent, plankton biodiversity metrics. For groundfish, annual variations in richness and Simpson's diversity index were high during the reporting period (2009–2019), but means for most years were similar to long-term means (2003–2018) (Figure S.LR.15.1; CCIEA, 2021). Over the last decade, groundfish density was fairly stable, but species richness and diversity both exhibited downward trends, particularly since 2014. Species richness and diversity estimates, however, are strongly influenced by sampling effort, and failure to recognize this can provide erroneous conclusions about the status and trends for the groundfish community (Greenstreet & Piet, 2008). Therefore, the biodiversity metrics in Figure S.LR.15.1 should be considered cautiously until more analyses are conducted to confirm the statistical power and robustness of the West Coast groundfish trawl survey's annual sampling effort within OCNMS boundaries.

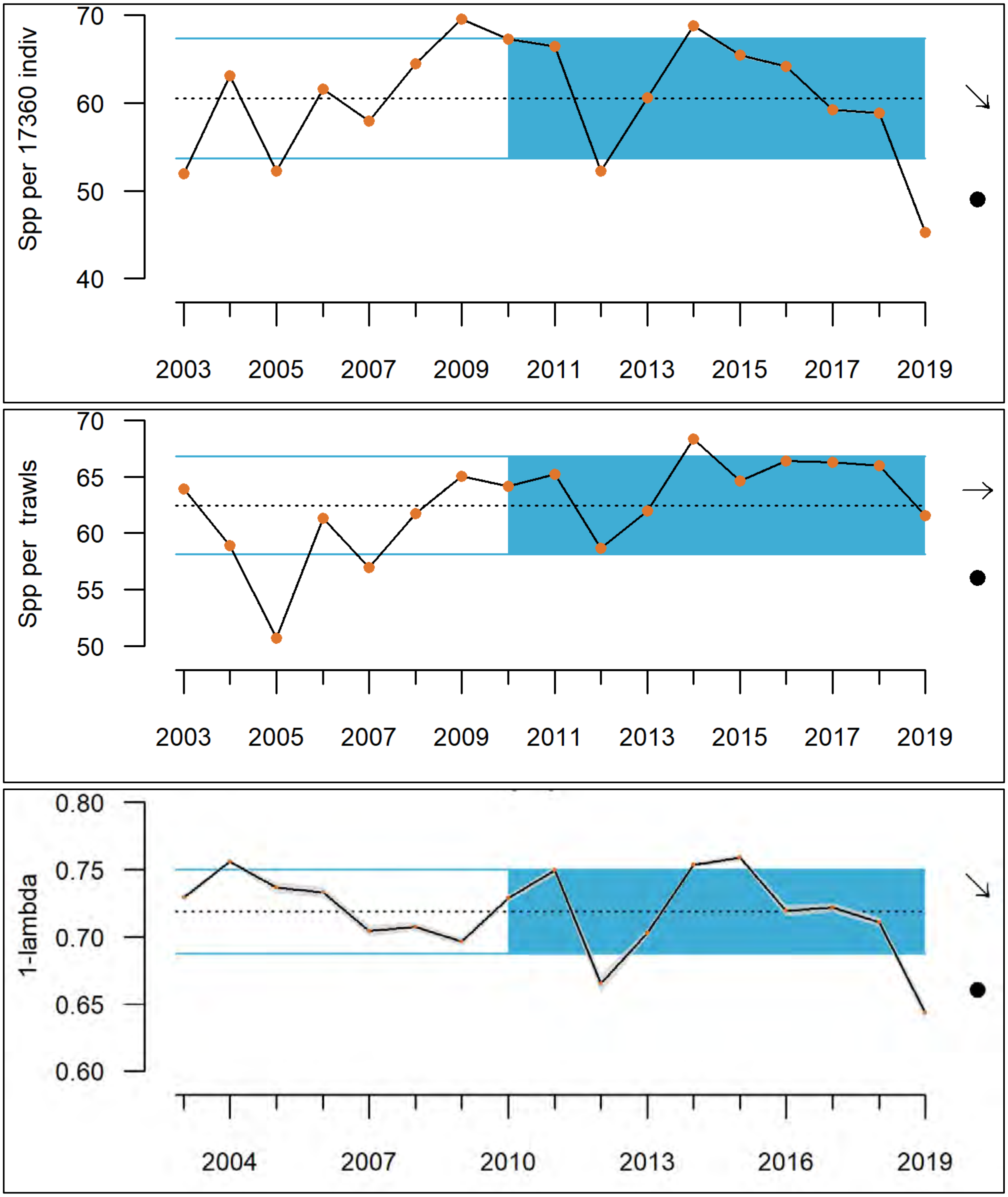


Figure S.LR.15.1. Species richness (top), species density (middle) and Simpson's diversity index (bottom) for groundfish from NOAA Fisheries scientific bottom trawl surveys inside OCNMS through 2019. The black dots (●) indicate that 10-year means (2010–2019, shaded in blue) are within one standard deviation of the long-term mean, and the horizontal (→) and declining (↘) arrows indicate 10-year trends. The dashed line is the long-term mean and solid blue lines are ±1 standard deviation. Source: CCIEA, 2021; Image: G. Williams/NOAA

Changes in the plankton community composition off Washington and Oregon were also observed starting in 2014 (Figures S.LR.15.2–S.LR.15.3). These changes were associated with the 2013–2014 marine heatwave (Peterson et al., 2017; Brodeur et al., 2019), and are reflected in the higher frequency of phytoplankton species richness anomalies over the last decade (Figure S.LR.15.2; Peterson et al., 2017). The data are, however, insufficient to determine whether these plankton community shifts are likely to persist. The marine heatwave also marked the beginning of significant declines in keystone species abundances (notably, purple and sunflower sea stars; MARINe, 2019). Biodiversity of organisms attached to the primary substrate has been shown to be positively correlated with the presence of purple sea stars (Wilkes, 2019). Declines in sea star abundances have had or will likely have negative impacts on biodiversity in rocky shore and kelp forest ecosystems.

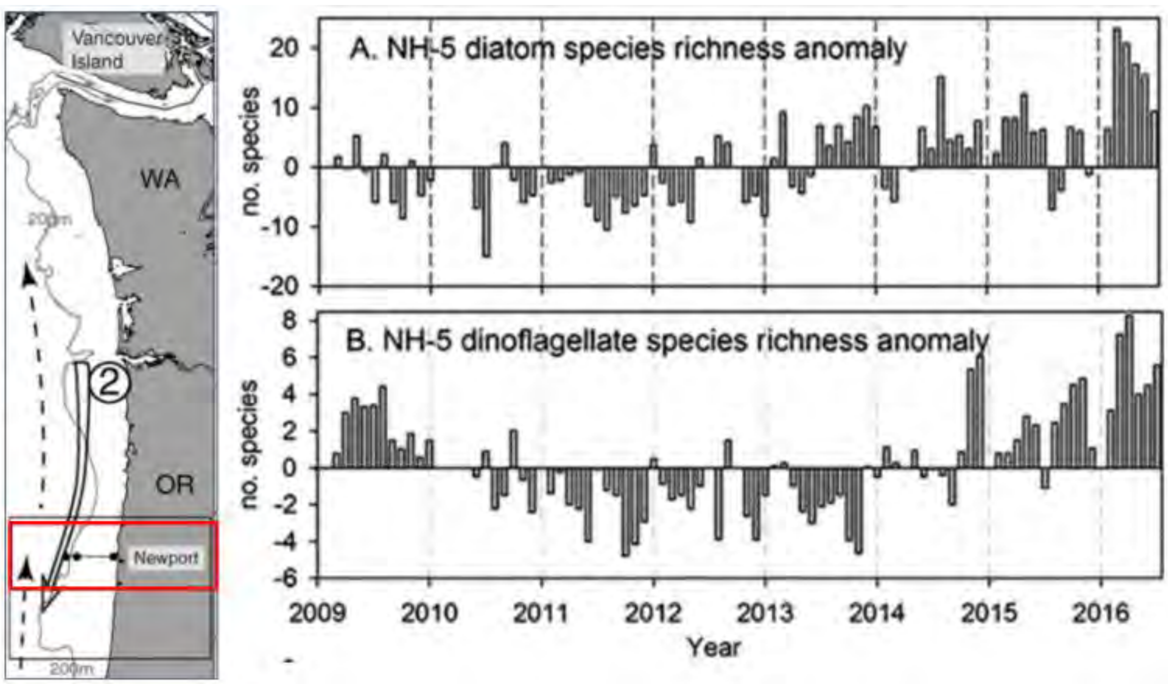


Figure S.LR.15.2. Diatom (top) and dinoflagellate (bottom) species richness anomalies for 2009–2016 offshore of Newport, Oregon. Image: Peterson et al., 2017

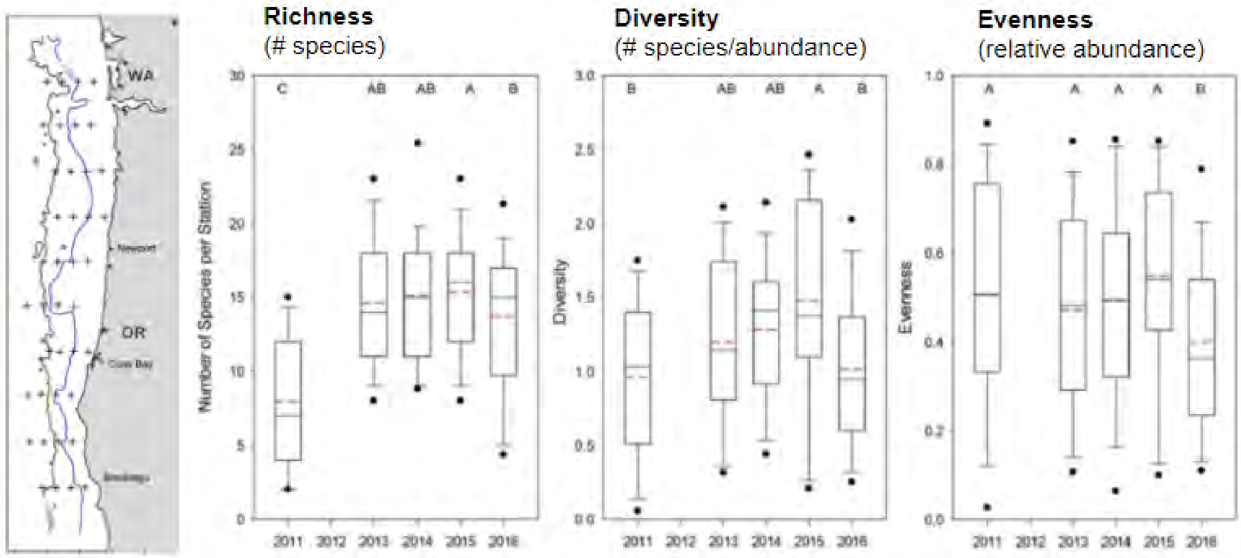


Figure S.LR.15.3. Box plots showing pelagic larvae and zooplankton species richness, diversity, and evenness for all trawls (see map, left) in southern Washington and Oregon (2011 and 2013–2016). Image: Brodeur et al., 2019

Discussions of findings elsewhere in this report also influenced the ratings of status and trends. These included concerns about recent severe HABs, episodic hypoxia, and the increasing frequency of non-indigenous species introduction. There is a lack of information, however, on the impacts of these factors on biodiversity.

Conclusion

In this assessment from 2008–2019, the status of biodiversity was good/fair (with low confidence), but the trend was worsening (with low confidence). Limited evidence, as well as data and analysis gaps, reduced expert confidence in the ratings. Experts also expressed concern that the limited biodiversity data available made it difficult to characterize and quantify the profound environmental changes experienced on the Olympic Coast during this assessment period, and to determine the differential potential impacts to mobile versus sessile organisms. Additionally, experts cautioned against relying on individual species abundances as proxies for biodiversity, when species composition has been clearly demonstrated as more relevant to ecosystem function (e.g., the relative abundance of northern to southern copepods; Figure S.LR.12.5). Because few studies have used biodiversity metrics in the sanctuary, developing such indicators is challenging but important, and substantial data gaps remain.

In particular, data gaps exist for infaunal predators in beach habitats and benthic invertebrates in kelp forests. Biodiversity surveys of rocky intertidal habitats done by MARINe prior to the 2008 condition report were not repeated during the 2008–2019 assessment period. Analysis gaps existed for shorebirds in sandy beach habitats, flatfish in sandy seafloor habitats, biogenic and benthic invertebrates in deep seafloor habitats, and cetaceans and seabirds in pelagic habitats. There was not enough information to determine whether some warm-water species (e.g., certain plankton and seabirds like the Manx shearwater) are temporarily present due to the 2013–2014 marine heatwave (Peterson et al., 2017; Brodeur et al., 2019) or are likely to become permanent residents as a result of geographic range expansions forced by climate change. Some data gaps may be filled by new monitoring programs coming online, including U.S.-Navy-funded seabird and mammal surveys on the West Coast. Additionally, eDNA may be useful for understanding biodiversity more broadly in the future.

Table S.LR.15.1. Status and trends for indicators discussed at the January 2020 workshop. There are no confidence scores for individual indicator status and trends.

Indicator	Source	Habitat	Data Summary	Figures
Groundfish (species richness, species density, species diversity)	NWFSC, 2019b; CCIEA, 2021	Deep seafloor	Status: Most, but not all, means were similar to long term mean. Trend: Decreasing richness. No trend in density. Decreasing diversity.	S.LR.15.1
Phytoplankton (diatoms:dinoflagellates species richness anomaly)	Peterson et al., 2017	All	Status: High species richness anomaly 2014–2016 for the Newport, Oregon Hydrographic Line. Trend: Frequency of positive species richness anomalies increasing.	S.LR.15.2
Pelagic larvae and zooplankton (species richness, civersity, evenness)	Brodeur et al., 2019	Pelagic	Status: Recent mean was similar to long-term mean. Trend: Community compositions in 2015 and 2016 were significantly different from previously sampled years due to a warm water event.	S.LR.15.3
Data gaps	Sandy beach, kelp forest, deep seafloor, pelagic		Sandy beach: Infaunal predators Kelp forest: Benthic invertebrates Pelagic: Manx shearwater new to West Coast, new seabird/mammal surveys year-round funded by Navy, new future eDNA data stream.	
Analysis gaps	Sandy beach, sandy seafloor, pelagic		Sandy beach: Shorebirds Sandy seafloor: Flatfish Deep seafloor: Biogenic invertebrates, benthic invertebrates Pelagic: Cetaceans and seabirds	

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. 2008 (left) and 2008–2019 (right) status, trend, and confidence ratings for the maritime heritage question.

2008 Condition Report Questions	2008 Rating	2008–2019 Condition Report Questions	2008–2019 Condition Report Rating
15. Maritime archaeological resource integrity	?	16. Maritime heritage resource integrity	Good/Fair ?

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

Good/Fair ?

Status Description: Selected maritime heritage resources exhibit indications of natural or human disturbance, but there appears to have been little or no reduction in aesthetic, cultural, historical, archaeological, scientific, or educational value.

Rationale: Shipwrecks in the nearshore, and to a lesser extent shipwrecks in deeper water, are degrading, primarily due to natural processes. Traditional canoe routes are actively being used during the annual Tribal Canoe Journeys.

Comparison to 2008 Condition Report

In the 2008 condition report, this question was rated fair with an undetermined trend (see Table S.MHR.16.1 and Appendix H). The basis for judgement included damage caused by fishing activities, cable installations, and unauthorized salvaging. Since 2008, trawling activity has remained steady, but with a southward shift in location. Since that report, no new activity or information on existing cables has been obtained, and no unauthorized salvage has been documented by OCNMS.

New Information in the 2008–2019 Condition Report

Similar to other ONMS sites, OCNMS has partial baseline data on maritime heritage resource conditions and impacts (Galasso, 2017). Of 197 reported vessel losses, nine have been located, and seven have been assessed. Appropriate data on cultural heritage resources and sites have not yet been integrated.

In August 2017, the first archaeological survey of the deep-water (242 meters) wreck of the ex-USS *Bugara* was conducted with an ROV. The survey provided eight hours of direct observation, with video and still camera documentation of the wreck. The 2017 assessment added considerably to an understanding of changes to *Bugara* after it sank while under tow in 1971.

On June 1, 1971, the U.S. Navy tug *Cree* (ATF-45) had the ex-USS *Bugara* in tow en route from the Naval Ammunition Depot at Bremerton, Washington, to a disposal site approximately 100 miles off of Cape Flattery. The submarine was to participate as a target vessel in a live warhead evaluation of the Mark 48 torpedo. Off Cape Flattery, near the mouth of the Strait of Juan de Fuca, the submarine began to take on water in the stern and started to sink. With USS *Cree* at risk of being pulled under, the steel hawser cable was cut. *Bugara* foundered shortly after (OCNMS, 2017a).

A goal of the 2017 survey was to determine ongoing processes of change to the wreck after nearly five decades on the bottom, including biological colonization. *Bugara* lies upright, resting on its keel on an uneven, compact seabed. There is little burial of the hull. It has been colonized, although not extensively, by anemones, a variety of rockfish, and algae. *Bugara*'s pressure hull appears intact, with all hatches closed, and there is no obvious source of the leak that sank the submarine. The steel superstructure that covers the pressure hull is more or less intact, although corroded, and the teak decking has been mostly consumed by marine wood borers, leaving few remnants.

The sail was found to be substantially damaged (figure S.P.16.1), with much of the fiberglass and light steel frame that formed it detached, exposing the inner structure of the conning tower (which formed an integral part of the pressure hull), as well as the periscope shears and the snorkel with its exhaust (Delgado et al., 2018).

Figure S.P.16.1. ROV image of the USS *Bugara* wreck site showing the conning tower area colonized by plumose anemones and a variety of rockfish. Photo: Ocean Exploration Trust

In addition to the ROV footage of *Bugara*, videos of *Temple Bar* and *Lamut* by divers at Frog Kick Diving were reviewed. These videos showed the poor condition of these two nearshore wrecks.

The British freighter *Temple Bar* struck a reef near Quillayute Needles NWR and foundered in shallow water two miles south of La Push in the pre-dawn hours of April 8, 1939. The crew of 36 safely abandoned the ship in lifeboats and were towed to shore by Coast Guard personnel from the Quillayute Coast Guard Station.

Originally visible from shore, *Temple Bar* became a magnet for tourists. Although visible from the La Push breakwater, a better view was to be had by walking two miles along muddy trails to Second Beach. From this vantage point the wreck was visible about a half mile offshore. The cargo of scrap iron and part of the hull were eventually salvaged, and the remaining hull rests in seven meters of water, no longer visible from the surface.

On March 3, 1943, *Lamut* encountered heavy seas and driving rain off the Olympic Coast. The captain, disoriented by the storm, took his ship too close to shore, and it ran aground in a narrow, steep-walled cove not far from Quillayute Needles NWR (Figure S.P.16.2). The crew attempted to launch one of the lifeboats, but it was smashed by the waves, killing one crew member and injuring another. Today, the heavily damaged remains of *Lamut* are in a surge channel immediately adjacent to Teahwhit Head, only accessible by experienced divers in unusually calm conditions.

Figure S.P.16.2. Aerial photo of the wreck of *Lamut* from U.S. Coast Guard aircraft. Image: Robert Schwemmer Maritime Library

In discussions with subject matter experts, there was a consensus that maritime heritage resources were broader than shipwrecks, and there was a desire to assess additional classes of resources that were more highly valued by Native American communities. Some of these important resources, such as middens, are located adjacent to, but just outside, the sanctuary and were not considered within the scope of the condition report. A number of options were discussed, including paleo-landscapes, ancient canoe runs, and traditional canoe routes, some possibly unchanged since contact with Euro-American explorers and traders. These routes are still used by Olympic Coast tribes as part of the annual Tribal Canoe Journeys. The value of Canoe Journeys is discussed in the Heritage chapter. Here, the resource being considered is not the event itself, but the specific location/route. Traditional cultural properties may meet National Register of Historic Places requirements because of the role they play in a community's traditional religion, beliefs, customs, and practices. Examples of properties possessing such significance include a location where a community has traditionally carried out economic, artistic, or other cultural practices important in maintaining its historic identity.

Figure S.P.16.3. Quinault canoe *Os-chuck-a-bick* navigating off the Olympic Coast during the 2009 Paddle to Suquamish Tribal Canoe Journey. Photo: NOAA

The annual Tribal Canoe Journey is an important event for Indigenous peoples of the Pacific Northwest, where canoe families travel in traditional ocean going canoes, following traditional routes, to meet with other native nations at the hosting tribe's home. During the 2008–2019 condition report period, the Makah Tribe hosted in 2010, and the Quinault Indian Nation hosted in 2013. The paddle to Quinault included nearly 100 canoes pulled by representatives from more than 75 tribes. Almost all the tribes are from the Washington/British Columbia region, but some came from as far away as Hawaiʻi, New Zealand, and New York. An estimated 10,000 people celebrated. A canoe journey event was held in all but one year from 2008–2019.

Conclusion

The rating of good/fair with an undetermined trend is an improvement from the 2008 rating of fair. This rating was based not only on the condition of known shipwrecks in OCNMS, similar to the 2008 rating, but a discussion of the use of historical routes and culturally important locations for annual Tribal Canoe Journeys. The confidence ratings of low for both metrics reflect the lack of comprehensive surveys to identify additional maritime heritage resource types and document their occurrence, which represents a major data gap.

State 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 B.

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.

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 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 OCNMS, nine of the 13 final ecosystem services were rated during the January 2020 workshop: consumptive recreation, non-consumptive recreation, science, education, heritage, sense of place, commercial harvest, subsistence harvest, and ornamentals. The other four 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, and tax revenues, or 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.

Consumptive Recreation

Recreational activities that result in the removal of or harm to natural or cultural resources

Status Description: Ability to provide ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Consumptive recreation includes recreational activities that result in the removal of or damage to natural and cultural resources. In OCNMS, this activity is primarily recreational fishing and razor clam harvesting, activities that the sanctuary does not manage. The number of charter boat angler trips had no clear upward or downward trend from 1998–2019, the number of private boat angler trips has increased during the same time period, and the number of razor clam licenses increased from 2011 to 2019. Though the quantity of some fished species kept by charter boats has increased or remained stable, some important or iconic salmon stocks have remained depressed and have yet to recover to provide the desired level of recreational fishing opportunities in the sanctuary.

Recreational fisheries are an important service on the Olympic Coast, contributing to local economies for towns like Neah Bay, La Push, Westport, Pacific Beach, Forks, and Seiku, as well as enhancing personal health and well-being for those who participate (Biedenweg et al., 2016). Shellfish harvesting and recreational fishing can also result in or enhance place attachment (Donatuto & Poe, 2015).

From 1998 to 2019, there was no statistically significant increasing or decreasing trend in the number of annual charter boat trips in OCNMS. The year with the highest number of angler trips was 2003, with over 45,000 trips, and the year with the lowest trips was 1998, with about 28,000 trips. During the same time period, the number of private boat angler trips in OCNMS significantly increased. The highest number of trips occurred in 2014, with almost 78,000; the year with the lowest number of trips was 1998, with about 33,000 (Figures ES.CR.1–ES.CR.2; E. Crust/WDFW, personal communication, December 18, 2020).

In 2019, charter boat fishing contributed $22.1 million in output, $9.6 million in income, and 234 full- and part-time jobs to coastal Washington.[17] Private boat fishing contributed about $15.8 million in output, $5.9 million in income, and 88 full- and part-time jobs in the same year. While there were about 27,000 more private boat angler trips than charter boat trips, charter boats have a greater economic contribution, as they are associated with higher levels of spending. Economic contributions from charter boats remained relatively stable from 1998 to 2019, with the highest contribution levels occurring in 2003 and the lowest occurring in 1998. Private boat contributions increased during this time period, with the highest contributions occurring in 2014 and the fewest occurring in 1998 (Tables App.ES.CR.1–App.ES.CR.2, Figure ES.CR.3; E. Crust/WDFW, personal communication, December 18, 2020).

Jostad et al. (2017) reported recreational fishing participation rates by different demographic categories for Washington state residents. Both saltwater fishing (by boat) and shellfishing were more common among males (11% and 14%, respectively) than females (4% and 10%, respectively). Whites had the highest participation rate for saltwater fishing by boat (8%), followed by Asians (5%), African Americans (4%), and Hispanics (2%). Whites also had the highest participation rate for shellfishing (12%), followed by Asians (11%), African Americans (9%), and Hispanics (1%). People over the age of 65 had the highest participation rate for both saltwater boat fishing and shellfishing (10% and 15%, respectively). People between the ages of 41 and 64 had the next highest participation rate for both types of fishing (8% and 12%, respectively), and people between the ages 18 and 40 had the lowest participation rates (4% and 8%, respectively). People with a master's degree or higher had the highest participation rate for saltwater boat fishing (8%). Those with more than a high school degree but less than a master's and those with a high school degree or less had equal participation rates (7%). People with a master's degree or higher had the highest participation rate for shellfishing (13%), followed by people with more than a high school degree but less than a master's (11%) and people with a high school degree or less (8%). People with an income over $60,000 had the highest participation rate for both saltwater fishing and shellfishing (10% and 14%, respectively), followed by people with an income between $25,000 and $60,000 (5% and 9%, respectively) and people with an income below $25,000 (2% and 7%, respectively). These data show a positive trend between recreational fishing and income, which suggests those with higher incomes may be better able to afford access to the resources. Additionally, the data show that, if there is no recruitment of new recreational anglers, there may be fewer people fishing in the future as those in the 65 and older age category reach a stage where engaging in the fishery is no longer possible.

[17] Coastal Washington is defined as the region composed of the following counties: Snohomish, King, Whatcom, Pierce, Thurston, Mason, Skagit, San Juan, Island, Clallam, Jefferson, Grays Harbor, Pacific, and Clark. This includes Puget Sound, the San Juan Islands, the Strait of Juan de Fuca, and the entire outer coast of the state.

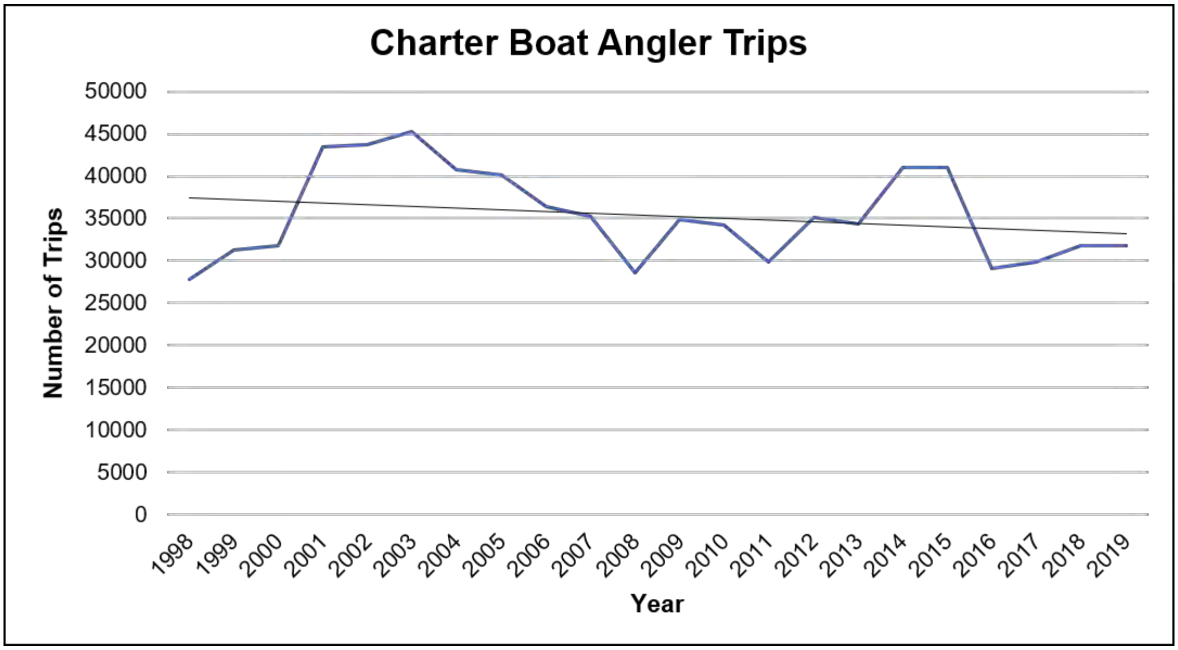


Figure ES.CR.1. Number of angler-days on charter vessels in statistical Areas 2 (Leadbetter Point [North] to Queets River), 3 (Queets River [North] to Cape Alava), 74, and 84 (Bonilla-Tatoosh Line [East] to Sekiu River) (1998–2016), with linear trendline. Source: E. Crust/WDFW, personal communication, December 18, 2020

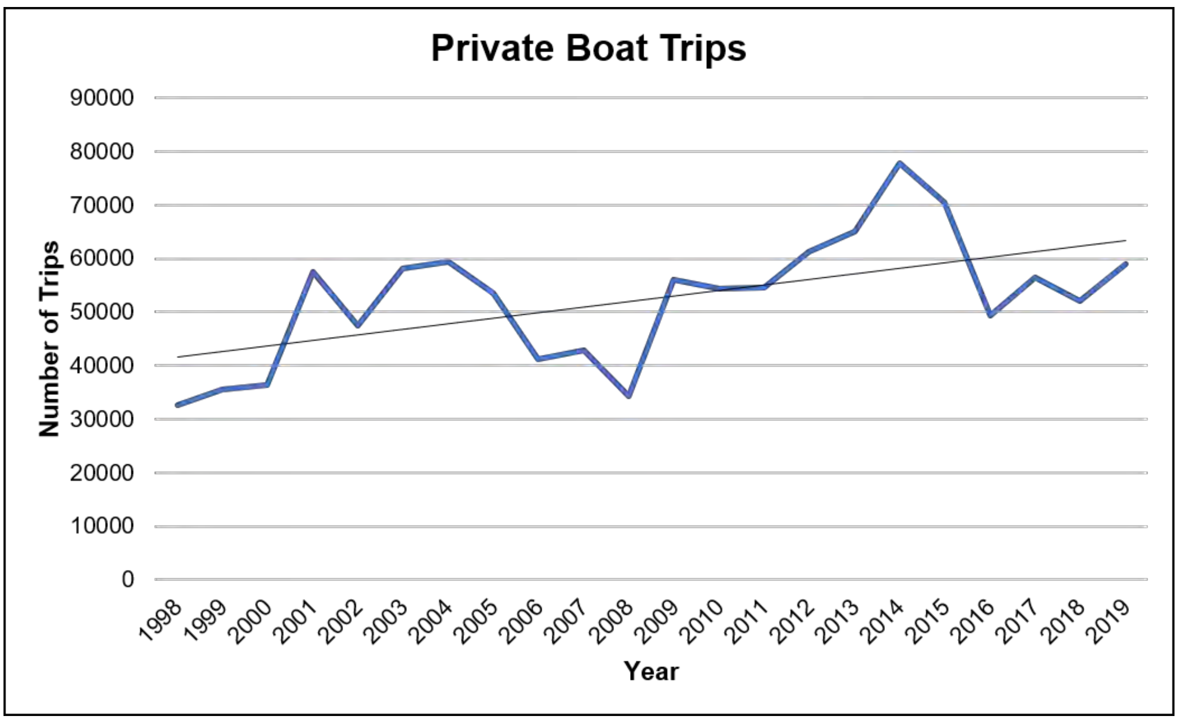


Figure ES.CR.2. Number of angler-days on private vessels in statistical areas 2, 3, 74, and 84 (1998–2016), with linear trendline. Source: E. Crust/WDFW, personal communication, December 18, 2020

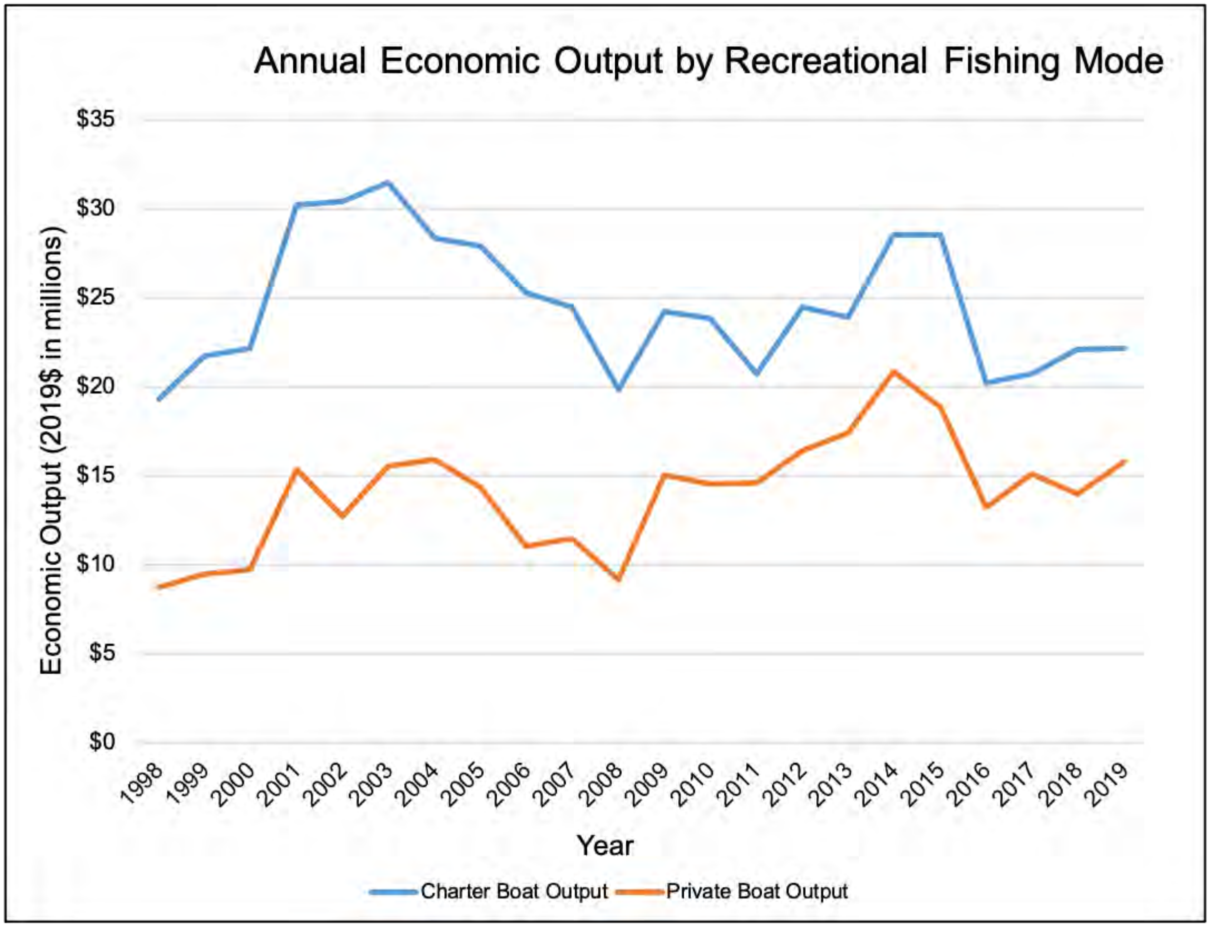


Figure ES.CR.3. Annual economic output from charter and private boat recreational fishing in and near OCNMS, 1998–2019. Source: J. Leonard/NOAA, personal communication, June 16, 2020

The top five species harvested by charter boat anglers between 1998 and 2019 were black rockfish, yellowtail rockfish, lingcod, tuna, and halibut (Table App.ES.CR.3–App.ES.CR.4). The top five species harvested by private boat anglers were black rockfish, lingcod, tuna, halibut, and kelp greenling. Charter boats had a higher number of fish kept from 1998–2019 despite fewer angler trips over the same time period, which indicates that there are more fish caught per angler trip for charter boats than private boats (E. Crust/WDFW, personal communication, December 18, 2020).

The quantity of yellowtail rockfish, lingcod, and tuna kept by charter boats increased from 1998 to 2019. During the same period, black rockfish catch remained stable and halibut catch declined (Figures App.ES.CR.1–App.ES.CR.5; E. Crust/WDFW, personal communication, December 18, 2020). For private boats, the quantity of black rockfish, yellowtail rockfish, lingcod, tuna, and halibut kept increased from 1998–2019 (Figures App.ES.CR.1–App.ES.CR.6; E. Crust/WDFW, personal communication, December 18, 2020). Data provided by WDFW show that the lowest catch levels for salmon during the study period (2008–2019) occured in 2008 and 2016 for both charter and private vessels. Further, peak salmon catch occurred in 2014 for both charter and private vessels. There is no clear linear trend in the data over time (Figure App.ES.CR.7).

Table ES.CR.1 shows residents' satisfaction levels for saltwater fishing (including fishing by shore, boat, or fly fishing) and shellfishing in Pacific, Wahkiakum, and Grays Harbor counties. A majority of residents were satisfied with saltwater fishing in these counties, with 79% of respondents reporting that they were either satisfied or highly satisfied. Residents are also satisfied with shellfishing, with 65% of respondents reporting that they were satisfied or highly satisfied (Jostad et al., 2017). It is worth noting that Pacific and Wahkiakum counties are not adjacent to the sanctuary and Grays Harbor County is partially adjacent to the sanctuary.

Table ES.CR.1. Satisfaction levels for recreational fishing among residents of Pacific, Wahkiakum County, and Grays Harbor counties. Satisfaction levels reflect responses to the prompt: "Please rate how satisfied or dissatisfied you are with the public facilities and opportunities for this activity you did in Washington [state] in the last 12 months." Source: Jostad et al., 2017

Satisfaction Level	Saltwater Fishing	Shellfish Fishing
Highly Satisfied	22%	23%
Satisfied	57%	42%
Neither Satisfied nor Dissatisfied	13%	26%
Dissatisfied	3%	3%
Highly Dissatisfied	2%	2%
No Public Facilities Nearby	3%	3%

Another common recreational activity in OCNMS is razor clam harvesting, which requires a separate license. Figure ES.CR.4 shows the number of razor clam licenses granted from 2009 to 2011. The number of licenses rose from 2011 to 2019, although there was a sharp drop in 2016. The year with the most razor clam licenses was 2017 (638,000), and the year with the fewest was 2016 (544,000).

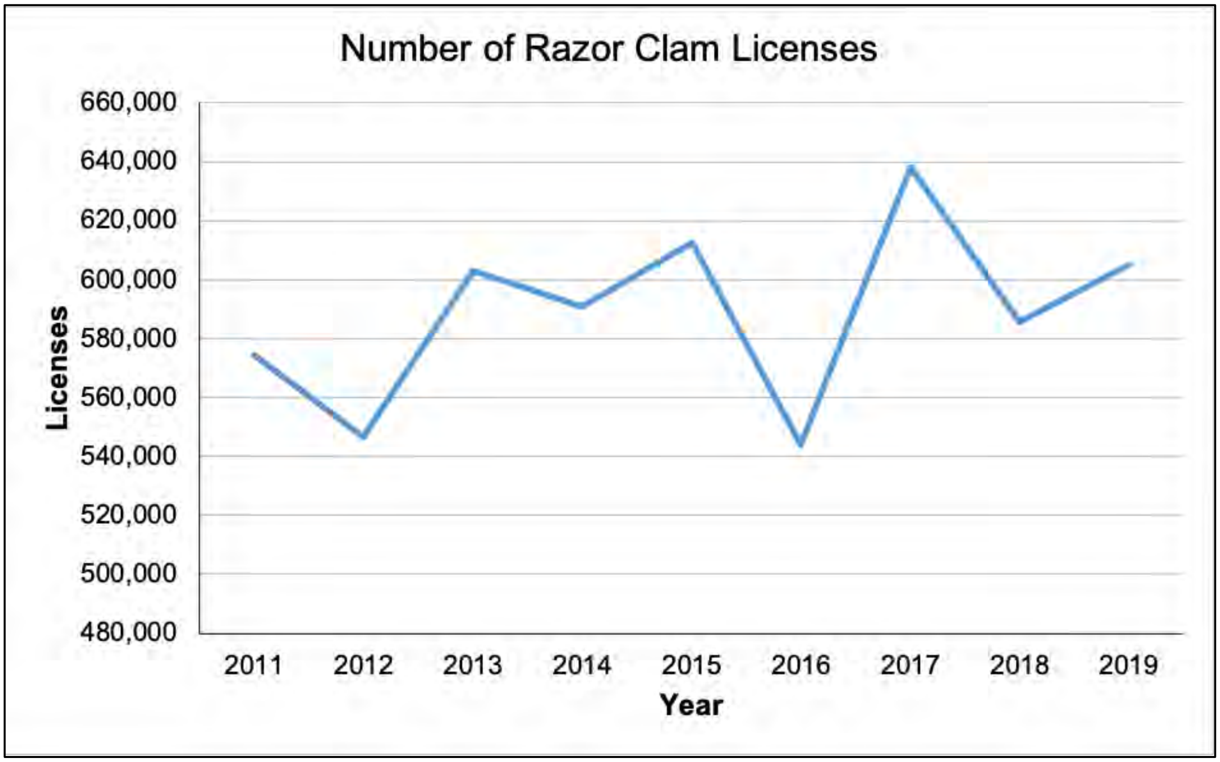


Figure ES.CR.4. Number of razor clam licenses granted from 2011–2019. Source: D. Ayres/WDFW, personal communication, August 11, 2020

Figure ES.CR.5 shows the effort and value for the razor clam fishery within OCNMS (Mocrocks and Kalaloch beaches). Both value and effort for razor clams increased from 1997 to 2020. The fishery was closed in 1998–1999 and 2002–2003 due to high levels of marine toxins, resulting in no catch or value reported for those years. For years the fishery was open, the year with the lowest catch and value levels was 1999–2000, with 319,000 clams harvested and $1.9 million in estimated fishery value. The year with the highest effort and value for razor clams was 2018–2019, with 1.1 million clams harvested and about $7.2 million in estimated fishery value. The 2019–2020 season was anticipated to reach record or near record levels in terms of effort and value, however, the COVID-19 pandemic forced an early closure to prevent the spread of the virus into coastal communities.

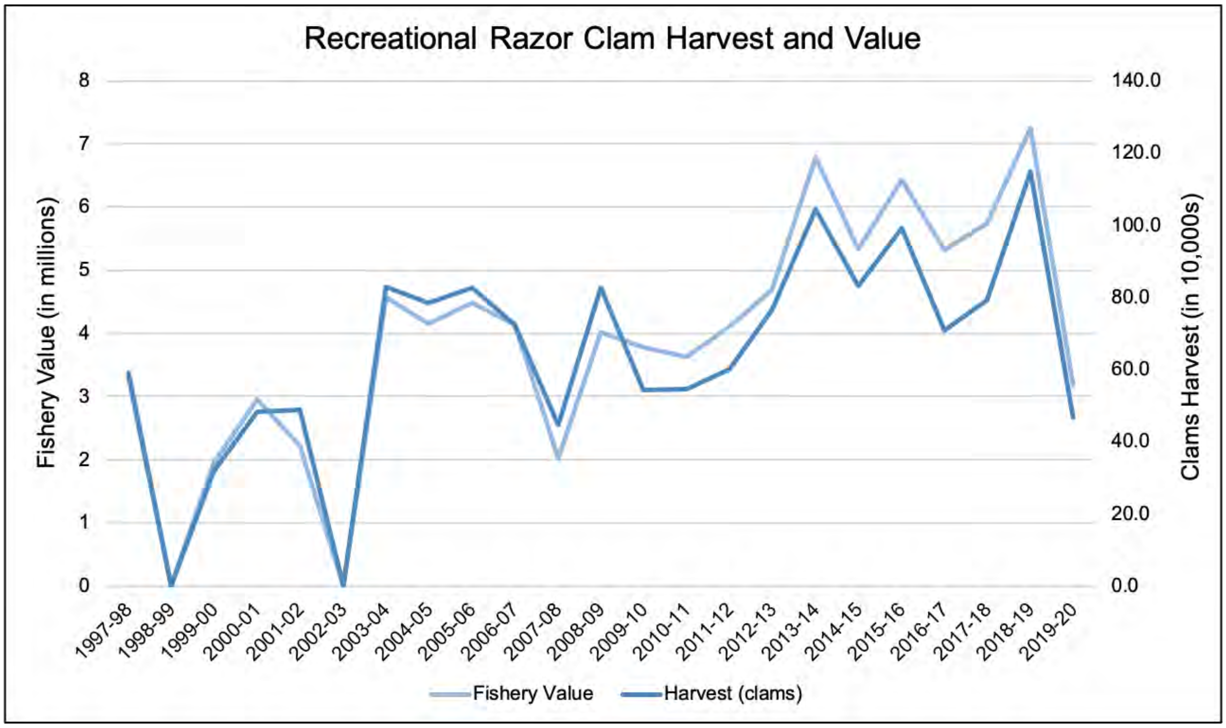


Figure ES.CR.5. Washington recreational razor clam harvest and estimated value. Estimates of fishery value are based on Dyson and Huppert (2010). Source: D. Ayres/WDFW, personal communication, August 11, 2020

Razor clams are one of the most sought after shellfish in Washington state. High densities of people (up to 1,000 per mi^2) visit the Washington coast to harvest razor clams in periodic, short-term (several day) events, including some who have been coming for generations and some first timers.

> "It's beyond a recreational activity. We've been coming to the same beach generation after generation. I even use the same shovel my grandfather used to dig clams back in the 50s. Clamming holds a cultural aspect tied to the tribes who have been around long before. I'm mindful of the traditional side, the patience and tranquility of being present. I see that evident with the traditional tribal side of shellfishing, too" (Frazier, 2017, p. 41).

Resource indicators help to determine whether current use is sustainable and if there is potential for the service to improve or decline. Many stocks have been stable or increasing since 2008, including razor clams (Figure S.LR.13.1; Figure S.LR.13.3) and groundfish (Figure S.LR.13.5). Pacific halibut biomass is increasing in Catch Area 2A (Washington, Oregon, and California; see Figure ES.CH.1). Salmon and steelhead populations on the coast are largely stable (56 of the 81 runs assessed), with six runs of Chinook, coho, and steelhead increasing and 19 runs declining (Figure S.LR.13.12). Populations of harvestable (legal size) Dungeness crab have declined north of Point Grenville since 2005 (Figure S.LR.13.3), but catch per unit effort (including sublegal size crab) has increased in NOAA trawl surveys in OCNMS since 2008 (Figure S.LR.13.4). Currently the trends for black rockfish, yellowtail rockfish, and tuna in the region are undetermined, and the lingcod stock is declining (Figure App.S.LR.13.6). The living resources section shows more details about resource indicators.

Conclusion

Consumptive recreation includes activities that result in the removal of or harm to natural or cultural resources. At OCNMS, this includes fishing and razor clam harvesting, neither of which the sanctuary manages. Recreational fisheries are an important service on the Olympic Coast, contributing to local economies for towns like Neah Bay, La Push, Westport, Pacific Beach, Forks, and Seiku, as well as enhancing personal health and well-being for those who participate. Fishing has remained stable or increased for most species. However, some important or iconic salmon stocks remain depressed, with harvest at a fraction of what it was in the 1970s–1980s.

Non-Consumptive Recreation

Recreational activities that do not result in intentional removal of or harm to natural or cultural resources

Status Description: Ability to provide ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Various measures of visitation have remained stable or increased from 2008 to 2018. Visitors and residents to the OCNMS area report engaging in a variety of non-consumptive recreational activities, including shore-based activities, wildlife viewing, sightseeing, and water-based sports. However, the popularity of recreational activities in OCNMS has led to substantial concerns regarding the region's ability to support increased visitor use, which was a key factor in determining the fair rating. The undetermined trend was driven by uncertainty regarding the effects of increased use on the condition of sanctuary resources and the quality of non-consumptive recreation at some sanctuary locations.

Recreational activities that do not result in the intentional removal of or damage to natural and heritage resources are considered non-consumptive. A variety of non-consumptive recreational activities occur in and adjacent to OCNMS, including whale watching (boat- and shore-based), visitation, shore-based recreational activities (e.g., tide pooling), watersports (e.g., surfing), and boating. Although museum and visitor center use may also be considered non-consumptive recreation, for OCNMS, this is a land-based activity, so these activities are included in the maritime heritage and education ecosystem service discussions.

Washington Marine Spatial Planning (2020) provides information on the spatial distribution of human activities in the state of Washington's marine environments (Figure ES.NCR.1). Diving activities, including scuba diving, free diving, and snorkeling, are generally infrequent within OCNMS, although moderate use is reported at some sanctuary locations. Surface water activities, including boating, kayaking, and surfing, are concentrated toward the northern half of the sanctuary. Shore-based activities (e.g., beachcombing, beach going, hiking, camping) and wildlife viewing/sightseeing (e.g., photography, scenic drives, wildlife viewing from shore or boats) are reported more frequently in the OCNMS region.

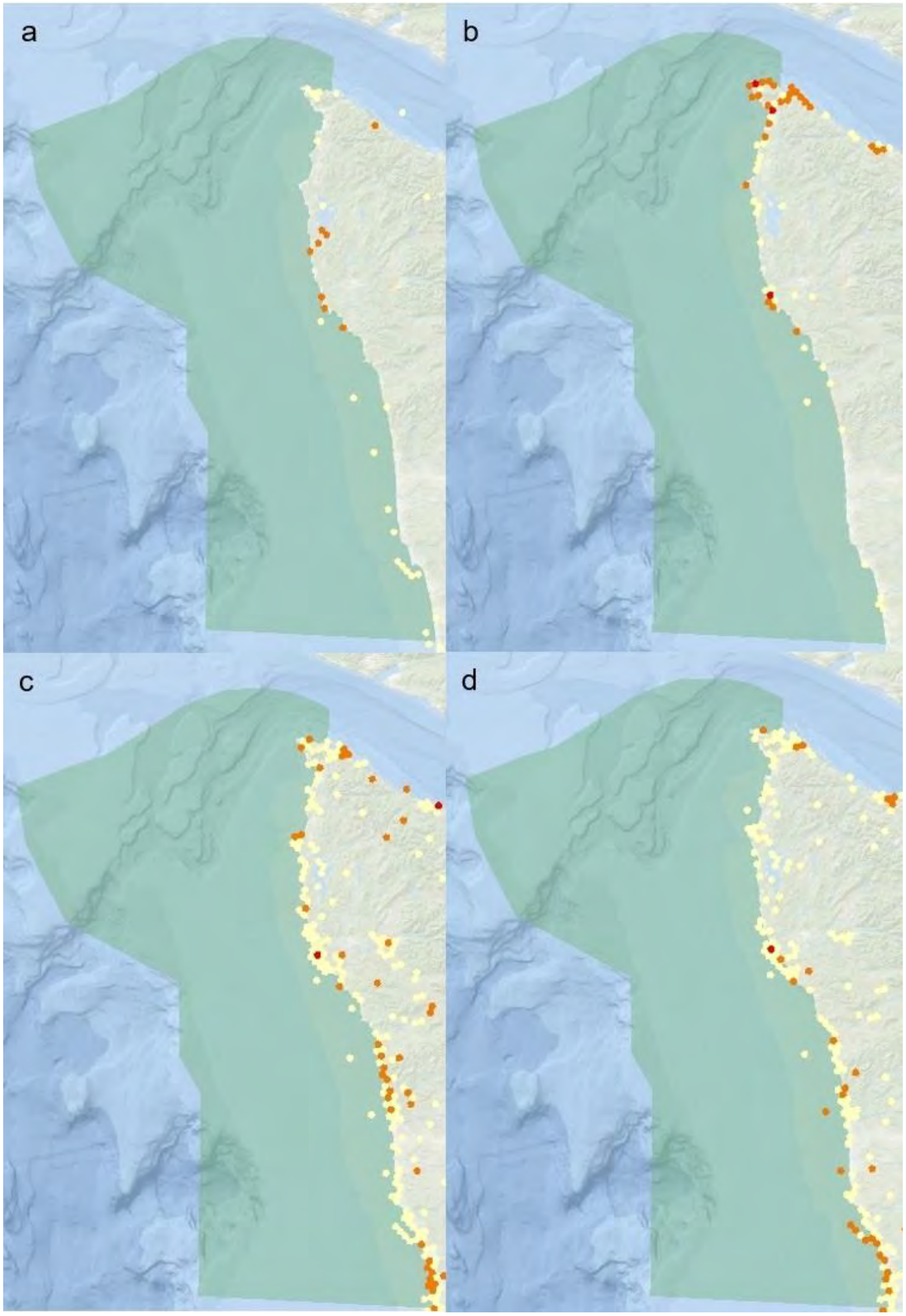


Figure ES.NCR.1. Spatial distribution of recreational activities in and adjacent to OCNMS. The green polygon represents OCNMS boundaries. Red points indicate high use, orange points indicate moderate use, and yellow points indicate low use. (a) Diving activities, including snorkeling, free diving, and scuba diving, from shore and boats. (b) Surface water activities, including boating and sailing, kayaking, kiteboarding, skimboarding, surfing, and windsurfing. (c) Shore-based activities, including beachcombing, beach driving, beach going, biking and hiking, camping, hang gliding and parasailing, horseback riding, and tide pooling. (d) Wildlife viewing and sightseeing activities, including photography, scenic drives, sightseeing, and wildlife viewing from shore and boats. Source: Washington Marine Spatial Planning, 2020

Households in the state of Washington were surveyed in 2014 to provide additional insight into use of the outer coast, including OCNMS, by state residents (Leeworthy et al., 2016). This study provides insight into the types of non-consumptive recreation that sanctuary visitors engage in. Among shore-based activities, those surveyed engaged primarily in beach going (69.0%), collecting non-living resources (31.4%), and tide pooling (30.6%) within OCNMS. Sightseeing (64.5%), watching wildlife from shore (35.2%), and watching scenery from a car (26.4%) were also popular activities. Survey respondents also reported engaging in water-based sports, such as swimming or body surfing (17.7%), snorkeling (12.4%), and kayaking (11.7%) within the sanctuary. While this study provides important insight into recreational use of the sanctuary by Washington residents, additional data are needed to assess recreational use by out-of-state visitors to OCNMS.

A small percentage of Washington residents also reported watching wildlife from a private (9.0%) or charter (2.0%) vessel within OCNMS (Leeworthy et al., 2016). A limited number of commercial whale watching charters operate within OCNMS boundaries. In general, however, whale watching is an increasingly popular activity in the state of Washington; from 1998–2008, the number of whale watchers, whale watch operators, and total expenditures related to whale watching increased statewide (O'Connor et al., 2009).

Although commercial whale watching is limited within OCNMS boundaries, self-guided, shore-based whale watching opportunities exist. The Whale Trail is a Washington-based non-profit organization that has identified a series of sites for shore-based viewing of marine mammals. Nine Whale Trail sites are directly adjacent to the sanctuary (The Whale Trail, 2018). However, data on visitation and use at Whale Trail sites are unavailable.

Workshop participants noted that bird watching is another popular wildlife viewing activity in and adjacent to OCNMS. The Great Washington State Birding Trail Olympic Loop identifies multiple key bird watching sites adjacent to OCNMS (United States Department of Agriculture Forest Service, 2020). Additionally, Olympic Birdfest, an annual bird watching event, includes birding tours in partnership with Audubon and the Makah Tribe at some sites adjacent to the sanctuary (e.g., Cape Flattery; Olympic Birdfest, 2020). Olympic Birdfest maintained steady attendance from 2014–2019 (Dungeness River Audubon Center, personal communication, August 3, 2020).

In addition to wildlife viewing, workshop participants noted that surfing is a popular and effective way to experience OCNMS. Warm Current, in partnership with the Coastal Treaty Tribes, offers community surf camps for Indigenous youth; these surf camps provide opportunities for youth to engage in recreation as well as exploration of their ancestral waters (Warm Current, 2020). Participation in Warm Current surf camps has increased from 2011 to 2018 (Figure ES.NCR.2).

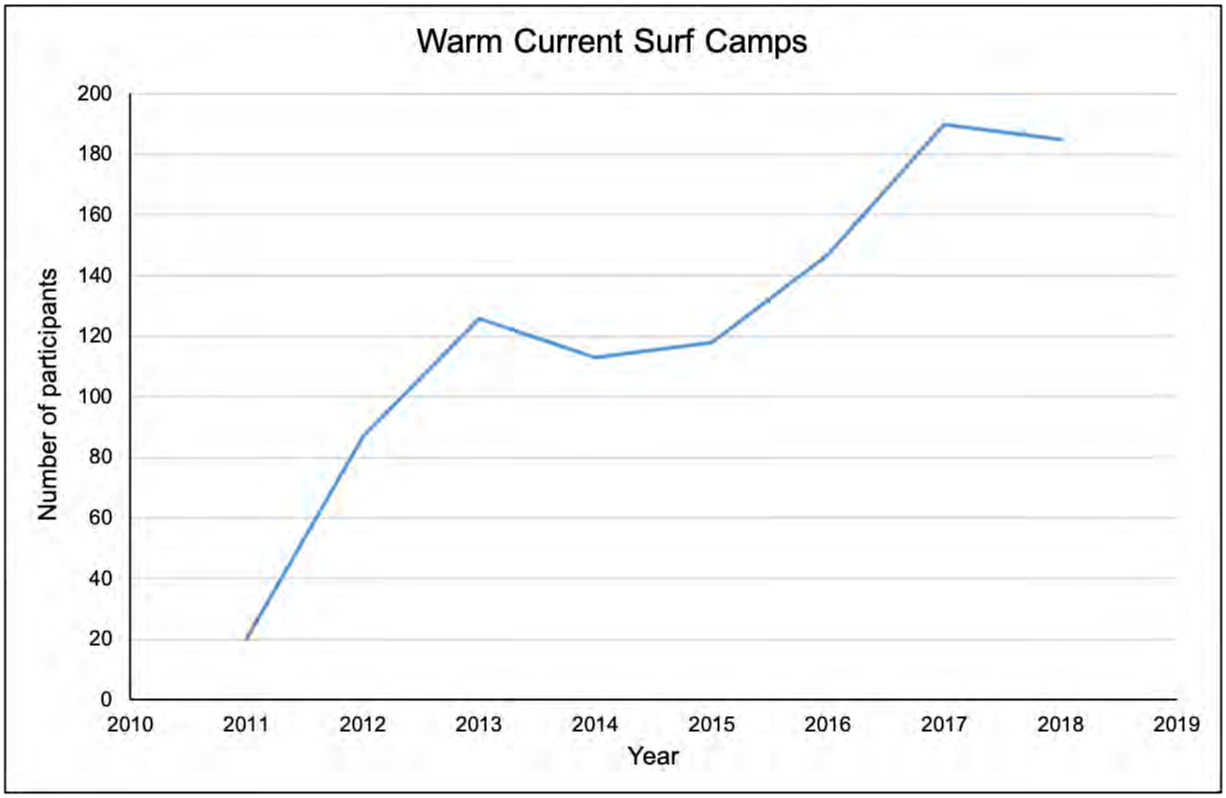


Figure ES.NCR.2. Number of participants in Warm Current surf camps adjacent to OCNMS, 2011–2018. Source: Warm Current, personal communication, September 16, 2020

Recreational boating is another non-consumptive activity in OCNMS, and the number of recreational boat registrations over time provides insight into how this activity has changed over the study period. In the state of Washington, recreational boat registrations decreased from 2009 to 2014, but slowly increased from 2014 to 2018 (Figure ES.NCR.3; National Marine Manufacturers Association, 2019). Data are not available for the portion of registrations that use the outer coast and/or sanctuary.

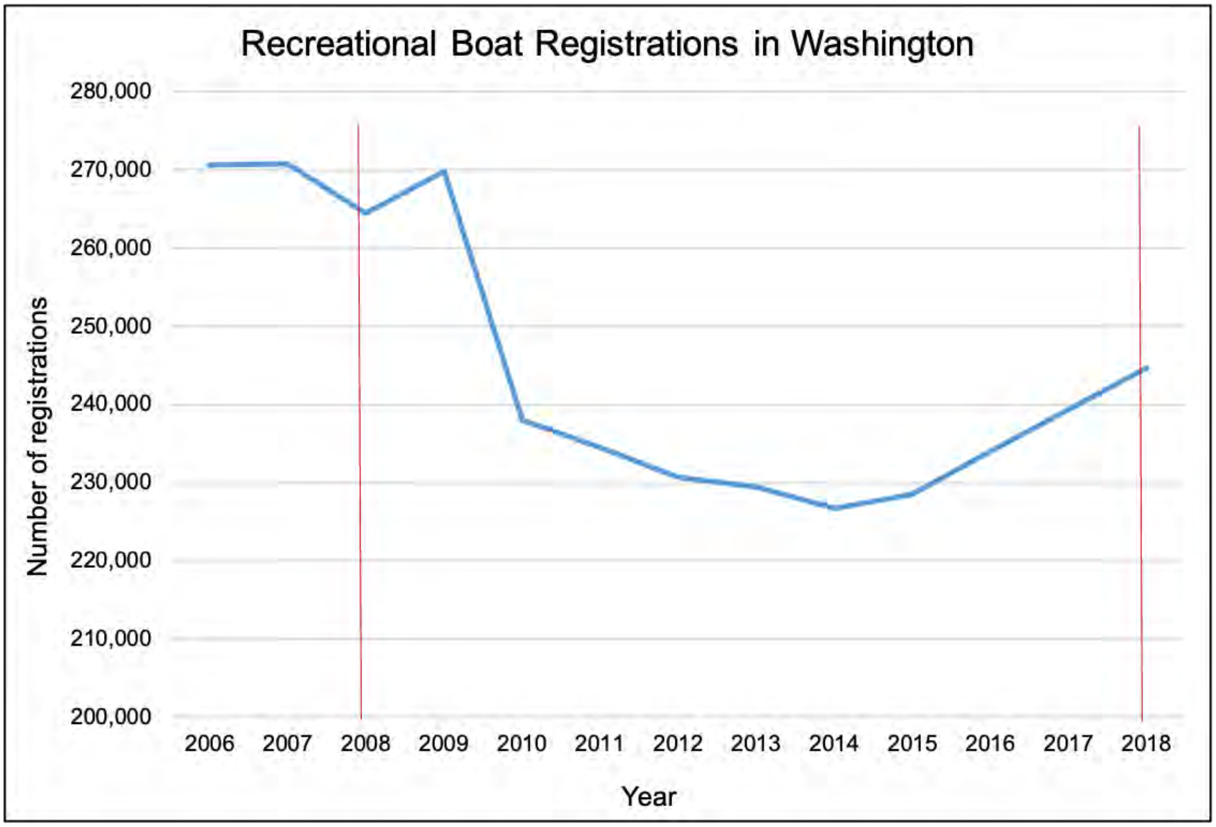


Figure ES.NCR.3. Number of recreational boat registrations in the state of Washington, 2006–2018. Vertical red lines indicate the study period, 2008–2018. Source: National Marine Manufacturers Association, 2019

Information is also available regarding visitation at Cape Flattery, the northern boundary of OCNMS and part of the Makah Reservation. The Makah Tribe offers interpretive talks about the area's natural history and marine wildlife for Cape Flattery visitors. Although visitation decreased from 2015 to 2016, the number of visitors to Cape Flattery steadily increased from 2016 to 2019 (Figure ES.NCR.4). In 2020, the Makah Reservation was closed to non-residents as a result of the COVID-19 pandemic.

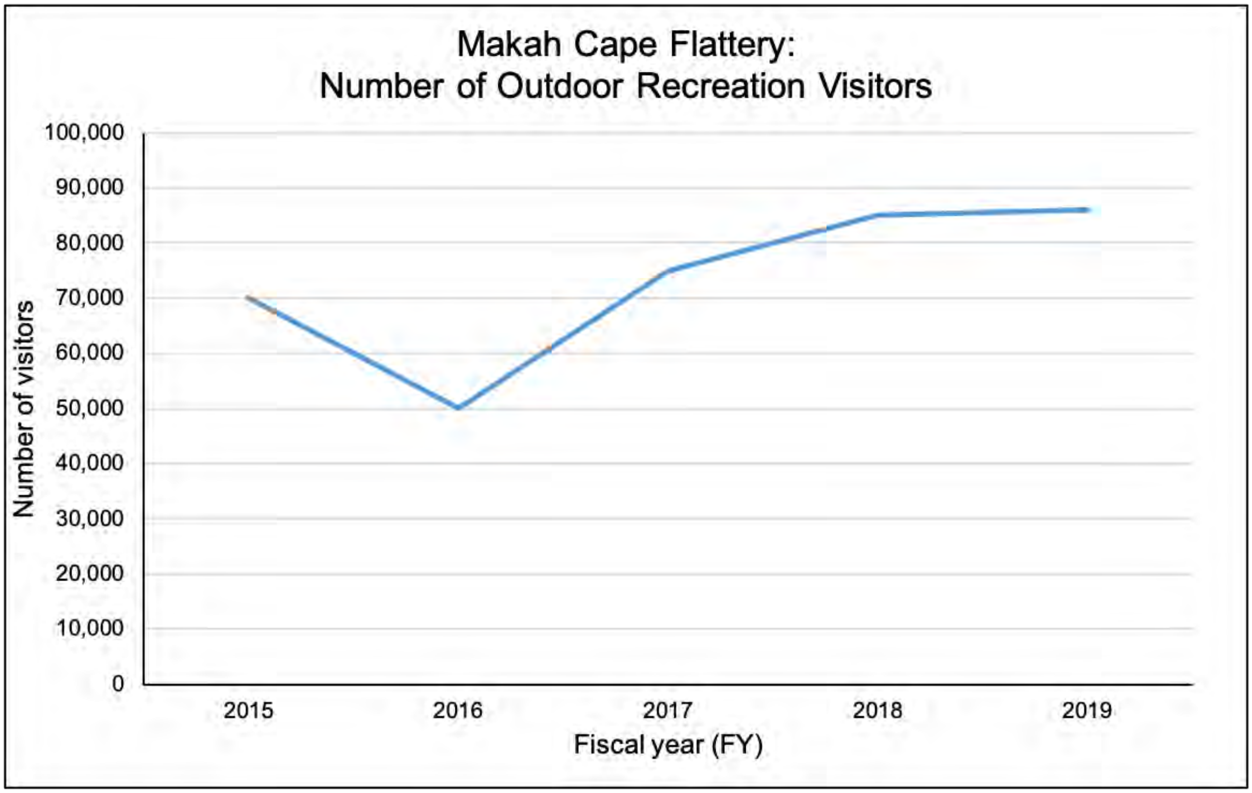


Figure ES.NCR.4. Annual number of outdoor recreation visitors to Cape Flattery, 2015–2019. Source: Makah Tribe/NOAA

Visitation at Olympic National Park, which directly borders a portion of the sanctuary, can also provide insight into the number of people engaged in non-consumptive recreation in the adjacent portion of OCNMS. Visitation to Olympic National Park remained relatively stable from 2008 to 2018 (Figure ES.NCR.5). Coastal areas adjacent to OCNMS (including Mora, Kalaloch, and Ozette districts) were the second most visited regions of Olympic National Park in 2015 (McCaffery et al., 2018). Additionally, the number of annual backcountry campers increased from 2008 to 2018 (Figure ES.NCR.6).

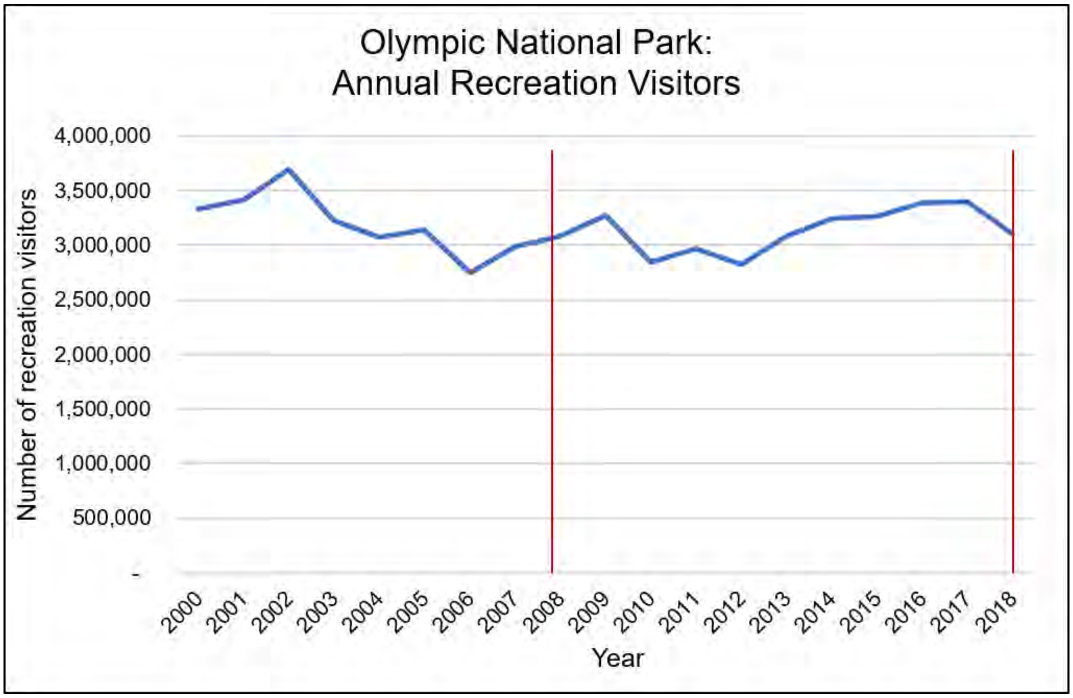


Figure ES.NCR.5. Annual visitation at Olympic National Park, 2000–2018. Vertical red lines indicate the study period, 2008–2018. Source: National Park Service, 2020

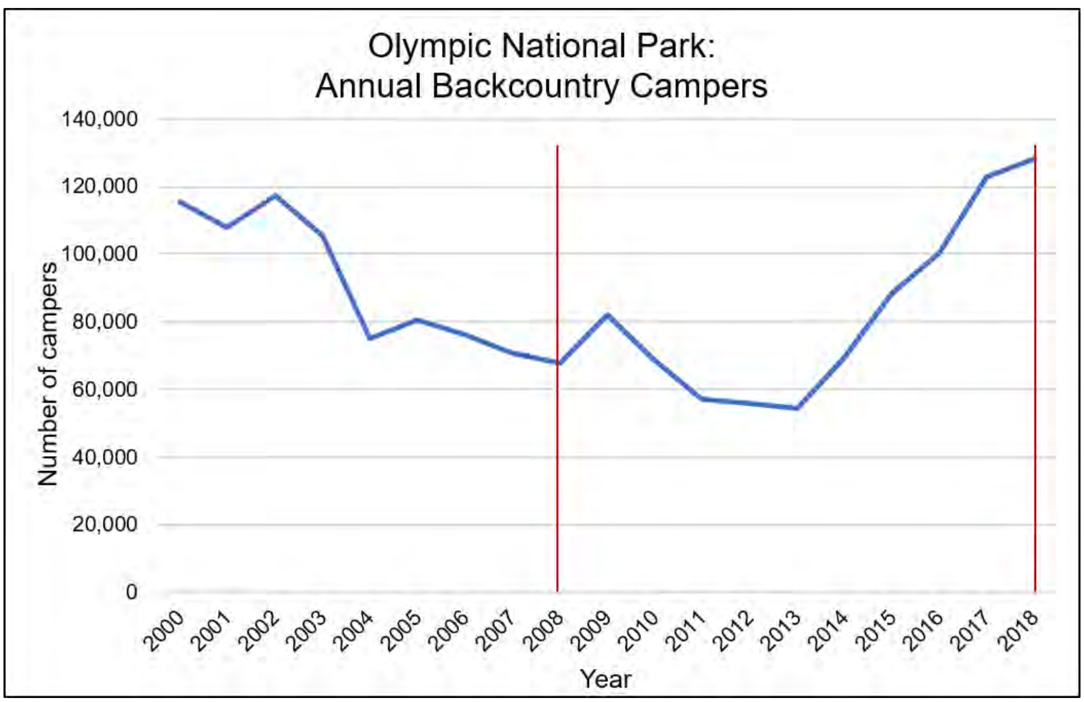


Figure ES.NCR.6. Annual number of backcountry campers at Olympic National Park, 2000–2018. Vertical red lines indicate the study period, 2008–2018. Source: National Park Service, 2020

Although people are able to engage in a wide variety of non-consumptive recreational activities in OCNMS, the volume of visitation at the sanctuary is a potential cause for concern in some areas. Thirty-four public access points to the sanctuary exist along the coast (Washington Marine Spatial Planning, 2020). While public access points are important for providing opportunities for residents and visitors to engage in non-consumptive recreation, they can also serve as indicators of increasing sanctuary use, which can affect the quality of non-consumptive recreational experiences and negatively impact sanctuary resources. Workshop participants noted that use has increased from 2008 to 2018 at a number of these public access points (Figure ES.NCR.7).

Figure ES.NCR.7. Photos depict increasing visitor use of key OCNMS public entry points. (A) Overflow parking at Second Beach, La Push, Washington. (B) Overflow parking on a highway shoulder near Third Beach, La Push, Washington. (C) Footprints in the sand illustrate the recent presence of a number of visitors at Second Beach, La Push, Washington. Photos: Jennifer Hagen/Quileute Tribe

The primary resources supporting non-consumptive recreation in OCNMS are water quality (contaminants and risks to human health) and the presence of species valued for wildlife viewing, particularly marine mammals and seabirds. Poor water quality can result in beach advisories or closures, which can negatively impact a number of shore-based recreational activities. Few beaches adjacent to OCNMS are monitored, resulting in a key data gap for this indicator. Of the beaches that are monitored, closures were rare, although at least one beach closure occurred in 2018 due to pathogenic bacterial levels. See Question 7 for additional details.

Populations of many marine mammal species valued for wildlife viewing have remained stable or increased in the OCNMS region from 2008 to 2018. However, endangered Southern Resident killer whales declined over the 10-year period, and gray whales experienced an unusual mortality event in 2019. Additionally, while seabird species like Cassin's auklet remained stable from 2008–2018, a number of other key seabird populations declined during the study period, and multiple unusual mortality events were recorded. See Question 13 for additional details.

Conclusion

The popularity of shore-based activities, like wildlife viewing, sightseeing, and water-based sports, has led to substantial concerns regarding the region's ability to support increased visitor use, which was a key factor in determining the fair rating for this service. The undetermined trend was driven by uncertainty regarding the effects of increased use on the condition of sanctuary resources and the quality of non-consumptive recreation at some sanctuary locations.

Science

The capacity to acquire and contribute information and knowledge

Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: The fair rating was driven by the fact that several critical science needs are not being met due to insufficient resource allocation. Limitations exist with regard to OCNMS capacity, staffing, resources, and infrastructure, including limited staff capacity in several areas; aging research vessels (R/V *Tatoosh*); and limited internet, lab space, and academic institutions on the coast to conduct all of the science activities required. However, research partnerships, collaboration, and coordination are improving, which is increasing the breadth of science conducted within OCNMS. New research programs have been initiated; these include the establishment of an ocean acidification sentinel site, kelp forest surveys, deep sea exploration, and ocean sound monitoring. Established activities, including oceanographic moorings, habitat mapping and seafloor characterization, and intertidal surveys, have continued throughout the study period. Furthermore, the extensive traditional ecological knowledge of the four Coastal Treaty Tribes significantly enhances our shared understanding of the Olympic Coast.

The Coastal Treaty Tribes have lived on the Olympic Coast since time immemorial, and each has cultivated a body of knowledge on ecosystem processes, timing, location of important habitats and species, and a variety of other topics over generations. ONMS and OCNMS acknowledge and honor TK as valued science that aids in understanding ecosystems and resources therein and contributes to successful ecosystem-based management, and agree that "respecting and embracing [I]ndigenous knowledge as important science benefits all of us" (Greene, 2018).

In addition to TK, each of the Coastal Treaty Tribes has developed research programs within their governments. These include a variety of biologists and ecologists monitoring ecosystem components, as well as social scientists, historians, archaeologists, and cultural resource specialists who may serve in the formal role of Tribal Historic Preservation Officers. Together, they gather relevant social and ecological data along the Olympic Coast, aligning TK and western science to inform management decisions. For example, in a recent study, the Makah Tribe tested the selectivity of traditional halibut hooks (*čibu·d* [chih-**bood**]) relative to modern circle hooks as a possible mechanism for reducing bycatch of rockfish (especially yelloweye rockfish, which are overfished) in the recreational halibut fishery. Using Makah TK, Makah Fisheries Management showed the *čibu·d* to be more selective for halibut than the modern circle hook, thus reducing bycatch and promoting sustainable fishery practices (Petersen et al., 2020).

Social science is an important area of study for OCNMS. Novel research to pair social vulnerabilities of each tribal community with biological vulnerabilities of important marine species to ocean acidification along the Olympic Coast is underway (2018 to 2021) to better understand research and management needs. A research partnership with Washington Sea Grant—specifically, a social science team with anthropology, ethnoecology, and socioeconomic expertise—is collecting and synthesizing new and existing data to help understand the importance of the marine ecosystem to community health and well-being, how ocean changes may adversely impact well-being, the range and distribution of multiple socioeconomic and ecological stressors, and effective strategies for social resilience and recovery.

The number of research permits issued by ONMS for studies in OCNMS waters from 2008 to 2019 increased nine-fold, with an average of 25 permits open each year (ONMS, 2020a; Figure ES.S.1). Although the number of permits provides some insight about changes in the level of research activity in OCNMS, not all research requires permits. Permitted research within OCNMS includes low overflights for marine mammal and seabird monitoring; ROV surveys of deep-sea communities, crushed cars, and submarine cable monitoring; deployment of oceanographic monitoring equipment; collection of sediment and organism samples; and much more. Recently, several agencies sought ONMS permits for the first time (for fisheries stock assessments and marine mammal research), potentially causing the apparent increase in permits. While the number of permits granted previously may not be a good reflection of past research effort, it may be useful for future OCNMS assessments and is presented below for reference.

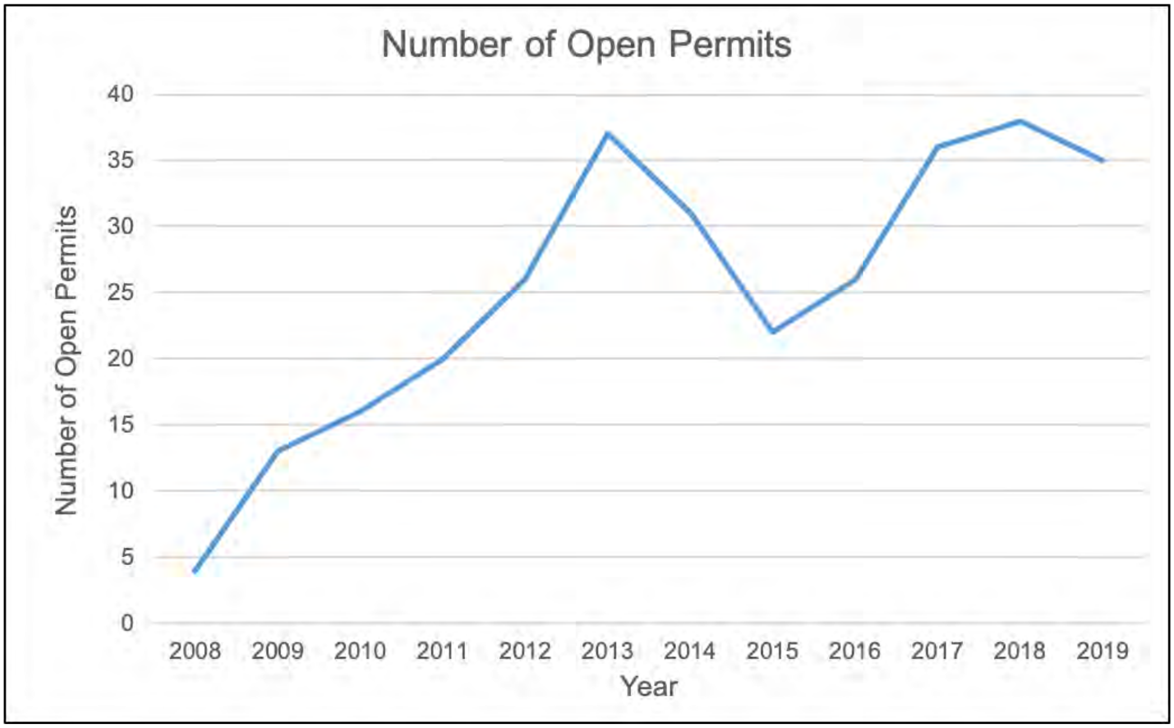


Figure ES.S.1. Open OCNMS permits by year. OCNMS issues permits for otherwise prohibited activities if the proposed activity will not substantially injure sanctuary resources and qualities, and will further research related to those resources and qualities. The most commonly issued permit is for conducting research in the sanctuary. Source: NOAA

The R/V *Tatoosh* was the first research vessel built specifically for a national marine sanctuary. Prior to its construction, sanctuary vessels were mainly repurposed surplus vessels. The contract for the R/V *Tatoosh* was a considerable investment by NOAA, comprising a large portion of the OCNMS budget in 1994, the year the sanctuary was designated. The vessel has been upgraded repeatedly to provide additional capabilities; most significantly, in 2000, the vessel was lengthened (from 36 feet to 38 feet), repowered, and equipped with deck gear, including an A frame to support additional oceanographic operations. In 2011, multibeam sonar was added to provide seafloor mapping capability, a high priority for the sanctuary. Even today, OCNMS's R/V *Tatoosh* is one of very few science platforms operating in this region. However, the vessel has several limitations and is nearing the end of its working life, which has led ONMS to invest significant funds toward a new research vessel. The new R/V *Storm Petrel* is expected to be fully operational by the beginning of fiscal year 2022 to replace R/V *Tatoosh*.

OCNMS also uses a small rigid hull inflatable boat (RHIB) to conduct some research activities. However, the Olympic Coast's notoriously rough marine weather offshore and the narrow safe operational limits of the RHIB mean that it is mostly used in protected waters, such as the Strait of Juan de Fuca, for work in nearshore habitats.

OCNMS conducts research from small boats, large research ships, and aircraft, engages community scientists, and collaborates with multiple partners. Since 2008, the number of hours and number of days the R/V *Tatoosh* has spent at sea fluctuated, but both indicate a downward trend overall, largely driven by operational restrictions in 2020 due to the COVID-19 pandemic (Figure ES.S.2).

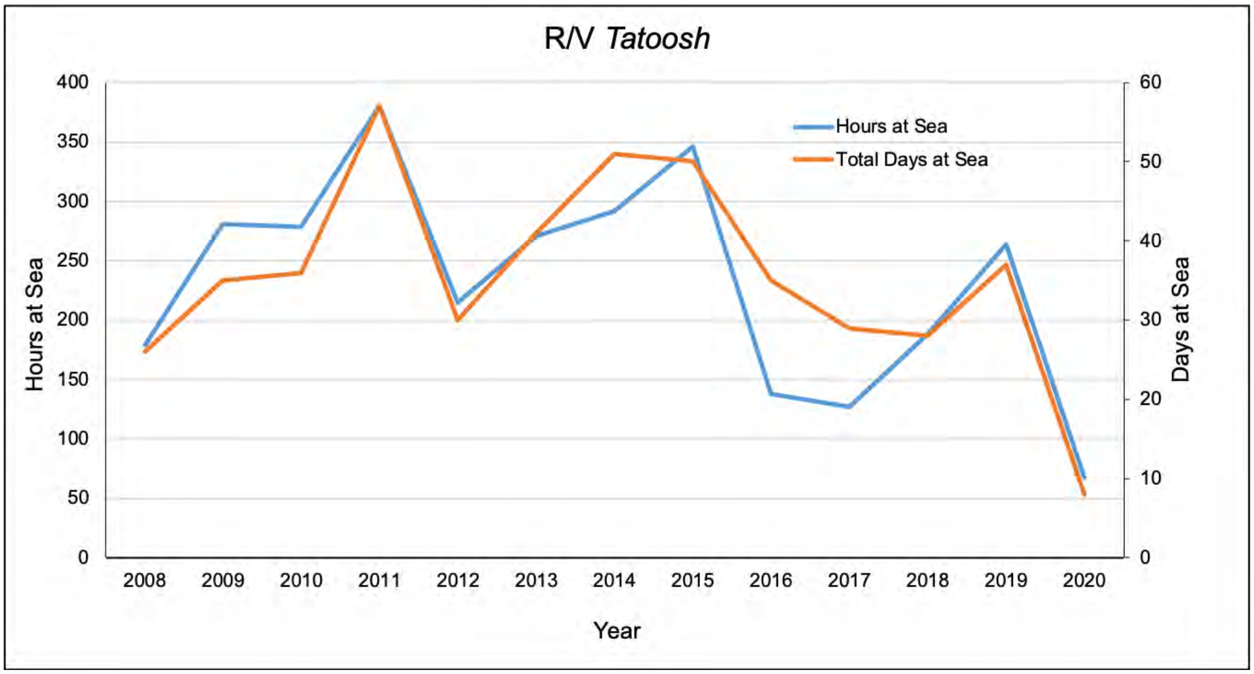


Figure ES.S.2. The R/V *Tatoosh* operates May to October on the Olympic Coast to conduct sanctuary research and facilitate collaborator research. Vessel use data for the assessment period are presented above, including hours at sea and days at sea. Source: NOAA; Image: A. Hallingstad

OCNMS engaged the public in sanctuary science and monitoring projects during the assessment period, usually as part of a broader effort, such as coastal surveys for marine debris and beached birds, which accounted for 93% of the contributed hours (Figure ES.S.3).

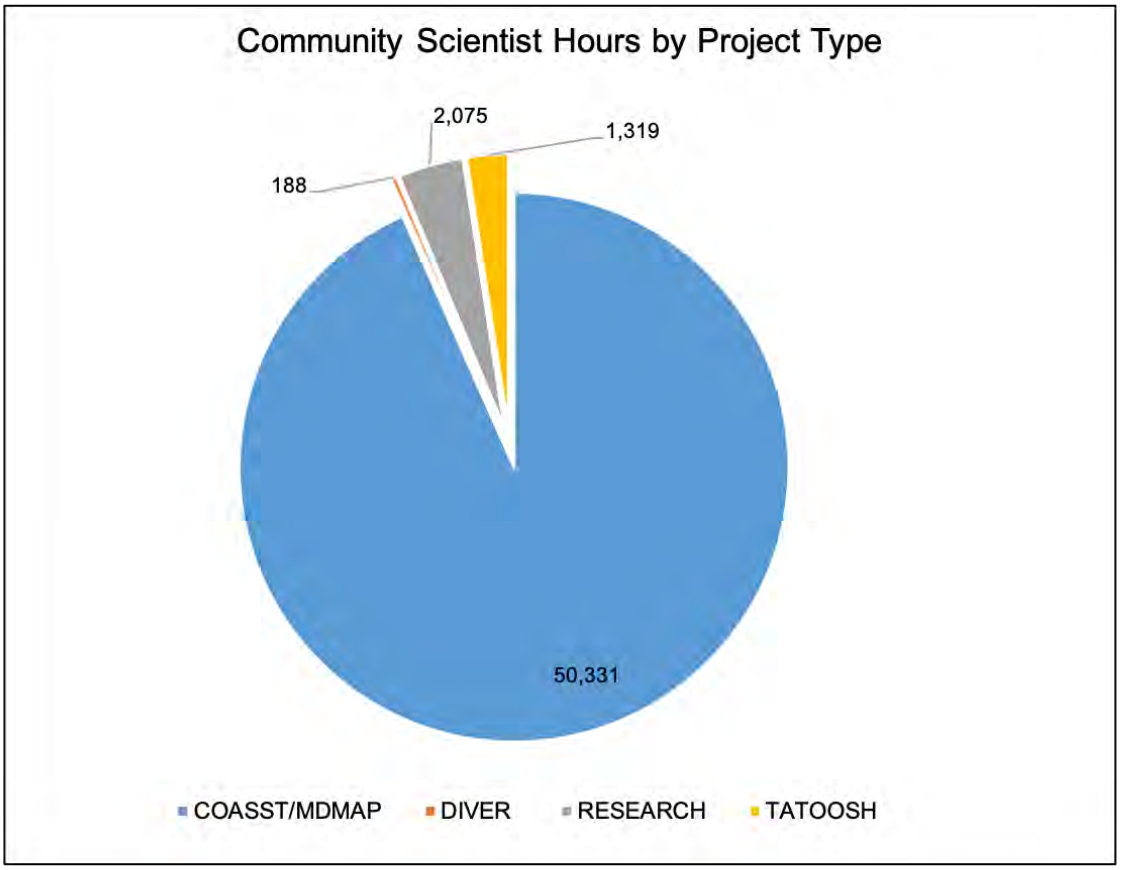


Figure ES.S.3. Between 2008 and 2019, community scientists contributed 53,913 hours toward a variety of activities. The majority (93%) of hours were associated with marine debris and beached seabird surveys (COASST/MDMAP), with the remaining 3,582 hours contributed to dive surveys, research projects, and mooring operations aboard the R/V *Tatoosh*. Source: NOAA; Image: C. Butler-Minor/NOAA

Currently, OCNMS does not have dedicated staff or funding to coordinate community science efforts. The two major programs that previously accounted for the bulk of contributed hours were either transferred to outside groups, such as the beached seabird surveys (Figure ES.S.3) that were transitioned in 2015 to the Coastal Observation and Seabird Survey Team (COASST), or were discontinued, as with the Marine Debris Monitoring and Assessment Project (MDMAP). Marine debris monitoring of the coast, which was initiated in response to the arrival of debris from the March 2011 tsunami in Japan, was slated to end in 2017; however, an extension was granted to support the remaining volunteers through fall of 2019, prompting a slight increase in hours in 2018. OCNMS staff continue to explore opportunities for volunteers, in addition to connecting them with COASST, which initiated a marine debris monitoring program in 2015 to complement beached bird surveys.

Both the number of community scientists and the number of hours they contributed decreased between 2008 and 2018 (Figure ES.S.4). The number of volunteers varied over time, ranging from a high of 392 in 2014 to a low of 52 in 2018. The number of volunteer hours was highest in 2010 (9,258) and lowest in 2017 (459).

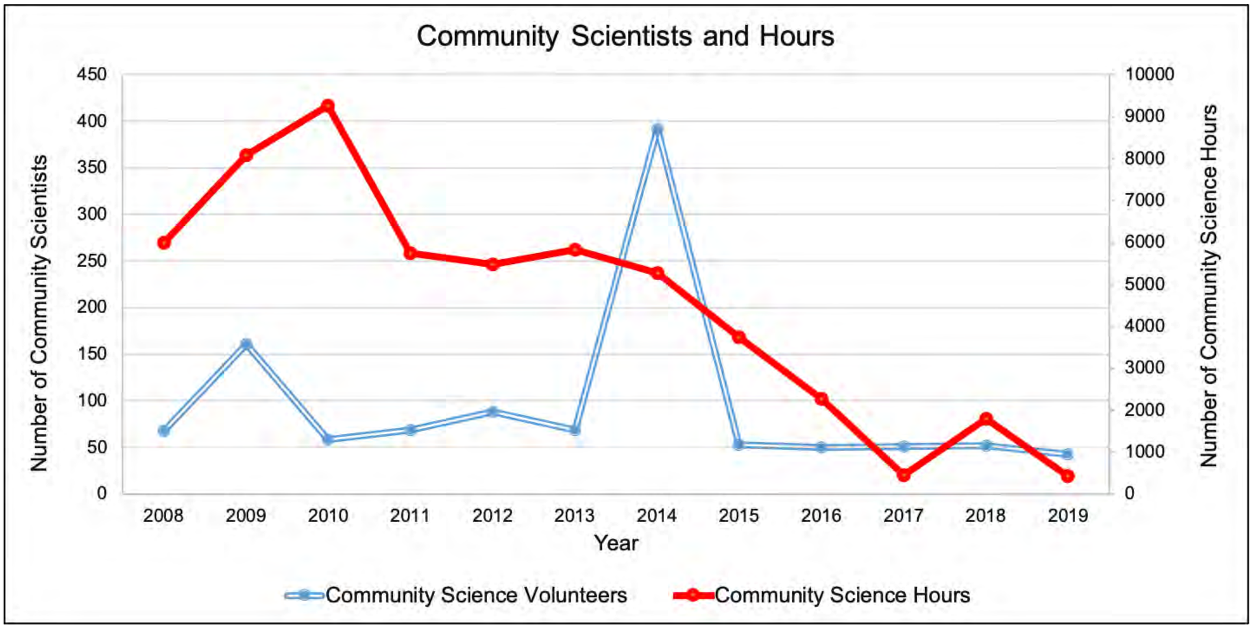


Figure ES.S.4. The number of volunteers participating in community science efforts (community scientists) and the hours of service provided have varied over the past decade. Both hours and number of community scientists have generally declined, however a pulse of activity occurred in 2014 as a result of tsunami debris monitoring. Source: NOAA; Image: C. Butler-Minor/NOAA

The greatest percentage of non-community scientist volunteer hours (69.59%) relates to educational outreach. This includes hours donated by volunteers serving as visitor center docents and supporting beach clean ups. However, nearly a third of volunteers have participated in community science projects, including COASST and MDMAP, research projects, and mooring operations on the R/V *Tatoosh*.

Natural challenges with community involvement in science and monitoring at OCNMS include a remote and rugged coastline that can be difficult to access, short days, challenging timing related to tide cycles, and frequent storms during winter months. This limits most field efforts to approximately 8 months of the year. Community demographics also play a role; the pool of potential participants living in rural coastal and tribal communities is small, and long distances separate the coast from more densely populated areas surrounding Seattle and Tacoma. Census data from 2018 show that about 11,100 people live in zip codes along the sanctuary coastline (see Drivers section). Recruiting and retaining community scientists is further complicated by information technology security protocols that can prevent community members from accessing data and computer systems.

Community members also participate in science through volunteer activities, which are described in more detail in the Education section. Although educational volunteer and community scientist hours are tracked separately, when viewed together (Figure ES.S.5), they reveal the importance of the International Coastal Cleanup, a one-day event held twice yearly that accounts for nearly 62% of all hours contributed. Cleanup events held over weekends in April and September regularly draw thousands of people to the coast, often with salmon bakes, free camping, and other perks. COASST and MDMAP make up 28% of total combined educational volunteer and community scientist hours. Approximately 2% of hours come from volunteers who support science and research efforts by participating in at-sea operations on the R/V *Tatoosh*, and nearly 7% provide educational and science interpretation to visitors at the sanctuary's Olympic Coast Discovery Center in Port Angeles.

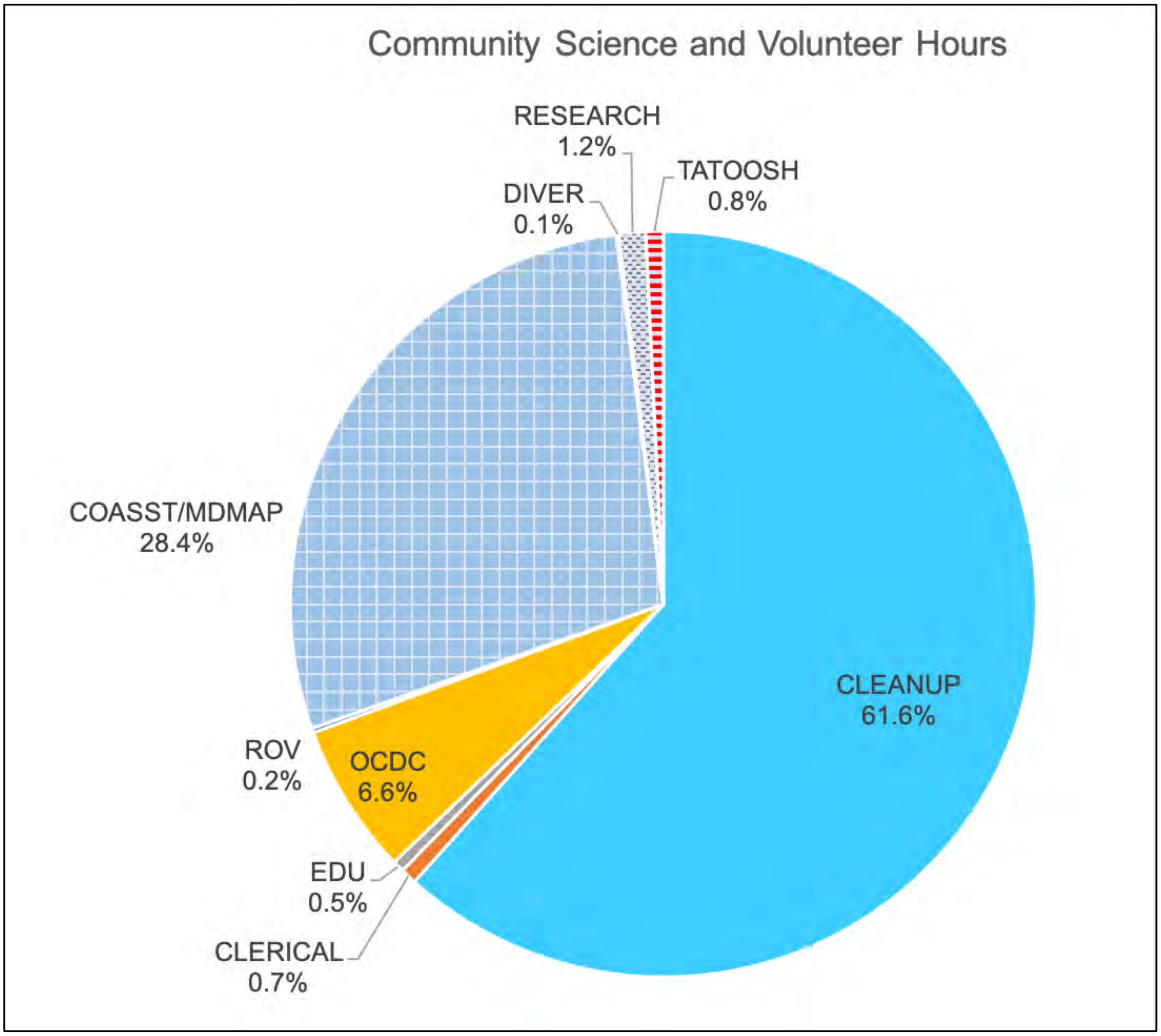


Figure ES.S.5. Volunteers at OCNMS participate in a variety of educational and community science activities. Source: NOAA; Image: C. Butler-Minor/NOAA

The Olympic Coast has been studied by numerous researchers over the decades, with a variety of research and monitoring programs collecting time series data. Key research topics have included oceanographic conditions, intertidal monitoring, kelp ecology, deep-sea coral, harmful algal blooms, and more. Tatoosh Island, for example, is considered one of the most well-studied field sites in the world, and was the site at which Dr. Robert Paine coined the ecological concept of "keystone species" in the late 1960s. Long-term research that has taken place within OCNMS is summarized in Table App.ES.S.1. Research cruises organized or led by OCNMS staff during the study period have been tabulated in Table ES.S.1.

Table ES.S.1. Summary of major research cruises organized/led by OCNMS staff, 2008–2020.

Date	Ship	Purpose	Key Partners
June 2008	NOAA Ship *McArthur II*	Survey of cetacean abundance and pelagic ecosystem	NOAA Southwest Fisheries Science Center (SWFSC)
July 2008	Canadian Coast Guard Ship *Tully*	Deep-sea coral and sponge ROV surveys associated with Pacific Crossing submarine cables	Fisheries and Oceans Canada
June 2010	NOAA Ship *McArthur II*	Deep sea coral and sponge ROV surveys	NOAA Deep Sea Coral Research and Technology Program
June 2010	NOAA Ship *Fairweather*	Seafloor mapping at Cape Alava	NOAA Office of Coast Survey
July 2011	R/V *Pacific Storm*	Seafloor mapping; ROV surveys of deep coral and sponge areas west of Olympic 2	Oregon State University, NOAA Deep Sea Coral Research and Technology Program
May 2016	NOAA Ship *Rainier*	Seafloor mapping: Washington offshore priorities	NOAA Integrated Ocean and Coastal Mapping, NOAA Office of Coast Survey
June 2016	E/V *Nautilus*	ROV dive to “ground truth” seafloor data near Quinault Canyon (one day at sea)	Ocean Exploration Trust, NOAA Ocean Exploration, NOAA Pacific Marine Environmental Laboratory
Aug/ Sept 2017	E/V *Nautilus*	ROV and autonomous underwater vehicle surveys for deep-sea coral and sponge habitats; USS *Bugara* (17 days at sea)	Ocean Exploration Trust, NWFSC
Sept 2017	NOAA Ship *Rainier*	Seafloor mapping: Washington offshore priorities (10 days at sea)	NOAA Office of Marine and Aviation Operations, NOAA Integrated Ocean and Coastal Mapping
June 2018	NOAA Ship *Bell M. Shimada*	Juvenile salmon ocean ecosystem survey (seven days at sea)	NWFSC
July 2018	E/V *Nautilus*	Recovery of Quinault meteorite fragments (one day at sea)	Ocean Exploration Trust, NASA
June 2019	R/V *Falkor*	Recovery of Quinault meteorite fragments (five days at sea)	NASA, Schmidt Ocean Institute
Sept 2019	NOAA Ship *Bell M. Shimada*	ROV surveys in deep-sea coral and sponge habitats (seven days at sea)	NOAA Deep Sea Coral Research and Technology Program, NWFSC

Date	Ship	Purpose	Key Partners
July 2020	R/V *Rachel Carson*	Charter of University of Washington vessel to recover/deploy NOAA ocean sound recorders (seven days at sea)	NOAA Fisheries Ocean Acoustics Program
Sept 2020	E/V *Nautilus*	ROV surveys in deep-sea coral and sponge habitats, methane seeps (12 days at sea)	Ocean Exploration Trust, Oregon State University

Despite research efforts within OCNMS, until recently, only approximately a third of the sanctuary was mapped with either side scan or multibeam sonar. In some parts of OCNMS, the best available information is from 1920s leadline surveys, which is inadequate for contemporary research or management. Further, OCNMS has lost internal expertise and capacity (e.g., seafloor mapping, geographic information systems, database management) and currently lacks the modern technology and equipment necessary to conduct this work in house.

In an effort to support ongoing coordination efforts for seafloor mapping, OCNMS has partnered with Washington state, NCCOS, the Integrated Ocean and Coastal Mapping team, USGS, and others in an effort to identify and survey high-priority areas of the seafloor. To date, the three offshore priority areas originally identified by the group in 2015 have been largely mapped (Figure ES.S.5). Additional priority areas were proposed by the group during a workshop in 2018; OCNMS staff contributed these to ongoing NOAA prioritization efforts, which are particularly important in light of the November 2019 presidential memorandum on ocean mapping (Executive Office of the President, 2019) and development of a National Ocean Mapping Strategy released by the NOAA Office of Coast Survey (2020). Seafloor mapping priorities identified in shallow nearshore areas, which at Olympic Coast are laden with pinnacles, rocks awash, and other navigation hazards, remain largely unmapped, which reduces scientists' ability to conduct certain studies, including nearshore seismic hazard modeling—a particular concern for coastal communities living in this tsunami-prone region.

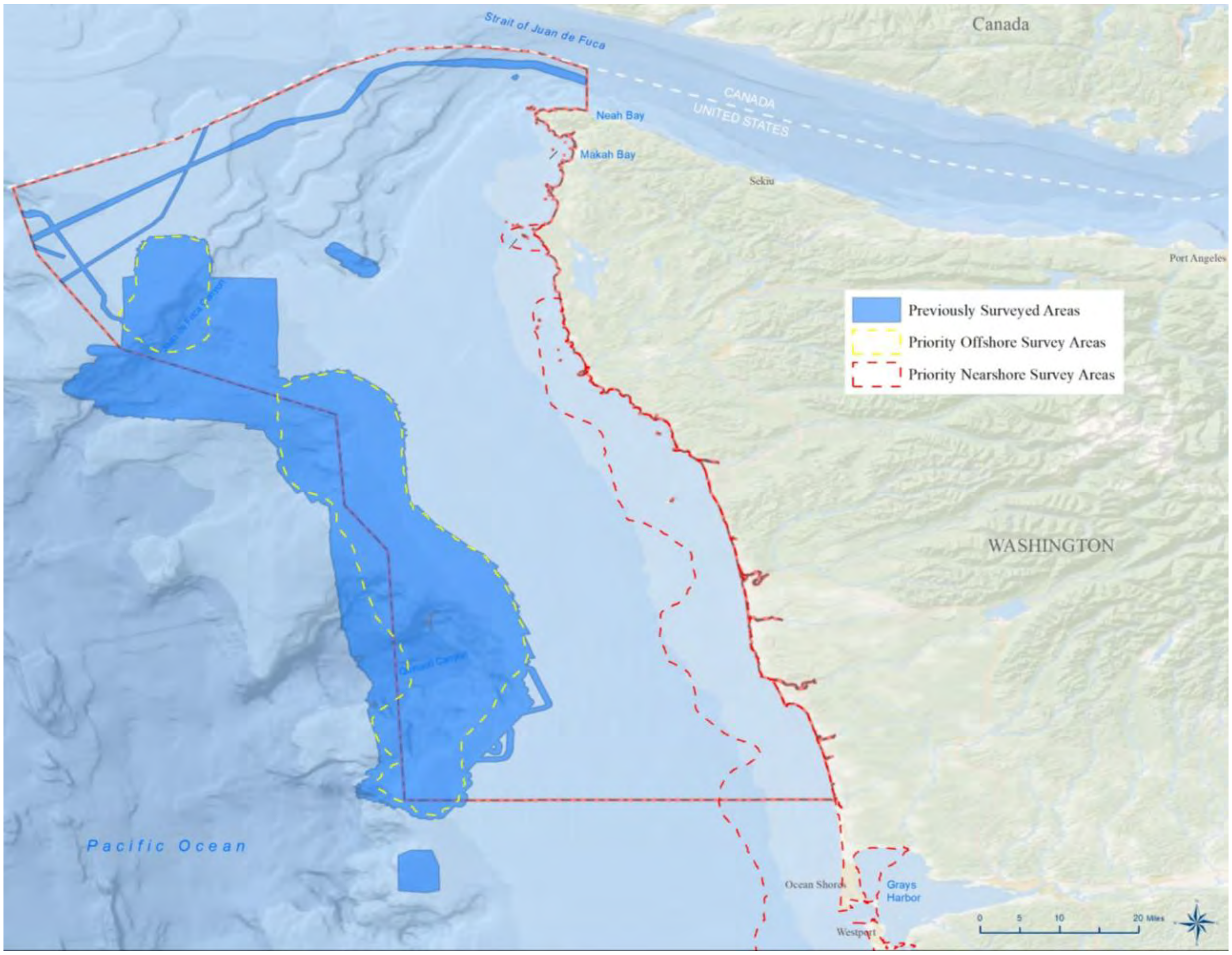


Figure ES.S.6. A 2015 seafloor mapping prioritization effort identified nearshore and offshore areas of the Washington coast where new high-resolution seafloor mapping activities would best support coastal management efforts ranging from hazard mitigation to fisheries management (Battista et al., 2017). Surveys conducted in 2016 and 2017 from the NOAA Ship *Rainier* and the E/V *Nautilus* largely completed data acquisition within identified offshore priority areas. Additional seafloor mapping has been conducted in the sanctuary since 2017. Image: NOAA

Classification of seafloor data for habitat mapping purposes reached a milestone in 2016 with release of two of the four components of the Olympic Coast Habitat Framework, a habitat mapping program led by the Northwest Indian Fisheries Commission and IPC, with technical support from OCNMS. The goal of this program is to develop a common understanding of marine habitats on the Olympic Coast based on NOAA's Coastal and Marine Ecological Classification Standard (CMECS) and use this standard as a shared framework, or language, for tribal, state, and federal resource managers (Goodin et al., 2016). CMECS is a standardized hierarchical system for classifying habitats that breaks the marine environment into four components: water column, geoform, substrate, and biotic. The use of CMECS will establish a robust system that will allow policy makers to determine the importance of habitats and how different practices might impact different parts of the marine ecosystem. Work is underway to complete the remaining two components of the habitat framework.

NANOOS, based on input from IPC and OCNMS, secured an award from the Murdock Charitable Trust to increase oceanographic observing capacity within OCNMS in 2009. This effort includes the Ćháʔba· surface buoy, the subsurface NEMO profiler, and an autonomous Seaglider. Sustained operational funds are now provided annually by the U.S. IOOS Program via funding to NANOOS. Each of these assets reports data via the NANOOS Visualization System (NANOOS, 2021a). The capacity of these observational assets has been extended far from its original vision; Ćháʔba· is now a national buoy supported by NOAA's Ocean Acidification Program; NEMO has been adapted to include an Environmental Sample Processor, supported by NOAA Monitoring and Event Response for Harmful Algal Blooms and IOOS; the observational data provide critical input to calibrate/validate of the LiveOcean and J-SCOPE models; and communication technology from the buoys' real-time relays has been proposed for use on OCNMS seasonal moorings.

In 2019, OCNMS was designated by NOAA as an Ocean Acidification Sentinel Site (OASeS). Sentinel sites, like national marine sanctuaries, are places where focused monitoring and research efforts take place to enhance understanding of ecosystems and how they are changing. The OASeS will expand coordination and collaboration on key science needs in OCNMS related to ocean acidification and the associated social and biological vulnerabilities of the Olympic Coast. In 2020, IPC members endorsed the sentinel site designation and will work to expand OASeS to the entire Washington outer coast.

While it is recognized that significant research has been conducted in OCNMS by a variety of partners (see Table App.ES.S.1 for a summary), the sanctuary's limited capacity and infrastructure to conduct research deemed necessary on the Olympic Coast were the drivers for the fair rating. OCNMS has few staff to conduct research, and there are gaps in capacity and expertise. With fewer staff, OCNMS personnel are limited to focusing on high-priority initiatives, such as maintaining the oceanographic mooring program, continuing other critical long-term data collection, and planning major research cruises, as well as coordinating and facilitating research conducted by partners.

Science activities of partner organizations are essential in building collective understanding. Partner organizations include the natural resource management departments of tribal governments, Washington state agencies, academic researchers, Sea Grant, and non-governmental organizations, often in collaboration with partners from across NOAA and within the U.S. Department of the Interior (i.e., National Park Service, USGS, Bureau of Ocean Energy Management).

The technical challenges of research in this remote environment make research costly, and rough, open ocean conditions and unpredictable weather along a wilderness coastline with only two navigable harbors add to the complexity of vessel operations and field work. In the two ports adjacent to OCNMS (Neah Bay on the Makah Reservation and La Push on the Quileute Reservation), there are limited fueling locations or pump-out stations, and nearby lodging can also be expensive and/or challenging to obtain during the popular summer season. Many coastal lodging options have implemented a two-night minimum. Further, OCNMS has recently lost dedicated accomodations in Neah Bay due to mold issues. The Olympic Natural Resources Center has proven to be an invaluable lodging asset for researchers visiting the coast.

Due to harbor limitations, large-ship science efforts focused on the Olympic Coast must use distant ports like Astoria or Newport, Oregon, or Seattle, Washington. Many NOAA Fisheries surveys, surveys by academic groups like the University of Washington and Oregon State University, and fishery surveys done by organizations like the International Pacific Halibut Commission fall into this category. In contrast to large-ship science efforts, locally based science activities tend to benefit local economies through expenditures, including lodging, provisions, fuel purchases, taxes, payment of recreation permits issued by the Makah Tribe, etc. However, because there is limited laboratory capacity on the outer coast to process or freeze collected samples, much of the research and analysis must be done in distant laboratories.

Overall, there is limited availability of ocean-going vessels, which often must be trailered to Neah Bay or La Push in order to access OCNMS. Charter vessels are limited, and some platforms, like *Windsong*, based in Neah Bay, are often not available during the fishing season, which overlaps with the summer field season. Academic institutions also maintain ocean-going research vessels that provide science support for the Olympic Coast as part of the University-National Oceanographic Laboratory System; some of these ships spend only a small portion of their time on the Washington coast. However, the University of Washington and Oregon State University each operate two ocean-going research vessels in the region, and Oregon State University is presently working with the National Science Foundation to design the first of three new Regional Class Research Vessels, including a ship that will replace the R/V *Oceanus* in 2021.

Logistically, conducting research on the Olympic Coast can be quite challenging due to its remoteness and ruggedness. The communities on the coast are small and rural, with limited infrastructure (e.g., lodging, restaurants, internet access), which can pose challenges to researchers unfamiliar with the region. For example, finding locations to install high-frequency radar on the Olympic Coast has been challenging for NANOOS due to lack of power and accessibility of ideal sites. Additionally, access to small ports or research stations are often on tribal reservations, for which tribal permissions, permits, and/or guides may be required. Furthermore, limited internet access and shifts in cellular networks pose challenges on the Olympic Coast, demanding innovative solutions. For example, the real-time sensors that are deployed in OCNMS rely on cellular networks to transmit data; however, recent changes implemented by cellular carriers have reduced spatial coverage and compromised real-time transmission of data.

Conclusion

Significant research has occurred over decades in OCNMS. However, persistent information gaps were deemed significant enough to rank the status of the science ecosystem service as fair. The limited capacity to conduct desired research for OCNMS was a key factor in determining this status. Capacity and infrastructure are limited on the coast, and geographic and technological challenges reduce the ability to conduct the science activities needed. Research partnerships, collaboration, and coordination are expanding, which is increasing the breadth of science conducted within OCNMS, resulting in an improving trend. OCNMS is at the forefront of research focused on changing ocean conditions, seafloor mapping, deep-sea corals, and ocean sound. Furthermore, the extensive TK of the four Coastal Treaty Tribes significantly enhances the collective understanding of the Olympic Coast.

Table ES.S.2. Status and trends for individual science ecosystem service indicators discussed at the January 2020 workshop.

Non-Economic Indicators	**Source**	**Figure or Table #**	**Data Summary**
Open sanctuary permits	ONMS, 2020a	Figure ES.S.1	The number of open permits has increased since 2008.
Vessel hours and days at sea, 2008–2019	A. Friel/OCNMS, personal communication, December 10, 2019	Figure ES.S.2	R/V *Tatoosh* days and hours remained stable from 2008–2018. RHIB days and hours increased from 2011–2018.
Total community science hours by project type	C. Butler-Minor/NOAA, personal communication, November 1, 2020	Figure ES.S.3	Community science participants and hours contributed declined between 2008–2018
Community scientist numbers and hours over time	C. Butler-Minor/NOAA, personal communication, November 1, 2020	Figure ES.S.4	The number of community scientists and hours contributed declined from 2008–2019.
Total community science and volunteer hours by activity	C. Butler-Minor/NOAA, personal communication, November 1, 2020	Figure ES.S.5	Community science and volunteer hours are dominated by coastal cleanups and beach surveys for marine debris and stranded seabirds.
OCNMS-led research cruises	J. Waddell/NOAA, personal communication, December 1, 2020	Table ES.S.1	Ten of the 15 research cruises led by OCNMS staff between 2008–2020 occurred in 2016–2020.
Long-term research		Table App.ES.S.1	Significant long-term research has occurred in the OCNMS area since the 1960s.
Seafloor mapping priorities	J. Waddell/NOAA, personal communication, December 1, 2020	Figure ES.S.6	Seafloor mapping progress has been made within offshore priority areas identified by partners in 2015.
Coastal ports for research access		Figure ES.S.7	OCNMS is characterized by limited port access, remote location, and a lack of local research institutions.
Infrastructure			Infrastructure limitations include the aging R/V *Tatoosh*, internet limitations, and limited lab capacity to store and process samples.

Education

The capacity to acquire and provide intellectual enrichment

Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.

Rationale: Key indicators used to determine the status and trend of the education ecosystem service were willingness to pay for educational programs, funding for educational programs, the number of people receiving formal and informal education, the quality of the educational experience, the number of volunteers working with OCNMS, and the number and types of educational programs offered. Studies focusing on similar California-based Ocean Guardian School programs show that parents have a willingness to pay for hands-on ocean conservation and stewardship programs. The number of Twitter and Facebook followers (those who like the social media page) of OCNMS has increased over the past few years. Driven by sanctuary, tribal, and partner education programs, educational activities focused on OCNMS and related ocean science and stewardship have increased in quality over time and contributed to the public's awareness of OCNMS, enhancing ocean literacy.

OCNMS is a place of national, regional, and local significance. OCNMS staff engage audiences through education and outreach using a variety of methods, including:

- **Pre-K–12:** Providing in-school educational programs at field-based summer programs for students,
- **Higher education:** Promoting adult learning and career-building opportunities,
- **Community outreach:** Improving the general public's awareness of ocean ecology and encouraging ocean stewardship,
- **Visitor services:** Providing information and high-quality educational experiences to Olympic Coast visitors, and working with local communities to encourage sustainable tourism in the sanctuary region.

Although there are no economic valuation studies specific to OCNMS for the education ecosystem service, in 2017, ONMS completed a study estimating the economic value of the Ocean Guardian School Program in California (Schwarzmann et al., 2017). This grant-based program is aimed at teaching students about ocean conservation and stewardship of local watersheds and special ocean areas like national marine sanctuaries. At the time of the study, the program was relatively new in the Pacific Northwest, and these regional schools were not included in the study. (The Pacific Northwest Ocean Guardian School Program was established in Washington and Oregon in 2015 and is now implemented the same way as the schools that were included in Schwarzmann et al. [2017]). The study focused on California schools and estimated parents' willingness to pay for five pathways of hands-on educational experiences: 1) refuse/reduce/reuse/recycle/compost ($21); 2) reduce marine debris (cleanups and reducing single use plastic) ($26); 3) watershed restoration ($45); 4) schoolyard habitat/garden ($59); and 5) energy and ocean health ($34). Although these exact values may not apply to OCNMS, it is likely that parents would also value similar hands-on education programs in the sanctuary region. Figure ES.E.1 shows that the number of schools and grant funding for the Ocean Guardian School Program, supported by the sanctuary, has increased since 2015.

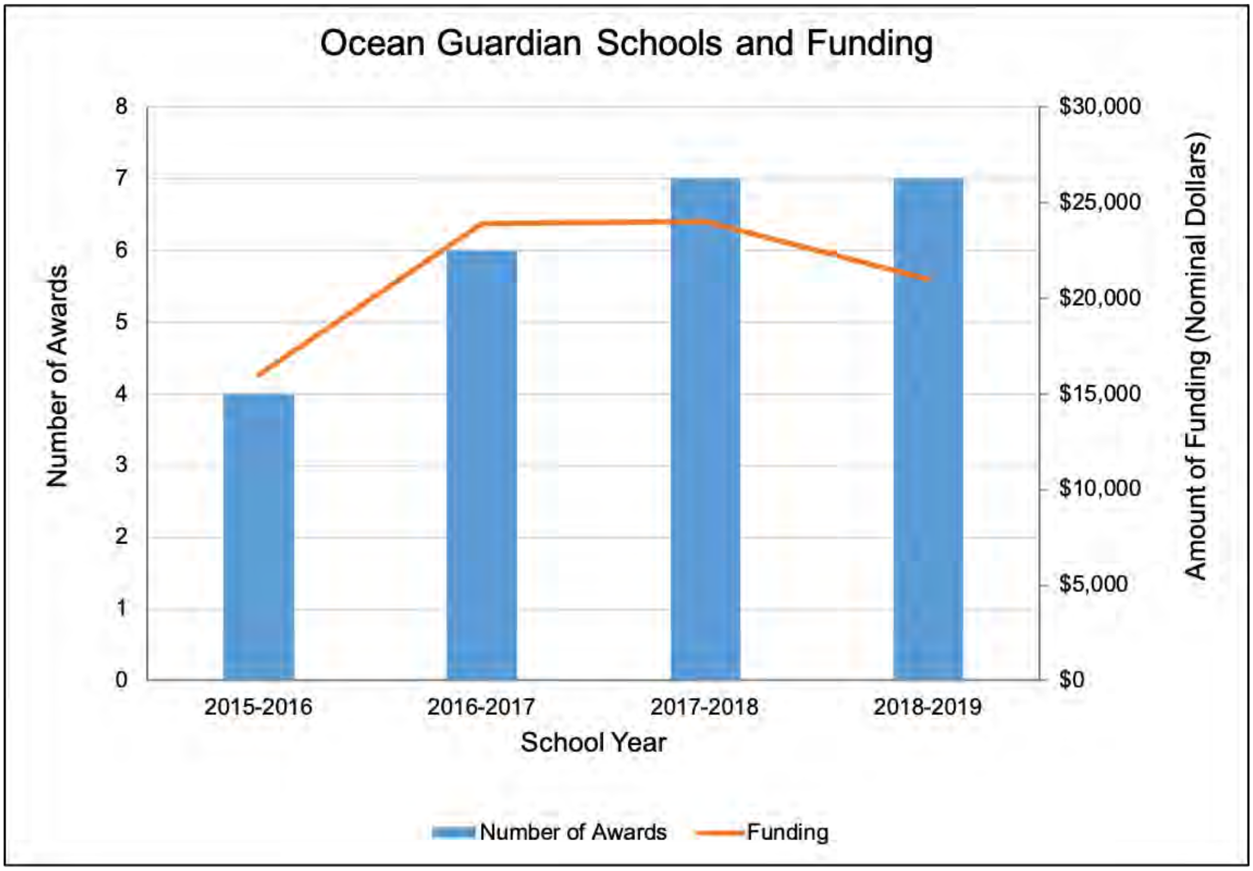


Figure ES.E.1. Number of participating Ocean Guardian schools and amount of funding for the Ocean Guardian School Program in Washington and Oregon. Source: J. Laverdure/NOAA, personal communication, April 20, 2020

Another economic indicator that can be used to evaluate the education ecosystem service is the amount of Bay Watershed Education and Training (B-WET) funding (Figure ES.E.2). B-WET is an environmental education program that supports locally relevant experiential learning among K-12 students. Each year, approximately 8–9 funded projects in the Pacific Northwest (totaling approximately $450,000 in grants) provide students with Meaningful Watershed Educational Experiences (MWEEs; NOAA Office of Education, 2017), which blend outdoor- and classroom-based learning to build environmental literacy. B-WET projects also include professional development for teachers and help support regional education and environmental priorities in the Pacific Northwest. Because B-WET funding, which includes Ocean Guardian School Program funding, is determined by Congress (and not OCNMS), it varies across years, which can influence the level of educational services offered (J. Laverdure/NOAA, personal communication, April 20, 2020).

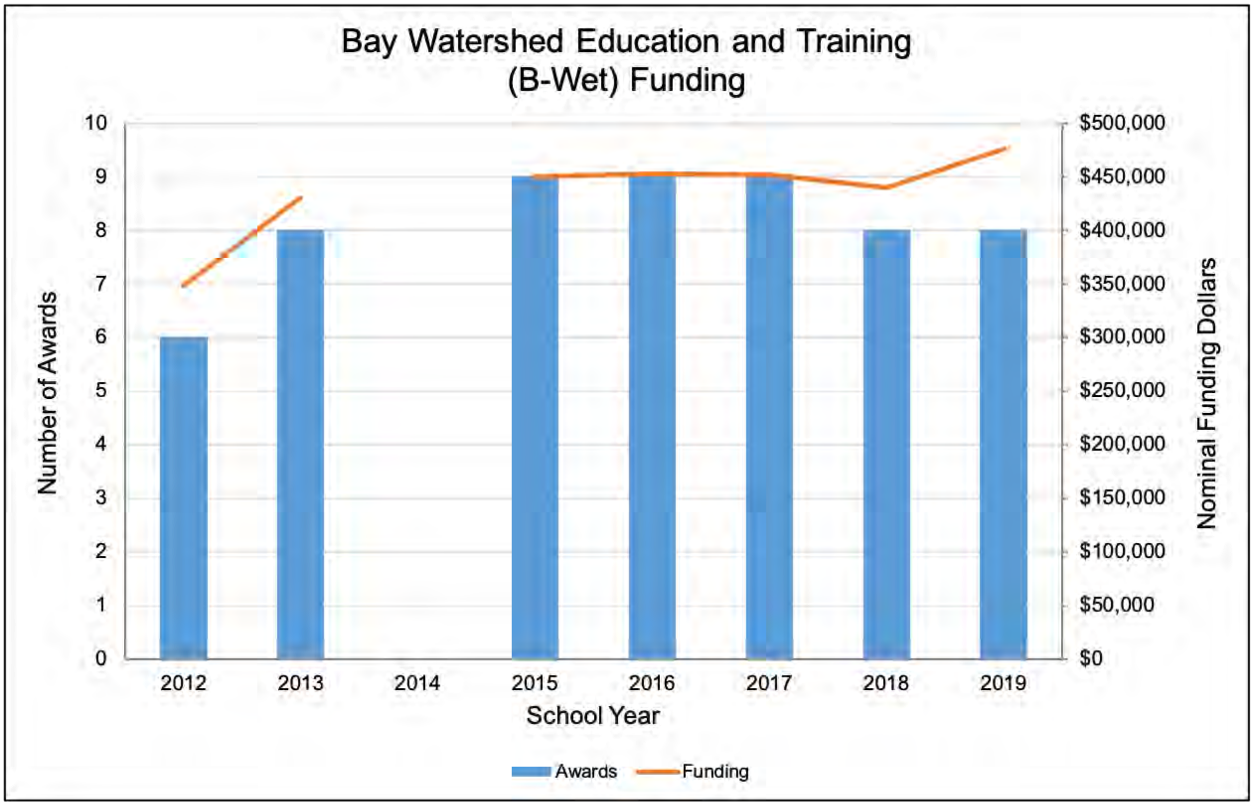


Figure ES.E.2. B-WET funding, 2012–2019. Normal funding dollars are values not adjusted for inflation. Source: J. Laverdure/NOAA, personal communication, April 20, 2020

In addition to looking at proxy economic indicators, reviewing the types of programs offered and the number of people impacted is also useful.

Pre-K–12

Pre-K–12 programs are summarized below and described in more detail in Table ES.E.1 and Table ES.E.2. The outer coast of the Olympic Peninsula is a remote and economically depressed region, and the pre-K–12 schools in the area do not have access to the resources necessary to provide students with hands-on marine science education. OCNMS is one of very few organizations on the Olympic Peninsula with staff expertise in both marine science and environmental education. The sanctuary's pre-K–12 ocean-literacy-based programs fill a gap in educational services in the region. Additionally, OCNMS is the only national marine sanctuary in the Pacific Northwest and is considered a significant regional resource for environmental education in Washington and Oregon.

Since 2008, OCNMS staff have engaged local and regional students in activities that promote ocean literacy in the field and in the classroom. Programming has expanded from year to year to increase student reach and quality of programs. B-WET and Ocean Guardian School Program funding, enhanced NOAA MWEE guidelines, easier access to students (i.e., long-standing programs are established in school districts), and support provided as a result of higher education internship and in-service opportunities (e.g., NOAA Hollings Scholarship, AmeriCorps) have contributed to program expansion. Benefits of expanded programs include increased and more robust contact time with students (based on MWEE guidelines and increased intern/AmeriCorps support), programming over multiple school years, increased student reach, and increased opportunities for teacher professional development.

Since 2008, several place-based and Science, Technology, Engineering, Arts, and Mathematics (STEAM) programs focusing on ocean literacy have been supported by OCNMS. Each year, the Ocean Science Program uses hands-on, inquiry, and place-based activities to support approximately 15 teachers, 350 students (grades 3–6), and their families to better understand their local marine environment and make local cultural connections. The program provides summer in-service workshops with follow-up support for teachers, classroom beach curriculum and resource kits, and beach field trips to monitor intertidal areas and collect debris.

The North Olympic Watershed Science Program , a partnership between OCNMS and Feiro Marine Life Center, Dungeness Audubon Center, Olympic National Park, and the City of Port Angeles, provides field science opportunities for approximately 800 4th and 5th grade students on the North Olympic Peninsula. Since 2008, the North Olympic Watershed Science Program has expanded from a three-hour marine science center field trip for 4th grade students to MWEEs for 4th and 5th grade students with pre-classroom visits, watershed field investigations, stewardship action projects, post-field trip classroom visits, and outreach, as well as teacher professional development.

More recently developed programs include Sanctuary Splash: Discover the Olympic Coast and Big Mama Meet the Humpback Whale programs, which reach approximately 800 students annually. Discover the Olympic Coast is a resource for 3rd grade students to discover the diverse habitats and organisms of the sanctuary through Florian Graner's underwater film *Discover the Olympic Coast*. Big Mama Meet the Humpback Whale is an interactive educational program, focusing on the 5th grade level, that allows students to explore the life-sized, walk-inside model of a humpback whale, named "Big Mama" (Figure ES.E.3). The program also includes hands-on, STEAM-focused activities that support ocean science and promote stewardship.

Figure ES.E.3. Big Mama is a life-sized model of a humpback whale. Photo: J. Laverdure/NOAA

The Ocean Acidification pHyter and Plankton Monitoring Program is an ONMS West Coast Region education and citizen science pilot project that provides approximately four Olympic Coast teachers and 75 middle and high school students with innovative new tools and technology to monitor for ocean acidification and other oceanographic conditions.

Olympic Coast Marine Advanced Technology and Education Robotics Clubs are offered both through in school and after school programs to prepare approximately 100 students and 20 mentors for the annual Olympic Coast Marine Advanced Technology and Education Regional Competition held in Forks, Washington.

Junior Oceanographer and Ocean Explorers youth summer camps, a partnership between OCNMS and Feiro Marine Life Center, provide K-9 students with experiential education focused on the local marine environment in order to improve ocean literacy and foster a lifelong respect for and understanding of the ocean.

Chalá· at Hoh River Watershed Adventure Camp, a partnership between OCNMS and the Hoh Tribe, began in 2015 as a four-day, three-night rafting and overnight watershed adventure summer camp with a focus on connecting tribal culture, treaty rights, traditional resources, harvesting, and climate change and its impact on resource sustainability and resilience. Due to loss of funding and support, the camp decreased in 2017 to four days and one night of camping and in 2018 to two days without overnight camping. OCNMS also supports other youth summer camps and programming in outer coast communities as requested.

Table ES.E.1. Pre-K–12 programs that are run by OCNMS staff.

Program Name	Years	Description	Example Activities	Schools Targetted	Sources of Funding
Ocean Science Program	2008–present	The Ocean Science Program uses hands-on, inquiry, and place-based activities to support teachers, students (grades 3–6), and their families to better understand their local marine environment, as well as enable them to make cultural connections with local Indigenous communities.	**Teacher summer in-service workshop and follow-up training:** The multi-day workshop provides content training in marine ecosystems, ocean conservation, and nearshore field investigations, as well as pedagogical models for teaching inquiry science. Workshops average 16–32 hours of instructional time, as well as ongoing teacher support. **A classroom beach curriculum and marine debris kits**, which include activities and supplies that provide a foundation for ocean science learning in the classroom, are distributed to teachers at the workshop. **Beach field trip/Trash-Free Seas!** Students investigate and clean up a beach near their school to collect intertidal and baseline data on the occurrence of marine debris on local beaches. Field trips average 3–4 hours in duration.	Clallam Bay, Neah Bay, Quileute Tribe, Forks, Queets/Clearwater, Lake Quinault, Taholah, Pacific Beach, Ocean Shores, Simpson, and Ocosta elementary schools	NOAA Environmental Literacy Program grant in partnership with the Seattle Aquarium (initially); local support from marine resources committees and OCNMS (present)
North Olympic Watershed Science Program	2008–present	Through this unique program, students visit their regional watershed in diverse locations. Students use their local watershed to make connections to the ocean and investigate the effects of human impacts on the ocean. OCNMS supports all aspects of the program, including providing hands-on ocean acidification lessons to all students in both 4th and 5th grades.	Since 2008, the North Olympic Watershed Science Program has expanded from a three-hour marine science center field trip for 4th grade students to multi-day meaningful watershed educational experiences for 4th and 5th grade students with pre-classroom visits, watershed field investigations, stewardship action projects, post field trip classroom visits, and outreach, as well as teacher professional development.	Port Angeles, Sequim, and Joyce elementary schools	B-WET (since 2009)

Program Name	Years	Description	Example Activities	Schools Targetted	Sources of Funding
Sanctuary Splash! Discover the Olympic Coast	2019–present	Discover the Olympic Coast is a resource for 3rd grade students to discover the diverse habitats and organisms of OCNMS through Florian Graner's underwater film *Discover the Olympic Coast*.	After viewing the film, students create a model of the complex marine food web, looking at predator prey relationships, adaptations for survival in marine habitats, and the interdependence of a healthy, balanced food web that includes humans.	Clallam Bay, Neah Bay, Quileute Tribe, Forks, Queets/Clearwater, Lake Quinault, Taholah, Pacific Beach, Port Angeles, Sequim, and Joyce elementary schools	North Pacific Coast Marine Resources Committtee, B-WET, and OCNMS
Sanctuary Splash! Big Mama	2017–present	This fun, interactive educational program allows students to explore the life-sized, walk-inside model of "Big Mama" the humpback whale while participating in hands-on STEAM-focused activities that support ocean science and promote stewardship.	An **introduction** teaches students about OCNMS, focusing on cetaceans, including humpback whales. The **Big Mama walkthrough tour** introduces students to Big Mama (external and internal anatomy and fluke identification). A **vocalization** component uses presentations and hands-on activities to engage students in the study of the science of sound, including the unique ways that cetaceans communicate and a comparison of human and cetacean skull structure. The **Healthy Humpback Habits take-home activity** allows students to share what they learned about Big Mama with their friends and families and develop healthy humpback habits. The experience is over three hours long.	Clallam Bay, Neah Bay, Quileute Tribe, Forks, Queets/Clearwater, Lake Quinault, Taholah, Pacific Beach, Port Angeles, Sequim, and Joyce elementary schools	B-WET and OCNMS
Ocean Acidification pHyter and Plankton Monitoring Program	2018–present	This program features the affordable and easy-to-use field-based instrument called "pHyter," a hand-held chemical indicator-based spectrophotometric pH-measuring device, still in beta testing phase.	Using plankton as the investigative model for ocean health, students are piloting a curriculum, monitoring tools, and protocols to implement ocean chemistry and plankton monitoring, while considering student-led stewardship action projects that can help mitigate the challenges of our changing ocean. The pilot program and curriculum was initiated using NOAA Ocean Acidification Program mini-grant funding. The pHyter instrument is still in beta testing phase.	Neah Bay, Quileute Tribe, Forks, and Taholah middle and high schools	

Program Name	Years	Description	Example Activities	Schools Targetted	Sources of Funding
Olympic Coast Marine Advanced Technology and Education Robotics Clubs and Regional Competition	2018–present	An underwater robotics club in schools or afterschool programs	Student teams engineer and pilot an ROV while meeting the competition's technical and safety inspections, delivering an oral presentation on their engineering design, and providing a marketing display to entice potential partners and clients. Students put their hard work to practice with the final challenge, where they pilot their ROVs in pool missions, which emulate real-world situations in which ROVs are used.	Clallam Bay, Neah Bay, Quileute, Forks, Queets/Clearwater, Lake Quinault, Taholah, and Ocean Shores middle and high schools	OCNMS, MATE, participating schools, team sponsors, and local marine resources committees
Junior Oceanographer Summer Program	2008–present	Junior Oceanographer youth camps, a partnership with Feiro Marine Life Center, provide K–9 students with experiential education programs focused on the local marine environment in order to improve ocean literacy and foster a lifelong respect for and understanding of the ocean.		Students in grade levels K–3, 4–6, and 7–9	
Chalá· at Hoh River Watershed Adventure Camp	2015–2018	The camp focused on connecting tribal culture, treaty rights, traditional resources and harvesting, and the impact of climate change on resource sustainability and resilience.	Rafting 30 miles down the Hoh River provided the opportunity to compare western science and watershed management to traditional relationships with the Hoh River Watershed and intertidal areas.	Hoh Tribe students in grade levels K–12 and their families	Hoh Tribe, Bureau of Indian Affairs climate change funds

Table ES.E.2. Number of students participating in selected programs annually. Source: NOAA Office of Education, 2020

	FY15	FY16	FY17	FY18
Junior Oceanographer and Ocean Explorers summer camps	71	82	73	42
North Olympic Watershed Science	900	750	954	440
Ocean Science Program beach field trips	400	350	412	360
Sanctuary Splash! Big Mama	0	0	150	304

Higher Education

Opportunities to learn basic and applied science skills in communities adjacent to OCNMS are limited, and pathways to science-based careers are scarce. OCNMS is in a unique position to lead the region in promoting adult learning and career-building opportunities in marine science, education, management, and policy. This is accomplished through opportunities such as Olympic Coast Discovery Center annual docent training, speaker series events (ONMS webinar series, Feiro Marine Life Center, Peninsula College), and internships and scholarships (e.g., AmeriCorps, NOAA Hollings Scholarship, NOAA Nancy Foster Scholarship, Peninsula College internships).

A number of other programs, while not directly supported by OCNMS, revolve around education and experiences related to resources found within and around the sanctuary. These programs include Washington Sea Grant and University of Washington programs such as fellowships, internships, and research assistantships, as well as programs that involve coastal students in the Orca Bowl and the Doris Duke Conservation Scholars Program, which partners with Quinault Indian Nation to facilitate learning about the coast. Additionally, the Makah Tribe offers a summer internship to high school and college students to work in the tribe's fisheries, forestry, wildlife, and environmental science departments. The Marine Resources Council also provides outdoor learning opportunities and other educational and outreach funding related to sanctuary resources and topics.

Community Outreach

OCNMS actively supports marine stewardship and citizen science volunteer programs with local and regional communities and maintains a presence at community events and meetings in the sanctuary region. Examples of OCNMS community outreach include active engagement (such as participating in a steering committee and dedicating staff time) for programs with Washington CoastSavers, MDMAP, COASST, and local marine resources committees. Additionally, OCNMS reaches the public through participation in special events and festivals (e.g., Makah Days, Grays Harbor Shorebird Festival, Dungeness Crab and Seafood Festival, Beachcombers Fun Fair) and live "ship to shore" science broadcasts when possible.

Visitor Services

Outreach initiatives are aimed at improving and enhancing the public's awareness of OCNMS. This is done through a variety of tools, such as the Olympic Coast Discovery Center (OCNMS visitor center in Port Angeles), coastal interpretive programs, interpretive signage, NOAA Olympic Coast kiosks, and the annual Get Into Your Sanctuary Day! (an ONMS-wide event that raises awareness about the value of national marine sanctuaries as iconic destinations for responsible recreation through a series of special activities) (Table ES.E.3). Table ES.E.4 shows that the number of walk-in visitors has been increasing at various sites throughout the region, including the Olympic Coast Discovery Center and the Seattle Aquarium.

Table ES.E.3. Names and descriptions of visitor services programs offered at OCNMS.

Visitor Services Program	Description
Olympic Coast Discovery Center	The OCNMS visitor center, located on the Port Angeles waterfront, includes maps, interactive kiosks, a video theater, and hands-on displays that present the major themes of conservation, science and exploration, and maritime heritage.
Coastal interpretive programs	Place-based educational services for visitors in partnership with the Makah Tribe (Makah Cultural and Research Center) at Cape Flattery overlook and Olympic National Park at coastal beaches.
Interpretive signage	Interpretive signs are located at strategic locations and access points adjacent to the sanctuary to provide information to visitors (examples include OCNMS trailhead signs and The Whale Trail signs).
Kiosks	OCNMS interactive touch screen kiosks are strategically placed at Pacific Science Center in Seattle, Kalaloch Lodge in Olympic National Park, and Forks Visitor Center.
Get Into Your Sanctuary!	This system-wide event raises awareness about the value of our sanctuaries as iconic destinations for responsible recreation through a series of special activities.
Earth Is Blue, website, and social media	Online media provides platforms for the most up-to-date research, programs, and information regarding OCNMS.

Table ES.E.4. Number of participants in select visitor service programs. Years refer to federal fiscal years, which run from October 1 to September 30. For example, fiscal year 2015 reflects visitor numbers from October 1, 2014 to September 30, 2015.

Visitor Services Exhibit	2015	2016	2017	2018
Exhibits at Feiro Marine Life Center	20,000	18,500	22,000	24,000
Exhibits at Seattle Aquarium	812,000	851,296	860,000	860,000
Forks Visitor Center kiosk	0	40,963	41,160	41,835
Olympic Coast Discovery Center	5,446	6,000	6,000	5,110
Total number of walk-in visitors	837,446	916,759	929,160	931,945

Additionally, media like Earth Is Blue, OCNMS and ONMS websites, 360° imagery, and social media are platforms for accessing up-to-date research, programs, and information about the sanctuary. Despite variation in social media data from month to month, Facebook reach has shown a decline overall since 2015 both for OCNMS and ONMS, but Twitter impressions have increased (Figure ES.E.4, Figure ES.E.5) (E. Weinberg/NOAA, personal communication, April 20, 2020).

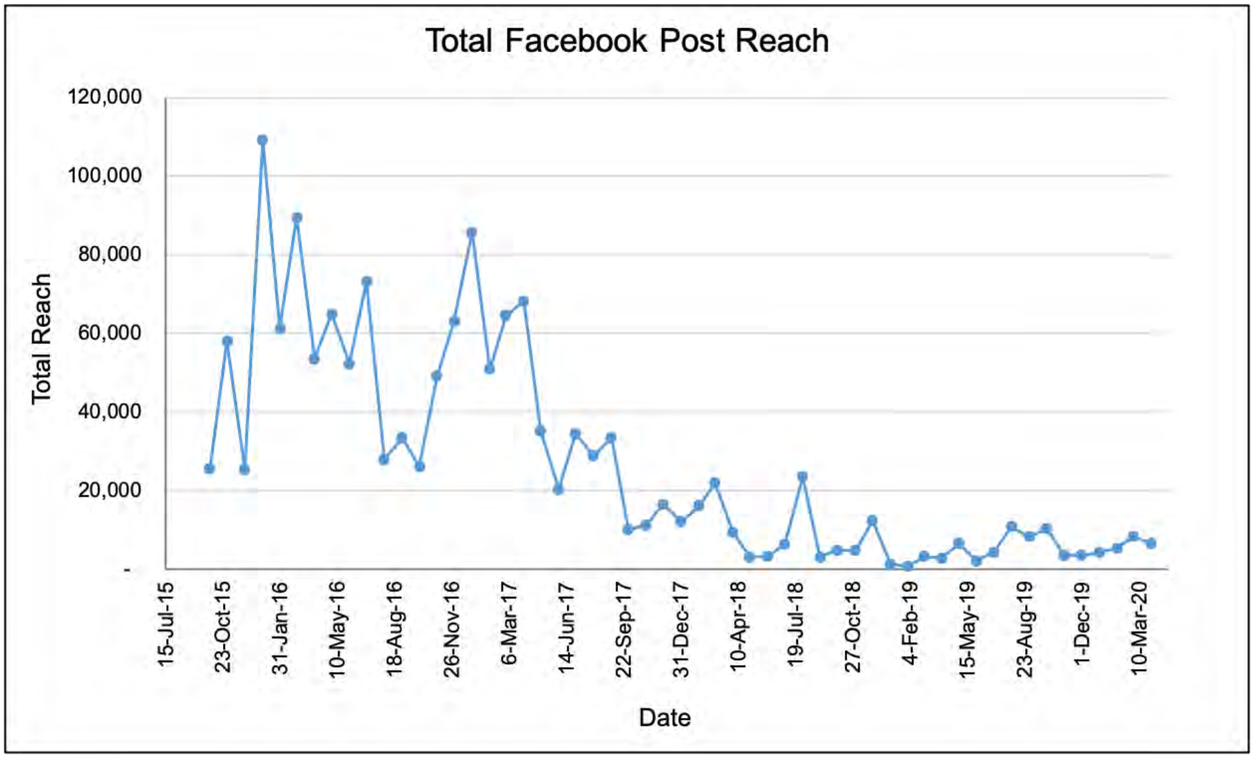


Figure ES.E.4. Total reach for OCNMS Facebook page. Source: E. Weinberg/NOAA, personal communication, April 20, 2020

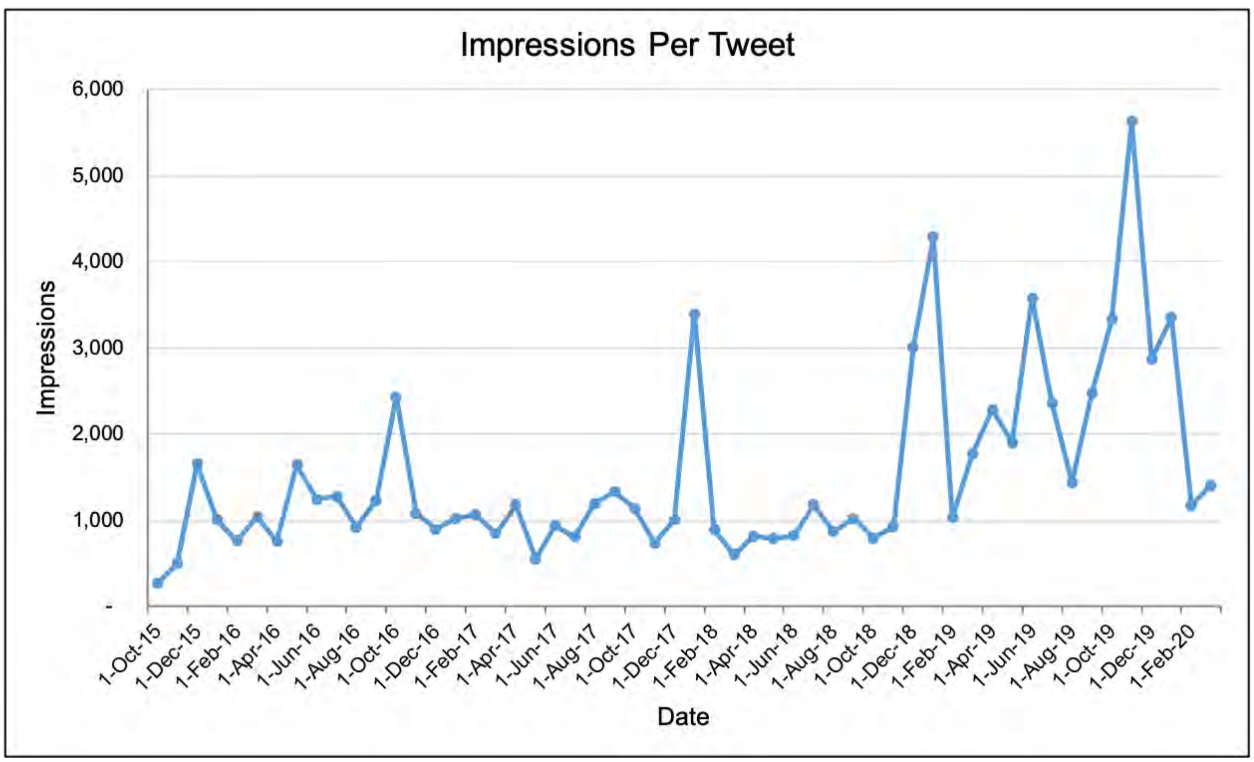


Figure ES.E.5. Impressions (total tally of all the times a tweet has been seen) by tweet for OCNMS Twitter account. Source: E. Weinberg/NOAA, personal communication, April 20, 2020

Other forms of communication related to the sanctuary include print and online newsletters such as Nugguam and The Talking Raven (produced by the Quinault Indian Nation and the Quileute Tribe, respectively) and books such as *Native Peoples of the Olympic Peninsula: Who We Are* (Olympic Peninsula Intertribal Cultural Advisory Committee, 2015) and *The Northwest Coastal Explorer* (Steelquist, 2016). Lastly, OCNMS has a robust network of volunteers that help with everything from educational programming to citizen science to the visitor center. The number of volunteer hours has generally increased since 2008 and peaked in 2015 (Figure ES.E.6). It is also worth noting some of the challenges OCNMS faces in providing education services. These include the distance between the OCNMS headquarters office and many regional communities, limited sanctuary access points and infrastructure (e.g., poor to limited internet connectivity, limited boat launches and amenities, limited lodging), and limited staff time and resources to support programming.

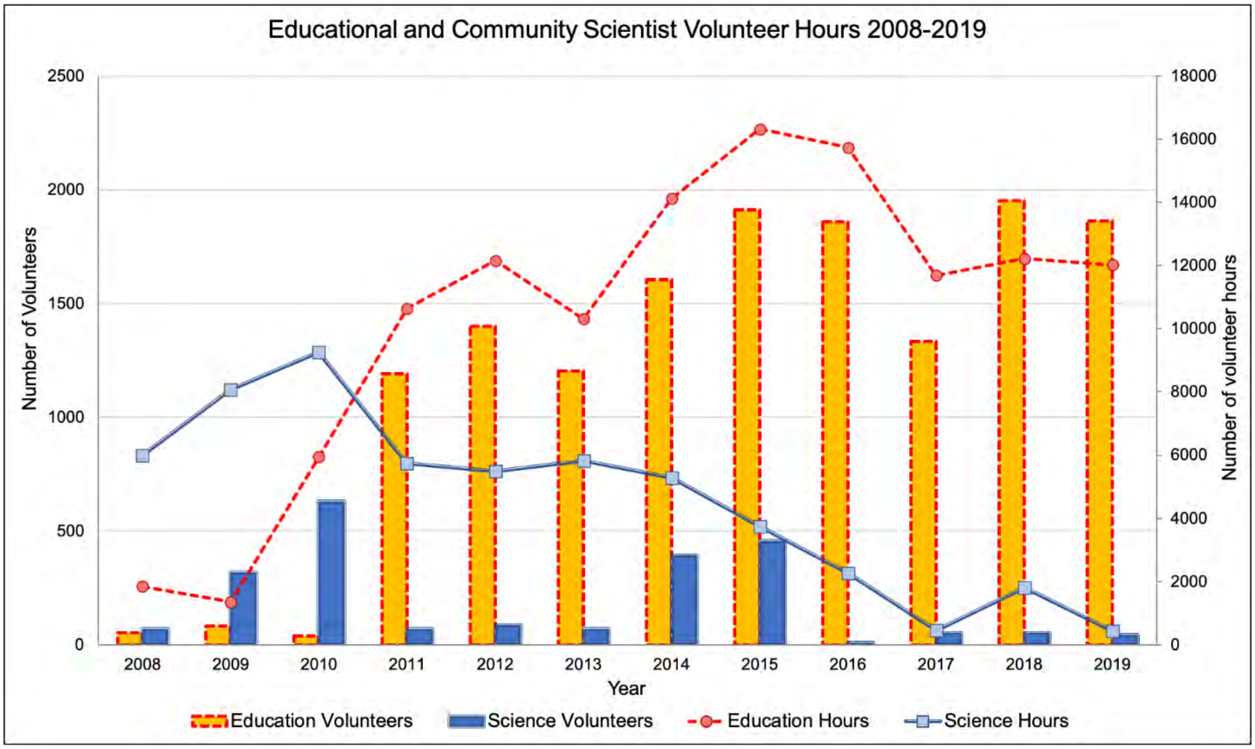


Figure ES.E.6. The number of volunteers and volunteer hours contributed toward OCNMS educational and community science efforts from 2008 to 2019. While the number of volunteers and volunteer hours focused on education remain high, volunteer contributions to science decreased following discontinuation of marine debris program funding. Image: C. Butler-Minor/NOAA

Conclusion

Services that provide intellectual enrichment are considered acceptable and improving, based largely on the many successful and broad ranging education and outreach programs that are offered by OCNMS, Coastal Treaty Tribes, and other partners. Education and outreach activities focused on OCNMS and related ocean science and stewardship have increased in quality over time and have contributed to the public's awareness of OCNMS, enhancing ocean literacy.

Table ES.E.5a. Status and trends for individual education ecosystem service indicators discussed at the January 2020 workshop.

Economic Indicators	Source	Figure or Table	Data Summary
Ocean Guardian parent willingness to pay	Schwarzmann et al., 2017		Parents have a willingness to pay for hands-on science education aimed at teaching students about ocean conservation and stewardship of local watersheds and special ocean areas like national marine sanctuaries.
B-WET funding	J. Laverdure/NOAA, personal communication, April 20, 2020	Figure ES.E.2	B-WET is an environmental education program that supports locally relevant experiential learning for K–12 students; funding has remained relatively stable since 2015.

Table ES.E.5b. Status and trends for individual education ecosystem service indicators discussed at the January 2020 workshop.

Non-Economic Indicators	Source	Figure or Table	Data Summary
Pre-K to 12 education programs	J. Laverdure/NOAA, personal communication, April 20, 2020	Table ES.E.1	The quality of programs has increased, despite some decreases in total number of students reached.
Pre-K to 12 education programs	NOAA Office of Education, 2020; OCNMS, 2018a	Table ES.E.2	The data show an overall decline in the number of students reached, but the quality and length of programs increased.
Higher education programs	OCNMS, 2018a; J. Laverdure/NOAA, personal communication, April 20, 2020		OCNMS has been successful in recruiting students to intern and create meaningful education experiences at the site.
Community outreach	OCNMS, 2018a; J. Laverdure/NOAA, personal communication, April 20, 2020		OCNMS has been expanding the variety of community outreach programs and special events to further engage with the community.
Visitor service programs	OCNMS, 2018a; J. Laverdure/NOAA, personal communication, April 20, 2020	Tables ES.E.3–ES.E.4	OCNMS has continued to work with partners and expand access to the sanctuary via remote visitor experiences.
Visitor service programs	NOAA Office of Education, 2020	Tables ES.E.3–ES.E.4	The number of walk-in visitors across all sites has increased since 2015.

Non-Economic Indicators	Source	Figure or Table	Data Summary
Social media	E. Weinberg/NOAA, personal communication, April 20, 2020	Figure ES.E.4; Figure ES.E.5	Facebook reach has declined overall since 2015, but Twitter impressions have increased over time.
Volunteers	C. Butler-Minor/NOAA, personal communication, January 12, 2021	Figure ES.E.6	The number of volunteer hours has increased since record keeping began in 2014; the number of volunteers has decreased over the same time period.

Heritage

Recognition of historical and heritage legacy and cultural practices

Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.

Rationale: The existence, and in some cases resurgence, of traditional cultural practices reflecting heritage contributed to the good/fair rating for this ecosystem service. These practices include exercising treaty rights, revitalizing tribal languages, subsistence harvest, potlatches, canoe journeys, the publication of several books about tribal histories and culture, and interpretive programs that help to restore and preserve heritage. However, some key heritage practices are compromised due to declines, closures, or shifts in resources (e.g., harvest of blueback salmon and other cultural keystone species). Cultural practices such as harvesting and sharing of knowledge (e.g., how and when to harvest) through the practice of harvesting are not as robust as they have been, indicating that improvements could be made.

The Olympic Coast has a strong historical and heritage legacy that includes the Coastal Treaty Tribes, historical maritime exploration and trade, timber harvest, recreational and commercial fisheries, wilderness protections, and long-term ecological research. Continued cultural practices and exercise of treaty rights by the Coastal Treaty Tribes are the strongest and most long-lived example of the heritage ecosystem service in the Olympic Coast region.

Pre-Contact

The Coastal Treaty Tribes have inhabited the Olympic Coast area since time immemorial. Each of the Coastal Treaty Tribes has a distinct culture, language, governance, and history prior to European contact. Tribes have unique connections to places and resources that have shaped their culture and heritage. Access to and, in some cases, ownership of productive ocean, coast, and river sites to facilitate harvest of salmon, cedar, halibut, whales, seals, and more allowed Indigenous peoples to thrive on the Olympic Coast for thousands of years and accumulate wealth through various trade routes (see Site History for more information).

Archaeologists speculate that ancient tribal archaeological sites off Washington's coast are likely associated with paleo-shorelines. The sea level history of the Olympic Coast is complicated, with older paleo-shorelines likely occurring subtidally and more recent paleo-shorelines occurring above current sea level (OCNMS, 2018). The sea level 20,000 years ago was about 120 meters lower than present. As a result of glacial melt, sea level rose to a point approximately 20 meters below present by 8,000 years ago and reached modern levels about 2,000 years ago. Researchers believe that between 8,000 and 2,000 years ago, regional sea levels may actually have been at least four meters above modern sea level, a finding supported by tribal oral tradition.

European Settlement

Prior to and throughout the period of European settlement on the western Olympic Peninsula, the link between the land and the ocean has shaped history and the Olympic Coast. The first recorded European contact with the Coastal Treaty Tribes was in 1775, which was quickly followed by other Europeans, and later Americans, all hoping to capitalize on the sea otter and fur seal trade. All coastal trade vessels working between California and Puget Sound, as well as vessels visiting the region for trans-Pacific trade, traversed the area that is now OCNMS. European and American contact included disastrous impacts for many tribes, including decimation of tribal populations by disease. By 1856, most tribes were consigned to reservations by the U.S. government, including those on the Olympic Coast with the signing of the Treaty of Neah Bay and the Treaty of Olympia.

Through the latter part of the 1800s, settlers moved into the Olympic Peninsula to farm, fish, and cut timber. The town of Forks had European settlers as early as the 1860s. People were originally drawn to Forks by gold prospecting, but timber became the mainstay of the economy in Forks and other western Washington towns. The lumber trade on the Pacific coast is a long-lived and dominant aspect of maritime trade along the coast. Fishing continues to be an important commercial, ceremonial, subsistence, and recreational venture for coastal communities like Neah Bay and La Push and is identified as a key component of coastal heritage (Washington State Department of Ecology, 2018). Coast-wide maritime trade linked the productive Olympic Peninsula with global markets. Today, commerce on the Olympic Coast still depends largely on commercial and recreational fishing, logging, and tourism (see Site History for more information).

Maritime Heritage Resources

Nearly 200 historical vessels are believed to have been lost in or near OCNMS, however only eight have been located. Of the located shipwrecks, the oldest are the clipper ships *Ellen Foster* and *Emily Farnum*, both built in 1852 and sunk in 1867 and 1875, respectively. The most recently built historic shipwrecks are the steamship *General M.C. Meigs* and a submarine, USS *Bugara*, both naval vessels built in 1944 and sunk in 1972 and 1971, respectively (OCNMS, 2018). Through interpretive signage, museums, and online resources, the stories of these vessels continue to be known today. Given the broad range of cultural expression, benefits of heritage may take many forms, such as traditional practices, coastal canoe routes, museum exhibits, post-European contact historic properties, etc. A number of studies have been conducted to assess how people value maritime heritage resources in national marine sanctuaries, with a heavy focus on shipwrecks. Although shipwrecks may provide reef structure and have historic significance, they often reflect specific ecosystem values that may not be widely shared at all sanctuaries.

Within the national marine sanctuary system, maritime heritage resources are valuable for generating visitation and tourism revenue (Schwarzmann et al., 2020), and surveys have found that people are willing to pay to protect these resources (Mires, 2014). While such data are not available for OCNMS, other metrics indicate that these resources are valued; for example, 28% of Washington residents report sightseeing at outdoor cultural or historical facilities (Jostad et al., 2017) and the natural-resource-based economy of the outer coast has been identified as an important aspect of cultural heritage to maintain (Washington State Department of Ecology, 2018). Although these studies are not specific to OCNMS, it is possible that visitors to this region also have demand and value for maritime heritage resources, such as shipwrecks within and around the sanctuary and opportunities offered on land, including museums and visitor centers that display heritage resources from the sanctuary.

Coastal Treaty Tribes

For many Indigenous communities, natural resources *are* cultural resources—inextricably connected to tribal heritage. These living resources, whether marine, riverine, or terrestrial, are the source of tribal origin stories, clan names, songs, art and technology, religion, subsistence foodways, clothing, and trade. Vibrant and active Indigenous cultures remain a defining and dominant element of the cultural heritage of some national marine sanctuaries. There are several terrestrial areas adjacent to the sanctuary that contain culturally significant sites important to maintaining the strong connection between the Coastal Treaty Tribes and their heritage. These include historic villages, petroglyphs/pictographs, cemeteries and burial grounds, and landscapes and scenic features, as well as tribally owned and operated museums (ICF International et al., 2013). Consideration of heritage beyond sanctuary boundaries is important to understand the significance of the sanctuary itself within an integrated cultural landscape.

Ball et al. (2015, 2017a, 2017b) worked with the Makah Tribe to assess their tribal cultural landscape with funding from the Bureau of Ocean Energy Management. Their goal was to identify "any place in which a relationship, past or present, exists between a spatial area, resource, and an associated group of Indigenous people whose cultural practices, beliefs, or identity connects them to that place" (Ball et al., 2015, p. 5). They found that the "Makah Tribe used the Makah Cultural and Research Center's wealth of historic documents, photographs, manuscripts, audio and video recordings, transcripts of audio recordings, legal records, cultural site reports, maps, pre-contact and historic artifacts and publications that relate to the area and resources" (Ball et al., 2017b, p. 32). These data were used to focus more narrowly on the Ozette tribal cultural landscape. Ball et al. (2017b) found that the interdependence between land and water, technology and resource use, people, and place was apparent. Tribal cultural landscapes are not presented here for other Coastal Treaty Tribes, as they have not been completed.

McLain et al. (2013) asked respondents (both tribal and non-tribal) to report meaningful places on the outer coast. Among other qualities, respondents were asked to spatially identify and rate places based upon the statement "I value this place because it has natural and human history that matters to me and it allows me to pass down the wisdom, knowledge, traditions, or way of life of my ancestors" (McLain et al., 2013, p. 5). Additionally, survey respondents were asked to select primary values associated with each meaningful place identified. The most frequently selected primary value associated with meaningful places in the Olympic Peninsula was recreation, followed by economic, aesthetic, home, and heritage (McLain et al., 2013).

A number of activities and events that connect people with their heritage, such as canoe journeys, have regained popularity in recent years and are important to many coastal tribes. Modern-era canoe journeys started in 1989 and became an annual event in 1995. During each journey, participants make predetermined stops, where they are welcomed by host tribes, and paddlers are able to rest, eat, and celebrate together. On the last day of the multi-day journey, there is a post-arrival ceremony based upon potlatch, a traditional ceremonial feast practiced by Indigenous peoples of the Pacific Northwest. Canoe journeys are significant to the Coastal Treaty Tribes: "'One of the things it was supposed to be was a healing process, the return to culture and a healing to find the way that the elders did it and the ancestors did it,' said Red Eagle. 'The saying was that we put the knowledge into the canoe and the canoe teaches'" (Paul, 2019).

Marine mammals are a significant component of heritage for the Washington coast, from the Coastal Treaty Tribes utilizing whales, pinnipeds, and sea otters for subsistence and trade to historical commercial take of whales, sea otters, and fur seals by European settlers. The Makah Tribe has hunted whales for at least 1,500 years, and whaling continues to be central to their culture (Renker, 2018). The right to take whales at usual and accustomed grounds is a Makah tradition secured by the 1855 Treaty of Neah Bay. However, due to significant population declines from non-tribal commercial whaling, the Makah Tribe ceased whaling in the 1920s to allow populations to recover. In 1994, the eastern North Pacific gray whale was removed from the ESA federal lists of endangered and threatened wildlife and plants, and the Makah Tribe requested authorization to hunt. In 1999, the Makah successfully took a whale, the skeleton of which is on display in the Makah Museum. However, a lengthy legal process halted additional hunts. The U.S. Ninth Circuit Court of Appeals ruled in 2004 that to pursue any treaty rights for whaling, the Makah Tribe must comply with the process prescribed in the Marine Mammal Protection Act for authorizing the take of marine mammals otherwise prohibited by the act's take moratorium. On February 14, 2005, the Makah Tribe submitted a request to NOAA Fisheries for a waiver of the Marine Mammal Protection Act take moratorium. In April 2019, NOAA Fisheries published a proposed rule to issue a waiver under the Marine Mammal Protection Act; that November, an administrative law judge hearing took place. By June 2021, a final decision by NOAA Fisheries on the waiver request had not been made. The Makah Tribe has demonstrated the significance of this cultural and subsistence practice through consistent engagement in international and domestic processes (i.e., International Whaling Commission, Marine Mammal Protection Act, and National Environmental Policy Act procedures), as well as investment into marine mammal research, monitoring, and management for more than two decades as they await a decision.

There are several significant heritage events that take place to celebrate the establishment of treaties and treaty rights, becoming U.S. citizens, culture, and community, as well as connecting people to history and to the natural environment around them. These events include, but are not limited to, Makah Days, Quileute Days, Queets Days, Chief Taholah Days, First Salmon ceremonies, potlatches, a weekly drum ceremony at La Push, and the Quileute Welcoming the Whales ceremony. Traditionally, the Quileute hunted whales and would celebrate their return to their traditional area. In 2007, the Quileute Tribe began welcoming gray whales again as they reached Quileute's U&A fishing grounds during their migration north through traditional songs and dances.

There are several writings and publications available related to coastal tribes and their connection to the ocean and Olympic Peninsula. These titles include: *Native Peoples of the Olympic Peninsula: Who We Are* (Olympic Peninsula Intertribal Cultural Advisory Committee, 2015), *Gifted Earth: The Ethnobotany of the Quinault and Neighboring Tribes* (Deur et al., 2019), *The Sea is My Country* (Reid, 2015), and *From the Hands of a Weaver: Olympic Peninsula Basketry Through Time* (Wray, 2014). This list is not exhaustive, but exemplifies the extensive heritage associated with the Olympic Coast, some, but not all of which, has been documented in writing. These books discuss creation and the significance of treaty signings, and also include more focused writings on the importance of plant life for food, medicine, and materials (including use in basketry).

Changes in resource conditions influence the ability of tribes to hold traditional ceremonies. For the Quinault Indian Nation, "the cultural importance of the salmon is represented in several traditional customs, including the First Salmon ceremony. The salmon must be treated with honor and respect so that they will return to the place of their birth. The Quinault understand that they are not simply the beneficiaries of the salmon as food; they also have responsibilities to carry out the practices of their ancestors" (Olympic Peninsula Intertribal Cultural Advisory Committee, 2015, p. 111). The conditions of several salmon stocks have declined, which can negatively impact cultural events, such as the First Salmon ceremony. Specifically, the blueback salmon is a unique sockeye run that exists in the Quinault River. Experts at the workshop noted that the Quinault people are indelibly connected to the river, and blueback salmon have immeasurable heritage value. Unfortunately, due to declines in blueback salmon, at times, the Quinault have had to purchase salmon from others to hold the ceremony.

Another species with important tribal and non-tribal heritage value is the Pacific razor clam. Razor clams have been a key species to the Quinault people for millennia and for non-tribal members for over one hundred years. Crosman et al. (2019) discussed "clam hunger"—the physical and emotional craving for traditional food, which connects tribal members with traditional places and connects them to childhood, family, and ancestry. Razor clams hold a great deal of significance in Quinault culture; they support intergenerational sharing and teaching of knowledge through harvesting together, and also have health benefits. For these reasons, razor clams are considered cultural keystone species for the Quinault people. Designation as cultural keystone species indicates that razor clams are woven throughout the culture of the tribe.

Changing ocean conditions can impact tribes' ability to exercise treaty rights and practice their culture. For example, closures of shellfish harvest due to harmful algal blooms or lack of sockeye for a season due to warmer ocean temperatures shifting migration pathways may result in fewer opportunities to harvest for subsistence, practice culture, and share knowledge. Though natural variation in ocean conditions on both short- and long-term scales is woven into the oral history of tribal peoples, changes occurring as a consequence of anthropogenic climate change threaten to alter ecosystem structure and function, and thus cultural heritage, permanently. Recognizing the scope and scale of this concern is key to developing proactive measures to ensure critical cultural practices endure despite these changes.

Although many of the activities mentioned here are considered cultural practices, workshop participants also stated that these ceremonies, activities, and practices are a natural part of daily life.

Heritage Designations

Special designations in and around the sanctuary are also important and can indicate the area's heritage legacy. At the state level, most Washington state waters (which overlap with OCNMS) were designated a Maritime Washington National Heritage Area in 2019. At the national level, Olympic National Forest was designated in 1897, Olympic National Park was established in 1938 (with the coastal wilderness added in the 1950s), and OCNMS was established in 1994. Further, there are three sites on the National Register of Historic Places: Tatoosh Island (est. 1972), Ozette Indian Village Archeological Site (est. 1974), and Wedding Rocks Petroglyphs (est. 1976). The Olympic Peninsula region has also been recognized internationally; the United Nations Education, Scientific, and Cultural Organization (UNESCO) designated Olympic National Park as Olympic Biosphere Reserve in 1976 and as a World Heritage Site in 1981. The Olympic Coast is often referred to as the wilderness coast due to its relatively pristine coastline and the state and national designations aimed at maintaining natural ecosystems and the heritage services they provide.

Wilderness designations are a result of, and continue to inspire, a conservation ethic on the Olympic Coast. The long-time stewardship of this region by the Coastal Treaty Tribes sets the foundation, as they have sustained their communities on the bounties of the ocean and lands for thousands of years. Furthermore, the Olympic Peninsula was also the site of the northern spotted owl (*Strix occidentalis caurina*) ESA listing, which resulted from a loss of old-growth forest habitat due to timber harvest. The Northwest Forest Plan of 1994 focused on protecting spotted owls and old-growth forests while still allowing some timber harvest. The sanctuary was designated at the same time, with support from the Coastal Treaty Tribes, to prohibit oil and gas exploration off of the Washington coast. Just as Supreme Court Justice William O. Douglas hiked the Olympic Coast in 1958 to protest a proposed highway, sixty years later, Washington's attorney general coordinated a protest against proposed oil and gas exploration off the Washington coast by hiking the same undisturbed coast (Washington State Office of the Attorney General, 2018).

Science Heritage

The Olympic Coast also has a strong science heritage, having been studied by numerous researchers over the decades. Considered one of the last relatively undeveloped coastlines in the contiguous U.S., it has drawn researchers and naturalists to its shores to study habitats and species, including the intertidal, kelp forests, deep-sea ecosystems, marine mammals, seabirds, and changing ocean conditions. Tatoosh Island, for example, is considered one of the most well-studied field sites in the world, and was the site at which Dr. Robert Paine coined the ecological concept of "keystone species" in the late 1960s. The science heritage of the Olympic Coast is significant and continues to grow and expand today; this aspect of heritage is summarized in the Science section.

Conclusion

This ecosystem service highlights the various indicators used to discuss heritage. It is not a complete accounting of the heritage of the Olympic Peninsula, and reflects only selected content from workshops, publications, and expert feedback for the specific topics and indicators discussed here. There is a tremendously rich historical and living heritage in the area, from tribes who have existed since time immemorial and settlers who came later. Several books have been penned to document heritage and history; studies have been conducted to understand how heritage is practiced today and to identify the location and meaning of culturally significant sites; cultural practices take place today that are part of everyday life to the Coastal Treaty Tribes, including a resurgence of tribal language programs; shipwrecks have been studied and documented; and there is a history of long-term scientific research and a persistent conservation ethic. The number of designations recognizing the heritage of the area, at a state, national, and international level, confirm the significance of this unique place. As some resource conditions decline (e.g., some salmon stocks) or experience boom and bust cycles (e.g., razor clams), the people of the Olympic Coast find ways to adapt and continue to practice their culture and heritage.

Sense of Place

Aesthetic attraction, spiritual significance, and location identity

Not rated: This ecosystem service was not assigned a status or trend rating (or accompanying confidence scores). The workshop participants determined that a context-specific narrative was more appropriate to discuss sense of place, particularly due to its many unquantifiable aspects.

Rationale: The Olympic Coast is a unique place that four Coastal Treaty Tribes, who have reserved treaty rights to the resources and area, have inhabited since time immemorial. Additionally, there are non-Indigenous inhabitants with a rich history since their ancestors' arrival hundreds of years ago. Further, there are newer members of the community and many visitors to the area from around the world. Given the diversity of inhabitants and timeframes, rating sense of place for the sanctuary is not only difficult, but unsuitable for collectively describing these perspectives. There was high agreement among workshop participants that a context-specific narrative was better suited to examine the breadth of this service.

The Olympic Coast hosts some of the most undeveloped natural coastline in the contiguous U.S., comprising tribal lands, Olympic National Park, wildlife refuges, the Washington State Seashore Conservation Area, and OCNMS. The wilderness coastline boasts sea stacks, cliffs, islands, tide pools, and sandy beaches coupled with a productive ocean ecosystem that has sustained Indigenous peoples for millennia and continues to draw visitors to its rugged shores today.

The benefits of sense of place are complex; some are quantifiable and some are not (Donatuto & Poe, 2015). Therefore, two categories of indicators are presented: measurable metrics and place identity. Measurable metrics may include willingness to pay for improvements to natural and economic resources, population and income changes, national and international designations, visitation, access to resources, and resource conditions. Other sense of place benefits cannot be assessed in this manner. Place identity is a term used to describe the relationship between one's identity and the landscape and resources. This cannot be measured, but can be qualitatively discussed.

Quantifiable Indicators

In 2014, Washington households were surveyed to determine their willingness to pay for various improvements in resource condition within OCNMS. Notably, Washington households that recreate on the outer coast were willing to pay the most annually for improving water quality, maintaining viewscapes unobstructed by onshore and offshore developments, marine mammal abundance and diversity, shoreline quality (reduced beach closures and marine debris), and the opportunity to see large predators (Table App.ES.SP.1). Additionally, wilderness lovers (people who prefer uncrowded conditions) were willing to pay more for improved conditions in comparison to crowd lovers (people who prefer crowded conditions) (Leeworthy et al., 2017).

These findings are consistent with other regional studies that have shown people are willing to pay for marine protected areas (Wallmo & Edwards, 2008). For example, a 2016 study in Channel Islands National Marine Sanctuary found that U.S. households were willing to pay a one-time fee of roughly $70 to reduce the number of whale deaths due to ship strikes (Bone et al., 2016). A more recent study found that whale watching passengers had a consistently positive willingness to pay for improvements that benefit large baleen whales; passengers were willing to pay between $181 and $221 depending on the amount of improvement (Schwarzmann et al., 2021). Although these studies estimated the monetary value of resource protection, they did not assess the value associated with place identity and the preservation of resources for the maintenance of culture. For some cultures, placing a monetary value on a place or resource may not be appropriate. Furthermore, evaluating sense of place strictly in terms of monetary value via personal income or willingness to pay may alienate lower income populations.

Additional metrics that reflect sense of place include population growth and per capita income. Population growth in the sanctuary study area was higher compared to that of the state of Washington as a whole in most years during the study period (2008–2019). In all study period years, population growth in the study area was higher than the average for the U.S. (Table App.ES.SP.2; Figure App.ES.SP.1). When population growth in the study area was compared among ZIP codes, the highest rate of growth was in the Port Townsend area, which is not directly adjacent to the sanctuary (Figure App.ES.SP.2). Per capita income in the study area was higher in every year of the study period when compared to Washington and the U.S. (Figure App.ES.SP.3). Additionally, per capita income increased in nearly every ZIP code within the study area from 2011 to 2014 (Figure App.ES.SP.4; Table App.ES.SP.2). Population and per capita income growth may put pressure on resources (e.g., increased demand for infrastructure), which could impact sanctuary resources and influence how people are able to experience the sanctuary (Bureau of Economic Analysis [BEA], 2020).

The opinion polls described in the Driving Forces section show that attitudes of respondents were increasingly supportive of conservation and preservation over the study period. In addition, a 2019 Gallup poll asked U.S. residents whether the environment should be given priority, even at the risk of curbing economic growth, or whether economic growth should be given priority, even if the environment suffers. Although the number of respondents who prioritize the environment was not as high as when the poll started in the mid-1980s, over the condition report study period (2008–2019), environmental prioritization increased (Gallup, 2020; Figure App.ES.SP.5).

There are several areas within the Olympic Peninsula that hold high aesthetic, cultural, and economic value to the regional residents that overlap with or benefit from sanctuary viewsheds[18] (McLain et al., 2013). Value of these areas varies by demographics. For example, there are notable differences when comparing the geographies and intensity of meaningful places by gender and by tribal versus non-tribal affiliation, suggesting that sense of place is highly personal and dependent upon not only demographics, but also how long a person has had a relationship and history with a place.

Special designations in and around the sanctuary are also important and can indicate the area's level of state, regional, national, and international significance. At the state level, most Washington state waters (which overlap with OCNMS) were designated a Maritime Washington National Heritage Area. Federal designations in the Olympic Peninsula include Olympic National Forest, Olympic National Park, and OCNMS. Further, there are three sites on the National Register of Historic Places: Tatoosh Island, Ozette Indian Village Archeological Site, and Wedding Rocks Petroglyphs. Olympic National Park has been recognized as a UNESCO World Heritage Site and biosphere reserve (i.e., Olympic Biosphere Reserve). For more information on these designations, see the Heritage section.

In 1958, Supreme Court Justice William O. Douglas referred to the Olympic National Park as

> "[t]he wildest, the most remote and, I think, the most picturesque beach area of our whole coast line ... It is a place of haunting beauty, of deep solitude" (McKeown, 2018).

Despite the number of designations and the region's recognition both locally and internationally, access to the sanctuary is limited. There are only 28 beaches adjacent to the sanctuary, which has roughly 300 miles of coastline (Washington State Department of Ecology, 2019b; Figure ES.NCR.3). Further, many of these access points have limited parking, which often overflows during peak season. Although limiting access can help to maintain a sense of place, it may also limit the number of people who can experience this truly iconic place and develop place attachment. Workshop participants noted that increased visitation to the area, coupled with declining enforcement, has impacted the way that both visitors and residents connect to the sanctuary.

[18] A viewshed is the geographical area visible from a location, often the view from a specific vantage point.

Non-Quantifiable Indicators

Place Identity

The discussion of factors that influence place identity is personal, nuanced, and complex. Although there may be tangible places or measurements discussed here, quantifying place identity is difficult and highly subjective. Despite their intangibility, place identity and the related concept of place attachment are crucial descriptors of the connection between peoples and the land.

Place identity, a component of personal identity, is defined as a process by which people describe themselves as belonging to a specific place (Hernández et al., 2007). Identification between self/family/community and place develops over the long term and can run very deep, particularly where lineage is place based, with genealogy going back many generations. Place identity is often expressed in reciprocal human-ecosystem relationships. This reciprocal relationship emphasizes that people are inseparable from the ecosystem, a common belief among Indigenous cultures; people derive benefits from the ecosystem (ecosystem services) and also contribute to the maintenance or enhancement of the ecosystem (services to ecosystems).

Place attachment is defined as a connection to a location that may develop and change over time, reflected in aesthetic attraction (e.g., books, film, artwork, national symbols), architecture, therapeutic rejuvenation, and even national iconic symbols (Hernández et al., 2007). At both the personal and societal level, place attachment may evolve into place identity; however, the timeframe over which this may occur is highly variable.

The Olympic Coast is home to four Coastal Treaty Tribes who have inhabited the area since time immemorial. Each tribe has their own creation story, place identity, and sense of place. The Quinault, Queets, Hoh, and Quileute have lived at the mouths of the rivers that are now named for them and depended on the resources from the rivers and ocean. The Makah Tribe has lived along the coast, depending largely on ocean resources. Below, members of select tribes describe elements of their sense of place in their own words:

> Chris Morganroth, Quileute Elder: “It’s been a great quality of life since the time of our beginning here, that all the things that were made available to us by the Creator, all the salmon, the cedar trees, just a wide variety of different life that’s here on the coast” (Sreenivasan, 2012).
>
> Russell A. Svec, Makah Fisheries Director: “The Makah Tribe is truly blessed as Northwest Indigenous people. I continue to be amazed with the connection we have with our marine environment and how it has shaped this unique culture of ours. Makah have been accessing the ocean since time immemorial and we appreciate that in the spirit of true nature, everything is connected through space and time. During the negotiations of the 1855 Treaty of Neah Bay, Makah statements articulated a connection to marine

space. For example, the leader from the Ozette village (a whaling village) Tse-kaw-wootl stated it clearest: 'I want the sea. That is my country.' Wanting to impress upon [Washington Territorial Governor Isaac Stevens] the importance of this statement, Tse-kaw-wootl refused to even consider the terms of the treaty until Stevens joined him in a canoe on the saltwater. While the two leaders paddled around, Tse-kaw-wootl explained that the sea was his country. Historical declarations such as these allow us to remain strong as ocean going people. We continue to benefit from the mental, physical, and spiritual wellbeing that comes from accessing our marine environment and its many resources.

Having access to our ocean places allows us to protect our living culture. We understand that both traditional and scientific knowledge remain essential if we are to preserve and protect our sense of place and the environmental dynamics within. Today, environmental protection is one of our primary strategies in preserving our treaty fishing rights. This brings me back to when I worked as a Timber, Fish, and Wildlife technician in the 1980s. At that time, I had the opportunity to review notes taken from an outsider in the early 1900s, which documented the response by a Makah river fisherman being asked: "How do you ensure that the salmon you are catching will return the following year?" The Makah fisherman replied, "If a rock was overturned you turned it back over". These values of our past will continue to endure and define the Makah Tribe's Fisheries Management Department in a way that supports an ecosystem-based management approach to all things. This strategy is essential if we are to maintain and protect a way of life that is rich in its connection to our traditional territory and its many environments. These are environments that support a wealth of commercial fisheries that have sustained us since time immemorial.

Today, many aspects of the Makah Indian Reservation and our community display a modern-day society and a contemporary lifestyle. However, the Makah also remain a people who preserve a distinctive and old culture that is inextricably linked to the land and waters of this region, and we are a people with a history never too far from its present day" (R. A. Svec, personal communication, October 23, 2020).

Many non-tribal residents also call the Olympic Coast home and have their own unique sense of place:

Dan Ayres, WDFW Coastal Shellfish Manager and Grays Harbor resident since birth (1955): "As a fifth-generation resident of the Washington coast, I am humbled to live and work in this beautiful area. It has been a genuine honor to have spent 40 years of my life working to ensure that the native shellfish here are harvested sustainably and will be around for many generations to come. The deep peace that I experience simply walking along these wild and seemingly endless beaches cannot be replicated. The excitement of sitting in the warm cab of my truck while being rocked by a raging storm swirling around outside and watching a pounding ocean surf hit the beach in front of me is exhilarating. The satisfaction of digging razor clams by lantern light on a cold winter night while watching the lights of fellow harvesters flicker up and down the beach is beyond compare. At the same time, the joy it brings me to help my children perfect their digging

> skills, as my parents did for me and their parents did for them, reminds me of the gift this place has been to generations of coast dwellers. This is where I feel closest to God. While I love to travel, I could never live anywhere but right here near the Washington coast. It is more than my home; it is my sanctuary" (D. Ayres, personal communication, August 6, 2020).

The U.S. Forest Service analyzed environmental quality, viewshed quality (including sound), remoteness from sights and sounds of people inside the wilderness, remoteness from occupied and modified areas outside the wilderness, facilities that decrease self-reliance, and management restrictions on visitor behavior within Olympic National Park and surrounding wilderness areas (Tricker et al., 2013). The study concluded that the soundscape has become somewhat degraded. Kuehne and Olden (2020) also found that 88% of audible air traffic was military, based on assumptions about flight schedules from nearby installations, with a substantial noise footprint that extended beyond the military operations area. Experts at the workshop confirmed having witnessed frequent, and loud, low aerial flyovers conducted by the U.S. Navy. Participants stated that these flyovers can interrupt cultural activities and peaceful use of wilderness, though the extent of these impacts has yet to be thoroughly documented. Workshop participants also noted that management activities by different agencies, and in some cases private landowners, in the area have limited Coastal Treaty Tribes' access to, and use of, traditional lands or resources for hunting, gathering, and other cultural purposes, as well as for research or monitoring efforts. For example, no hunting and limited gathering are allowed in Olympic National Park, which includes traditional lands of the Coastal Treaty Tribes. Additionally, in some cases, private timberland owners have restricted tribal member access for hunting (limited entry permits) and other private landowners have not allowed tribal staff to conduct monitoring on stream health.

With regard to historical sites, a study funded by the Bureau of Ocean Energy Management and partners identified multiple archaeological resources along the Olympic Coast (ICF International et al., 2013). Many of these resources are important to the Coastal Treaty Tribes, as they are not only tangible cultural heritage resources, but also provide a connection to past generations. Resources include villages, middens, petroglyphs/pictographs, cemetery and burial grounds, and other cultural landscape features. Although there are no known sites within OCNMS boundaries, additional research into paleo-shorelines may identify significant sites.

There is an inherent relationship between Indigenous people and place that is evident in Indigenous languages, oral histories, river and place names, and village sites. In attempting to maintain this inherent relationship and exercise sovereignty, some Coastal Treaty Tribes have restricted or limited access of non-tribal members to their lands. Beginning in 1969, Quinault Indian Nation closed 27 miles of beach to non-tribal members. During the workshop, participants expressed that knowing this place is theirs and that they don't have to share it with tourists, even if it could be economically fruitful, is important to the tribe. The Quileute Tribe has also restricted non-tribal member access to their beaches from dusk to dawn and, while it is challenging to enforce, banned beach fires by non-tribal members. The ability to find solitude on their lands has enhanced sense of place for many tribal members. Furthermore, maintaining relatively pristine aspects of the environment, like dark skies, not only contributes to sense of place, but benefits the marine ecosystem by limiting light pollution.

Housing shortages and the imminent necessity to relocate tribal communities farther inland to protect them from earthquake and tsunami hazards and from storm damage worsened by the climate change will likely negatively impact sense of place. Pindus et al. (2017) found that identifying land near existing infrastructure that is suitable for relocation is difficult for the Makah Tribe. The majority of Makah land is surrounded by forests used for timber production. Further, water shortages, exacerbated in the summer by limited groundwater storage capacity, limit the ability to expand development (American Indian and Alaska Native Public Witness Day 1, 2020). The necessity for tribal communities to relocate will likely be driven by changing ocean conditions, which can impact fisheries vital to maintaining culture, subsistence, and economic security. In addition, 60% of the Makah population, including the Makah village, clinic, schools, and other critical infrastructure, is located within a tsunami inundation zone. Not only is the population impacted by changing ocean conditions, but culturally significant sites like Hobuck Beach and Ozette Indian Village are at risk of erosion, threatening access to public beaches and culturally significant artifacts.

The Quinault Indian Nation also faces similar challenges from climate change. Nearly 1,000 people live in Taholah, which has experienced flooding, landslides, and culvert failures as a result of storm surge and rain, most recently in 2014, 2016, and 2018. Recently, Quinault Indian Nation declared a state of emergency due to the risk of losing reliable road access due to landslides, which would devastate the community of Taholah. Of particular concern is an area one mile south of Taholah, known as the "88 corner," where a slow-moving landslide has caused cracked pavement on State Route 109 and could lead to collapse of the highway. Plans are in development to relocate the lower village of Taholah to higher ground (Quinault Indian Nation, 2020).

The Hoh and Quileute Tribes are also experiencing flooding and sea level rise impacts on their communities, as well as the inherent risk of a tsunami on their coastal villages. Approximately 90% of Hoh tribal members on the reservation live in a flood zone. The Hoh Tribe is working to relocate to a safe elevation; the tribe has purchased land from adjacent landowners, and some national park land was returned to the tribe, adding a total of 420 acres on which the Hoh can relocate their village (Callis, 2008). An effort by the Quileute Tribe, titled "Move to Higher Ground," describes a strategy to move their largest community out of the tsunami, earthquake, and flood zones to higher ground on former national park land (Quileute Tribe, 2020). These efforts often take enormous time and resource commitments and, in some cases, legislation (e.g., returning land to the Hoh and Quileute Tribes from Olympic National Park). These large-scale disruptions alter the ways in which tribal members interact with both their community and nature, can impact place identity, and alter tribes' interactions with the federal government. In some cases, elders may be more resistant to relocating, despite knowing the risk of flooding or tsunamis, due to place identity and the strong connections to their lands and viewscapes.

Despite these changes, workshop experts expressed a positive view of sense of place due to the vibrant tribal cultures, the level of conservation and protections, and long-term stewardship of the land and waters in the Olympic Coast region. Quotes from members of the Coastal Treaty Tribes help communicate how their identity is interwoven with the land and waters of the Olympic Peninsula and OCNMS.

Conclusion

This section closes with a poem written in the 1960s by Quinault cultural representative Clarence Pickernell that describes the tribe's association with their homeland (Storm et al., 1990, p. 274):

This is My Land

This is my land.
From the time of the first moon,
Till the time of the last sun. It was given to my people.
Wha-neh- wha-neh, the great giver of life,
Made me out of the earth of this land.
He said, "You are the land, and the land is you."
I take good care of this land,
For I am part of it.
I take good care of the animals,
For they are my brothers and sisters.
I take care of the streams and rivers,
For they clean the land.
I honor Ocean as my father,
For he gives me food and a means of travel.
Ocean knows everything, for he is everywhere.
Ocean is wise, for he is old.
Listen to Ocean, for he speaks wisdom.
He sees much, and knows more.
He says, "Take care of my sister Earth.
She is young and has little wisdom, but much kindness.
When she smiles, it is springtime.
Scar not her beauty, for she is beautiful beyond all things.
Her face looks eternally upward to the beauty of sky and stars,
Where once she lived with her father, Sky."
I am forever grateful for this beautiful and bountiful earth.
God gave it to me.
This is my land.

Commercial Harvest

The capacity to support commercial market demands for seafood products

Not rated

Rationale: Workshop participants opted to not rate this service due to complexity and dynamics among the human and natural factors affecting commercial fisheries, and because OCNMS does not manage fisheries. Throughout the study period (2008–2019), variability has been showcased by both high catches and fishery disasters. Although management seeks to reduce variability within this ecosystem service, changing ocean conditions and weather are key contributors to the variability of annual harvests.

Commercial fishing is an important activity off of the Olympic Coast that provides a variety of services to local and broader communities through economic and non-economic benefits. OCNMS is a highly productive ecosystem and many communities along the coast are strongly dependent on fisheries, as well as fish and shellfish resources within the sanctuary; however, OCNMS does not manage fisheries. Fisheries are managed by federal, state, and tribal co-managers (see the Pressures section). Although the focus here is on how fish and shellfish resources are used to support commercial harvest, it is important to note that fish contribute to many other ecosystem services. For example, in addition to commercial harvest, salmon are important to the Coastal Treaty Tribes in exercising their treaty rights, for food security and subsistence, ceremonies, maintaining food networks, and practicing their heritage, and are intimately intertwined into their identity. Salmon are also used for consumptive recreation by non-tribal people.

Several indicators are used in other ONMS condition assessments to inform the rating of the commercial harvest service, and were considered here despite the decision not to formally assign a rating. These include landings and ex-vessel value,[19] jobs, output and income supported by commercial fisheries, the productivity of the region, fishery disaster declarations and their impacts, socio-economic studies of commercial fisheries and fishers, and the status of the resources (as determined in the State section). Data and information were provided for this report by the WDFW, Quinault Indian Nation, Quileute Tribe, and NOAA Fisheries, in addition to peer-reviewed studies that analyzed the economics of fisheries and the impact of fishery disasters. When possible, sanctuary-scale analyses were used. When that was not possible, data from larger management areas, such as state or federal waters off Washington, were used.

The WDFW compiled data on the top species landed in the combined commercial catch reporting areas 29, 58B, 59B, 59A-1, 59A-2, and 60A-1 for marine and shellfish and 4, 3, and 2 for salmon (Figure ES.CH.1). Data reported are based on trip tickets that commercial fishermen submit to the state and respective tribes.

[19] A measure of the dollar value of commercial landings, usually calculated as the price per pound at first purchase of commercial landings multiplied by the total pounds landed.

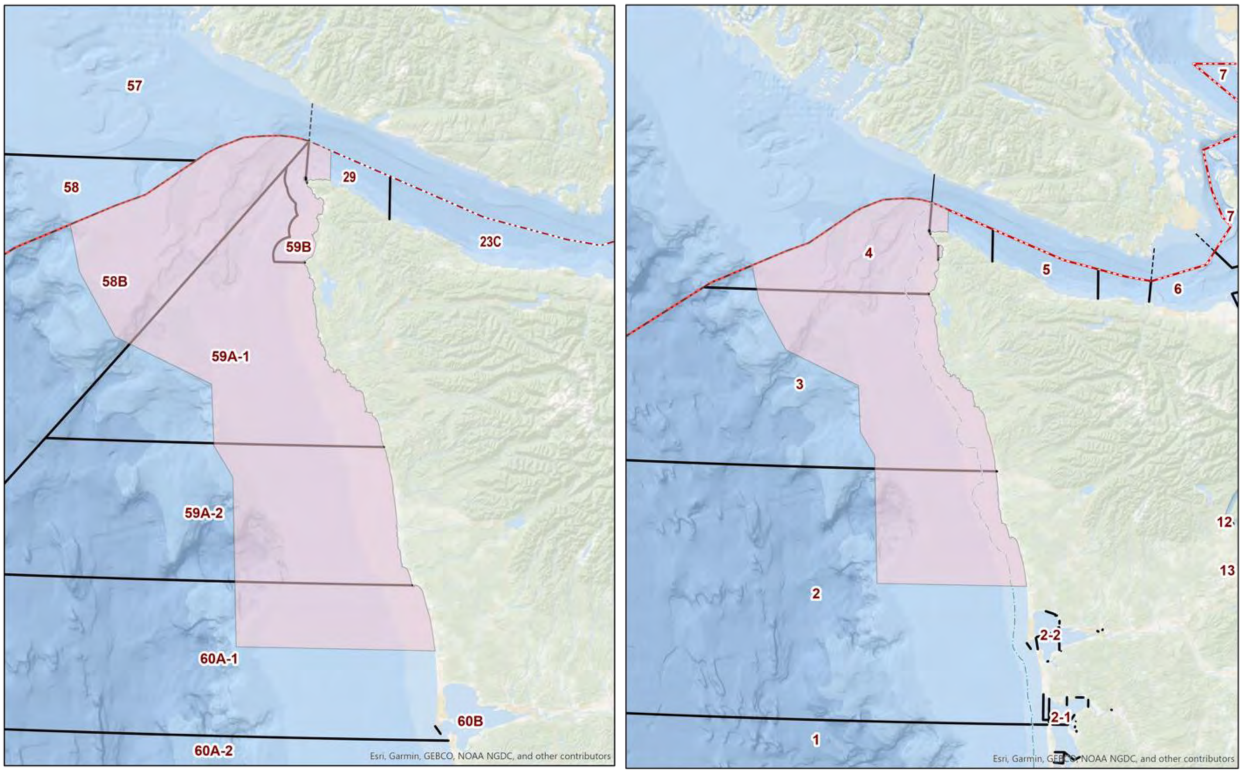


Figure ES.CH.1. WDFW commercial catch reporting areas for marine fish and shellfish (left) and salmon (right). Source: WDFW

The top 12 species by pounds landed and ex-vessel revenue are shown in Figure ES.CH.2. The majority of landings from catch areas of interest (Figure ES.CH.1) during the study period were composed of three species categories: Pacific whiting harvested both at sea and shoreside (over 700 million pounds combined); coastal pelagics (sardine and other forage fishes; over 100 million pounds); and shrimp and spot prawn (predominantly Pacific pink shrimp; over 100 million pounds). Pounds landed for all other species were substantially lower.

With regard to nominal ex-vessel revenue, the top two species categories were Dungeness crab (close to $250 million) and shrimp and spot prawn (more than $75 million). Shrimp and spot prawn ranked second during the study period for both value and landings. Additionally, even though Dungeness crab ranks fifth in terms of pounds landed, it was by far the highest in terms of value. The third highest species category based upon value was non-trawled groundfish (more than $40 million).

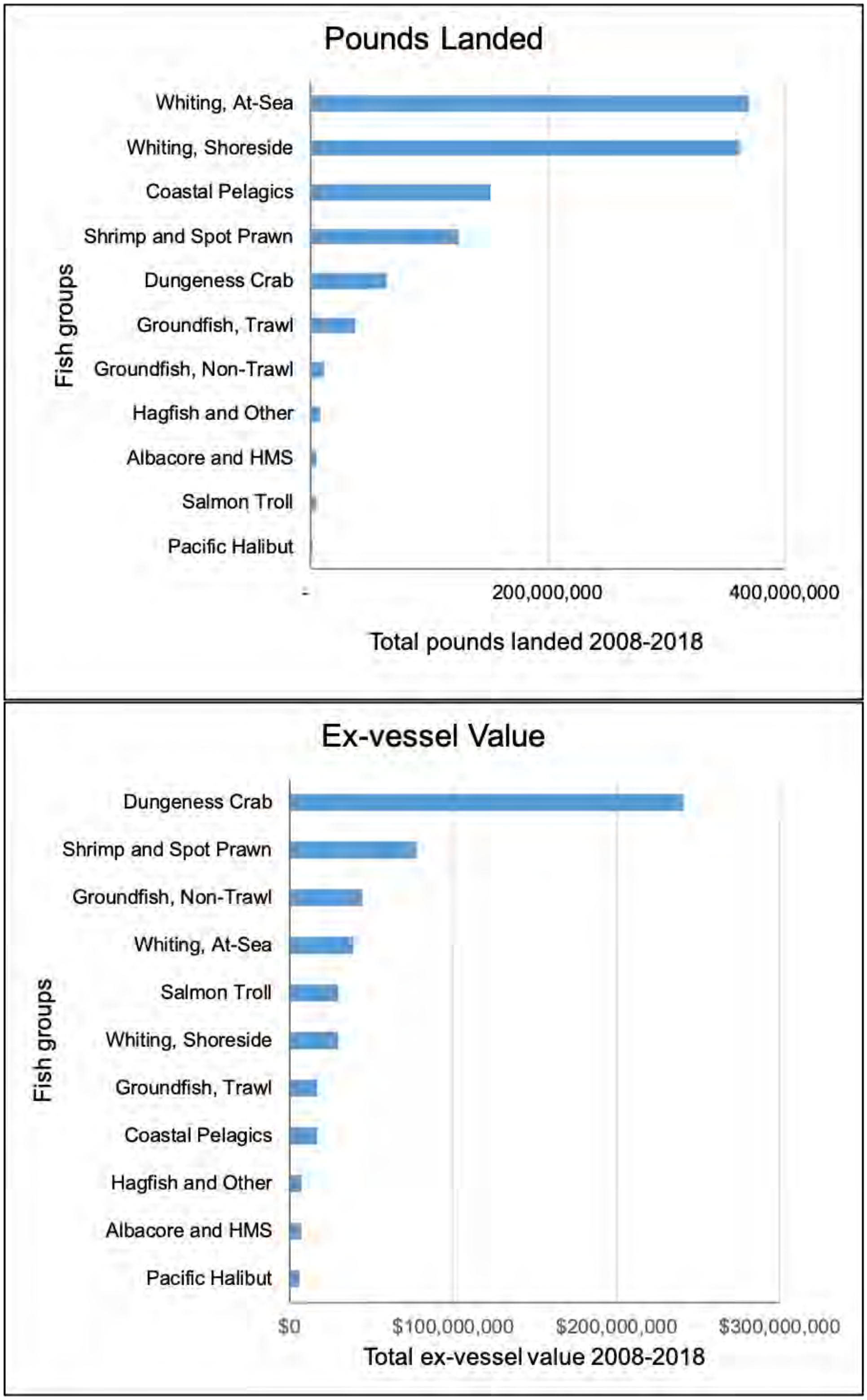


Figure ES.CH.2. Top 11 species categories by pounds landed and ex-vessel value (2018$). (These graphs do not include all fisheries landing data.) Source: WDFW

Trends for these species within the study period can also be informative, as fish populations and distributions exhibit substantial variability both within and across species over time. The high value for coastal pelagics, which ranked third overall, was largely driven by higher catches in the early years of the study period (Figure ES.CH.3). The shrimp fishery exhibited a boom during the study period (from 2014–2015) and has since declined. Further, most shoreside Pacific whiting, the second highest ranked species category in terms of pounds, were caught in just three years: 2016, 2017, and 2018. At-sea Pacific whiting showed more variation over the study period. Furthermore, most non-tribal landings of Pacific whiting were from outside the sanctuary. While the total catch of Pacific whiting has been increasing over time, the total non-tribal catch within the sanctuary remained stable over the study period (see Figure App.1).

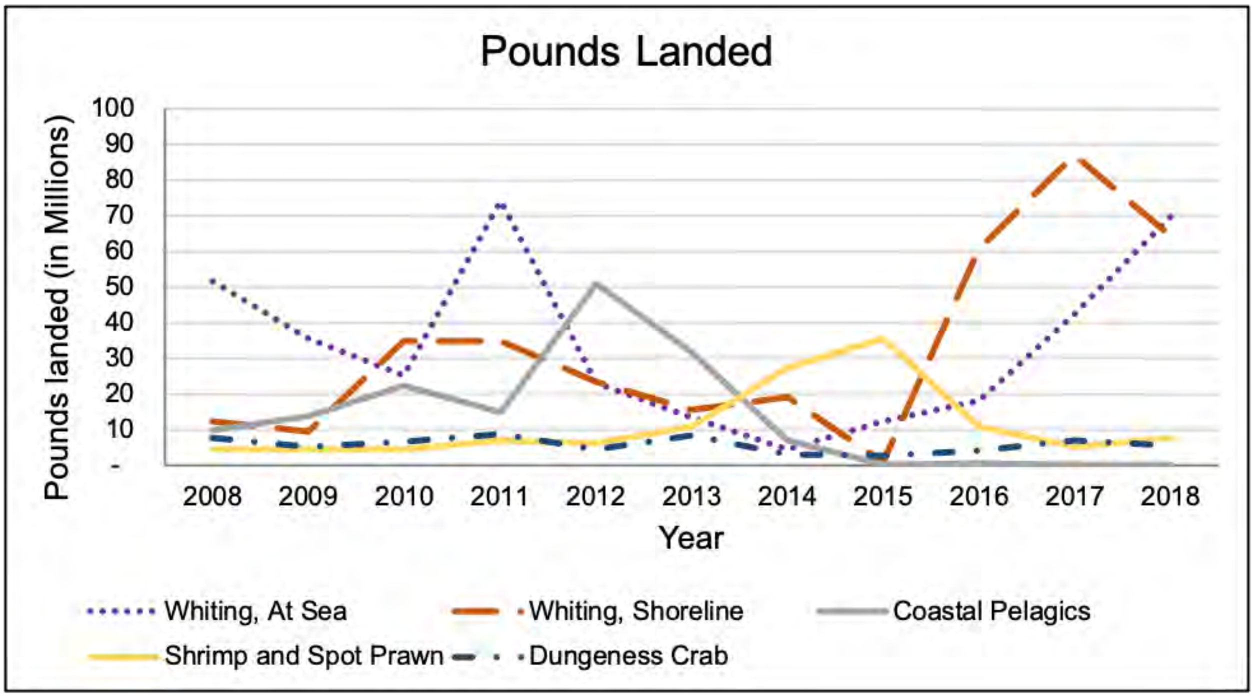


Figure ES.CH.3. Top five species categories by weight, 2008–2018. (This graph does not include all fisheries landing data.) Source: WDFW

Annual ex-vessel value of the top five species categories landed was also considered. Dungeness crab ex-vessel value varied substantially, and had the highest value in 2010–2011 and 2012–2013 (Figure App.ES.CH.3). Despite variation in value, in 10 of the 11 years evaluated, Dungeness crab had the highest ex-vessel value of all species caught (Figure ES.CH.4). Shrimp and spot prawn was the only species category to exceed Dungeness crab value, and only in 2015 when crab catch was lowest during the study period.

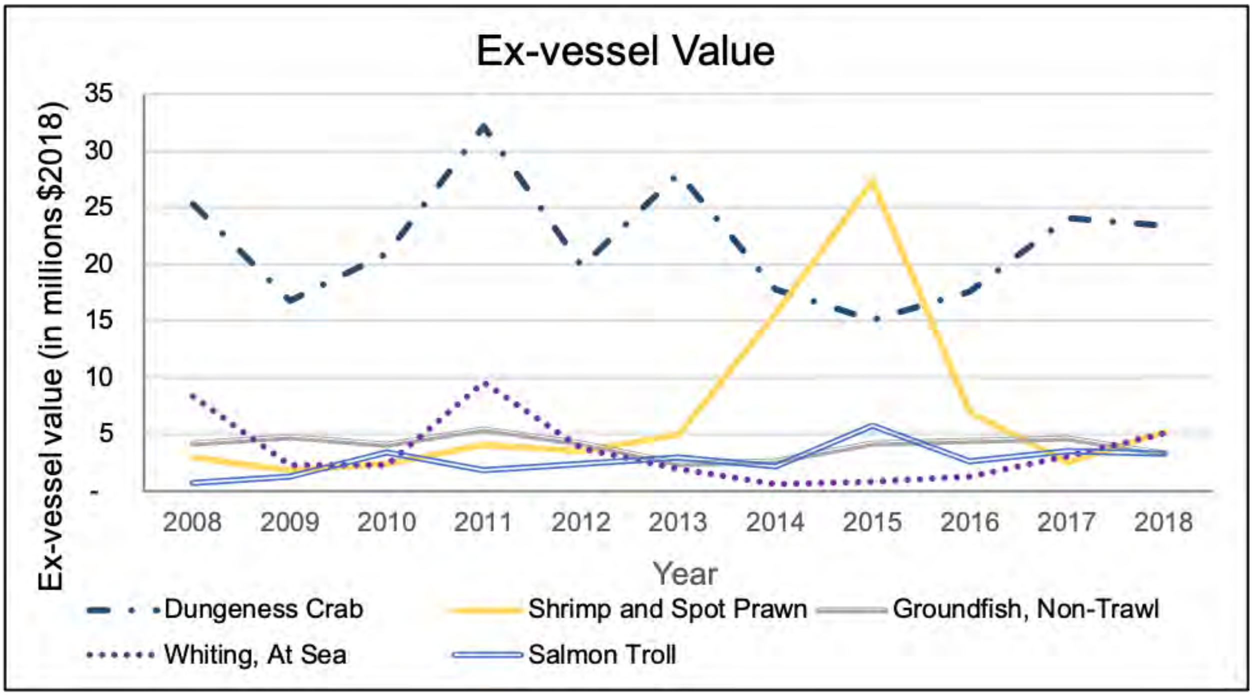


Figure ES.CH.4. Top five species categories by ex-vessel value, 2008–2018. (This graph does not include all fisheries landing data.) Source: WDFW

A West Coast Fisheries Participation Survey[20] was conducted in 2017 (NOAA Fisheries, 2017). For Washington state commercial fisheries participants, "graying of the fleet" is occurring: over half (53.91%) of vessel owners are older than 60 years of age and only 20% are under 50 years of age[21] (Figure App.ES.CH.4). Graying of the fleet may threaten the future of commercial fisheries on the West Coast, and a common hurdle in entering the fleet is the sizable capital necessary (purchasing a vessel, quota, gear, maintenance, and fuel) (Silva et al., 2021). There is a wide range of household incomes reported by Washington fishers, with nearly half (46.76%) earning more than $100,000; 41% of respondents reported that fishing accounted for 100% of their income. Salmon and Dungeness crab were viewed as the most important fisheries, economically and personally. Over 80% of commercial fishers who took the survey strongly agreed that being a fisher was important to them (Figure App.ES.CH.5). A variety of factors contributed to respondents' satisfaction with fishing as a job, including being their own boss, setting their own schedule, producing healthy food, being on the water, and working outdoors (Figure App.ES.CH.6).

Commercial fisheries are of great importance to the Coastal Treaty Tribes. As expressed by Dave Sones of the Makah Tribe, "fishing brings me back to my culture and makes me feel connected with my ancestors and my past. That's the best part of fishing for me, experiencing that connection" (Washington Sea Grant, 2020). Fisheries employ significant portions of the community, and are one way to exercise treaty rights that contribute to ceremonies, subsistence,

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[20] This survey was open to all commercial fishermen in Washington state and was not limited to those who fish only in OCNMS. Therefore, survey results may not be reflective of those who fish commercially within OCNMS.
[21] This trend may not be reflective of tribal commercial fisheries (data specific to tribal commercial fisheries were unavailable).

and spirituality. For some tribes, fishing contributes significantly to their local economy, with the majority of families on the reservation engaged in commercial fishing. Members of the Quinault Indian Nation fish commercially both on the ocean and in the river systems within their treaty harvest area. The incomes generated by these fisheries are sole, primary, or supplemental sources of annual revenue for a majority of Quinault tribal members. Coastal Treaty Tribes are place-based peoples with legally defined fishing areas, known as U&A fishing areas. U&A fishing areas limit where tribal members can exercise their treaty fishing rights, posing an additional challenge to accessing resources in response to management decisions or as species ranges or behaviors shift in response to conditions. For example, hypoxia events have implications for commercial fisheries, such as Dungeness crab and halibut. They can result in shifts in distribution, decreased fitness, or mortality. In 2017, the International Pacific Halibut Commission (IPHC) annual setline surveys were impacted by a hypoxic event off of the Washington coast; very few halibut were caught at locations where they are normally found (Figure ES.CH.5). This incident reinforced several concerns of local resource managers. First, it highlighted the vulnerability of the Coastal Treaty Tribes to changing ocean conditions and difficulties the tribes may face in maintaining access to fisheries with place-based rights as ocean conditions change. Second, it emphasized the importance of fisheries survey timing; the 2017 survey occurred later in the season than normal, and thus captured the hypoxia event, which affected stock assessment models. Last, this incident raised questions regarding the ability of existing survey designs (i.e., IPHC setline and NOAA trawl surveys) to accurately reflect the biomass in OCNMS due to the high heterogeneity of habitats influencing fish distribution.

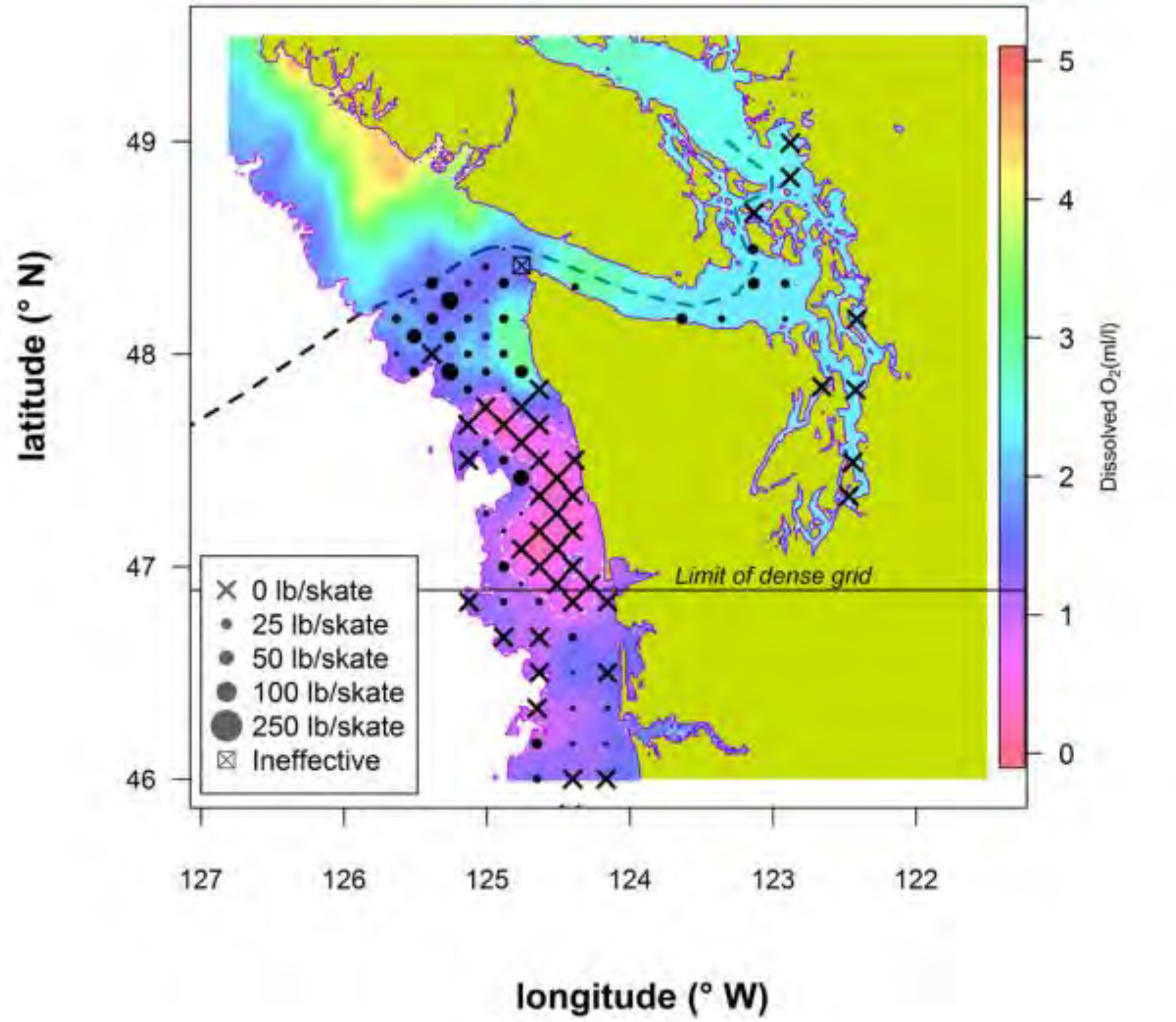

Figure ES.CH.5. Estimated dissolved oxygen in summer 2017, with weight per unit effort values from the IPHC setline survey overlaid with black symbols (IPHC, 2018). No halibut were caught within the severely hypoxic area. Weight per unit effort is expressed as pounds per skate. "Skates" are halibut gear, consisting of units of leaded ground line in lengths of 100 fathoms (600 ft [183 m]) with about 100 circle hooks attached. Image: IPHC

The Quinault Pacific razor clam fishery is another example of the significance of commercial fisheries to the Coastal Treaty Tribes. Despite razor clams not being among the top species by pounds or value, they are very significant to the Quinault Indian Nation (Weinberg, 2017). The Quinault people have harvested Pacific razor clams throughout their history, and populations have remained relatively stable over the condition report study period. They continue to be harvested from sandy beaches in the southern region of OCNMS as a readily available food source. Razor clams have historically been harvested for subsistence, were used for bartering and trading for other food and items in the past, and have become an important commercial harvest product in recent times. Razor clams are harvested by individuals digging with narrow-bladed shovels, and minimal capital is required to enter the fishery. Any Quinault tribal member can be licensed to harvest clams during regulated openings. Clams are purchased by approved buyers on the beach and many are processed for sale to the public at the Quinault Pride Seafood facility in Taholah. Razor clam harvesting is a vital contributor to the economic livelihood of many Quinault tribal members. The primary threat to this fishery during the study period has been HAB events that eliminate or limit harvest opportunities.

Landings, ex-vessel value, and the resulting economic contributions from the catch reporting areas that overlap with OCNMS are not indicators of the sanctuary's productivity. The Olympic Coast is among the most productive habitats in the world, driven by strong, nutrient-rich upwelling that fuels high primary productivity, a variety of habitats (submarine canyons, rocky reefs, and kelp forests), and coastal estuaries that serve as important nursery grounds for species like Dungeness crab (Hughes et al., 2014). Many commercial fishery stocks have been stable or increasing since 2008, including Pacific razor clams (Figure S.LR.13.1; Figure S.LR.13.3), groundfish stocks that have recently been rebuilt (Figure S.LR.13.5), and Pacific hake. While Pacific halibut are declining coastwide (Alaska to California), biomass is increasing in catch area 2A (Washington, Oregon, and California; Figure App.ES.CH.1; IPHC, 2020). Salmonid and steelhead populations on the coast are largely stable, with six runs of Chinook, coho, and steelhead increasing and 19 runs declining (Figure S.LR.13.12). Dungeness crab populations have also declined north of Point Grenville since 2005 (Figure S.LR.13.3), but catch per unit effort from NOAA trawl surveys in OCNMS has increased since 2008 (Figure S.LR.13.4).

Productive fishing grounds in OCNMS not only support local communities, but also communities outside of the Olympic Coast and outside of Washington. For example, Astoria, Oregon bottom trawl observer data show that roughly 70% of total harvest occurs off of Washington, and 30% of harvest off of Washington occurs specifically within OCNMS, yet vessel trip tickets do not reflect this (C. Niles, personal communication, October 27, 2020).

Despite the high productivity of OCNMS, multiple human and natural factors contribute to variability in commercial fisheries. These factors include: supply, demand, and other market factors that affect fishery effort and profitability; permitting, management decisions, and court rulings (e.g., impacts on hatchery production); continued habitat loss outside of OCNMS (Puget Sound salmon recovery efforts); and changing ocean conditions that can shift species ranges for one or more seasons (i.e., warming waters within and outside OCNMS that affect migratory fish stocks). Changing ocean conditions have impacted, and will continue to impact, commercial fisheries. Warmer waters can have cascading effects throughout the food web (e.g., community shifts to lower-lipid copepods), causing changes in species ranges for both target and non-target species (e.g., higher pyrosome abundance, which can foul fishing gear; see Figure S.LR.14.7) and compressing habitat availability for pelagic species that also experience benthic hypoxia. Mass mortality events caused by hypoxia, evidenced by large fish kills on local beaches, are also becoming more frequent (Figure ES.CH.6). Hypoxic events occurred from July through September of 2008, 2009, 2011, 2012, 2016, 2017, and 2018, when crab, groundfish, and pelagic species washed up dead, primarily at the Point Grenville tribal beach. However, off-reservation events also occurred on Mocrocks and Copalis beaches in recent years. This correlates with OCNMS and Ocean Observatories Initiative mooring data at those times. Shelf hypoxia is common but seems to come ashore more often in the Grenville region, potentially because of the adjacent Quinault canyon. In interviews, Quinault tribal elders do not recall ever seeing these types of mortality events, prior to 2006 (J. Schumacker/Quinault Indian Nation, personal communication, November 20, 2020).

Figure ES.CH.6. A wolf eel washed ashore on Point Grenville beach following a mass mortality event due to hypoxia. Photo: J. Schumacker/Quinault Indian Nation

Fishery disaster declarations highlight the variability that commercial fishers experience in the Pacific Northwest and, more specifically, the Olympic Coast. Table ES.CH.1 shows fishery disasters by year, species, and fisheries affected. Fishery disasters can also affect access to subsistence resources, amplifying economic and social impacts to many communities.

Table ES.CH.1. Fishery disasters. Source: NOAA Fisheries, 2019c

Disaster	Year	Hoh	Quileute	Quinault	Makah	Washington State
Fraser River sockeye	2008				X	X
Fraser River sockeye	2013				X	
Fraser River sockeye	2014				X	
Dungeness crab	2015		X			
Coho salmon	2015	X	X	X		X
Coho salmon	2016		X			
Ocean troll (coho and Chinook salmon)	2016				X	X

Although not all fishery disasters have been assessed for their socioeconomic effects, some have. Richerson and Holland (2017) analyzed the impact of the 2008 salmon closure on vessels of the U.S. West Coast salmon fleet. Roughly 209 vessels (17% of the fleet) exited the fishery during the closure, and in 2016, the fleet remained roughly 10% smaller than prior to the 2008 closure (Figure App.ES.CH.7). The authors found that vessels with higher revenue, a more diverse fishing portfolio, and more experience were likely to remain in the fishery through the closure, while vessels that had a higher portion of salmon troll revenue were more likely to exit. Not only has the number of vessels failed to recover, but the total revenue from salmon has also remained lower, on average, in the years after the closure (Figure App.ES.CH.8).

In 2015, the presence of HAB biotoxins delayed the opening of the commercial Dungeness crab fishery for Washington, Oregon, and California. The closure resulted in a fisheries disaster declaration for the Quileute Tribe and California. West Coast Dungeness crab revenue decreased by $97.5 million from the previous year (Moore et al., 2020). Roughly 82% of fishery participants indicated their income decreased. The mean decrease in income for fishery participants was $3,000–$9,999, and the mean decrease in income for non-fishery participants (such as the hospitality industry) was $1,000–$2,900. The decrease in income forced slightly more than a third of fishing participants to borrow money from family and friends (37.1%), fish other species (33.7%), or apply for government assistance (17.1%) (Moore et al., 2020).

Crosman et al. (2019) analyzed the impact of the 2016 and 2017 commercial razor clam fishery closure to the Quinault Indian Nation. The study found that roughly half of tribal members participate directly in the razor clam harvest and others benefit from the harvest as employees of the processing plant. Much of the earnings from the harvest are spent locally at tribally owned businesses. The closure of the fishery reduced income and increased food insecurity among many Quinault members. Additionally, the study found that closures reduced the ability to share intergenerational knowledge about razor clam harvest, preparation, and consumption.

Workshop participants recommended several ways OCNMS can help support the commercial harvest ecosystem service. They indicated finding ways to enhance the mooring program would help to improve oceanographic monitoring within OCNMS to better inform fisheries management. Additionally, continued protection from oil spills and maintaining shipping traffic farther offshore via the ATBA is also helpful. They also noted that some vessels operating in the sanctuary (primarily at-sea whiting processors) may also negatively impact water quality, which may require active sanctuary management. Lastly, it was noted that more research on key fisheries species at multiple life history stages, combined with year-round, real-time monitoring of ocean conditions, would help provide data to inform fisheries management. This information would also contribute to the Olympic Coast Habitat Framework initiative[22] to better understand essential fish habitat. Experts also suggested increasing public awareness relative to the productivity and habitat of the sanctuary and the importance it plays in supporting fisheries.

[22] The Olympic Coast Habitat Framework is a habitat mapping program led by the Northwest Indian Fisheries Commission and Intergovernmental Policy Council, with technical support from OCNMS, to develop a common understanding of marine habitats on the Olympic Coast based on NOAA's Coastal and Marine Ecological Classification Standard, which will serve as a common framework or language for tribal, state, and federal resource managers.

Despite data and knowledge relative to the level of harvest, contributions to the economy, and reliance on commercial fishing among the tribes and peoples of Washington, workshop participants decided not to rate the status and trend of commercial harvest. In the North Pacific, commercial fishing is managed by several governing agencies on a scale that exceeds sanctuary management. Despite improvements to some fisheries, primarily the bottom trawl groundfish fisheries, several other species experienced one or more disasters from 2008–2019 and are more variable over the study period. Further, not only do human actions and management influence the ability of the sanctuary area to provide commercial harvest, but there are several exogenous factors such as climate change, HABs, and marine heatwaves that not only impact species distribution and composition, but also highlight the need for dynamic management. By providing a status and trend, the experts felt the condition report may oversimplify the complexities of fisheries management and not do justice to the importance of cooperation among federal, state, and tribal governments, as well as NGOs and other advocacy groups involved in West Coast fishery management.

Conclusion

Due to the complexity of and dynamics among the human and natural factors affecting commercial fisheries in OCNMS, this ecosystem service was not rated. The key factor supporting commercial fisheries and the local and broader economies that depend on them is the high productivity of the region. The presence of the Coastal Treaty Tribes with reserved rights to fish, their continued ability to exercise those rights in their U&A fishing areas, which encompass OCNMS, and the reliance of tribal communities on commercial fisheries are strong indicators of the value of this ecosystem service. Most of the key fisheries targeted are stable or increasing, with some in decline, as well as others with unprecedented high variability attributable to changing ocean conditions. Washington state commercial fishers reported that fishing was important to themselves and their communities. The lack of fisheries data specific to OCNMS was a data gap identified in the discussion of this ecosystem service. Recent fisheries disasters have demonstrated the adverse impacts communities experience and the difficult decisions some fishers face, including whether to remain in or leave the fishery. Such decisions may have far-reaching consequences for tribal fishers, considering the cultural significance and community reliance on fishing, and the place-based nature of both fishing and tribal culture.

Table ES.CH.2a. Summary table of indicators used.

Economic Indicators	**Source**	**Figure or Table #**	**Data Summary**
Top species categories by landings and harvest revenue	WDFW, 2020	ES.CH.2	The top three species categories by landings (from 2008–2018) are Pacific whiting, shrimp and spot prawn, and coastal pelagics. The top three species categories by ex-vessel value are Dungeness crab, shrimp and spot prawn, and sablefish.
Top five species categories by weight	WDFW, 2020	ES.CH.3	Landings of the top five species categories varied by year. Pacific whiting had the highest landings in 2016–2018, but was not one of the top five species in terms of landings from 2008–2010.
Top five species categories by ex-vessel value	WDFW, 2020	ES.CH.4	In most years, Dungeness crab was the top species by value, but in 2015 and 2015, shrimp and spot prawn was the top species category by value. There was less variation in the top five species by ex-vessel value than by landings from year to year.
Pacific whiting	WDFW, 2020	App.ES.CH.1	The majority of non-tribal landings are outside of OCNMS. Total catch within the sanctuary has remained stable over the study period, while total catch in Washington has increased over time.
Dungeness crab	WDFW, 2020	App.ES.CH.2	The highest seasons by value and catch occurred in 2010/2011 and 2012/2013. Although Dungeness crab remains one of the most valuable species landed annually, there was a declining trend in ex-vessel value and landings during the study period.
West Coast Fisheries Participation Survey	NOAA Fisheries, 2017		20% of Washington commercial fishing vessel owners are under the age of 50. Roughly half of fishery participants earn more than $100,000, and 41% rely solely on fishing income. Salmon and Dungeness crab were the most important to survey respondents from an economic perspective.
Razor clams and Quinault Indian Nation	Weinberg, 2017		Razor clams continue to be an important commercial fishery to the Quinault Indian Nation.

Table ES.CH.2b. Summary table of indicators used.

Non-Economic Indicators	Source	Figure or Table #	Data Summary
Fisheries disasters	Various	App.ES.CH.3	Fisheries disasters were declared for salmon, Dungeness crab, and razor clams at least once over the study period.
Salmon closure	Richerson & Holland, 2017	App.ES.CH.4	The 2008 salmon closure resulted in 17% of the fleet exiting the fishery, and the fleet has remained roughly 10% smaller than it was prior to the closure (as of 2017).
Dungeness crab closure, 2015	Moore et al., 2020		Roughly 82% of surveyed Dungeness crab fishers reported a decrease in income as a result of the fishery closure.
Razor clam closure, 2016–2017	Crosman et al., 2019		The closure primarily affected the Quinault (within OCNMS) and resulted in a reduction of income to many Quinault Indian Nation members, as well as an increase in food insecurity.

Table ES.CH.2c. Summary table of indicators used.

Resource Indicators	Source	Figure or Table #	Data Summary
Razor clams	State section	S.LR.13.1, S.LR.13.3	Razor clams have been stable or increasing since 2008.
Pacific hake	State section		Biomass has increased.
Pacific halibut	State section		Biomass is declining coastwide (Alaska to California), but increasing in catch area 2A (which includes OCNMS).
Salmonids and steelhead	State section	S.LR.13.12	Populations on the coast are largely stable, with 6 runs of Chinook, coho, and steelhead increasing and 19 runs declining.
Dungeness crab	State section	S.LR.13.3, S.LR.13.4	Populations have declined north of Point Grenville since 2005, but catch per unit effort in OCNMS has increased since 2008.
Groundfish	State section	S.LR.13.5	Most groundfish populations have recovered since 2008.

Subsistence Harvest

The capacity to support non-commercial harvesting of food and utilitarian products

Status Description: The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.

Rationale: Over the study period, razor clam subsistence harvest has remained relatively stable, while other species, such as the prized blueback sockeye salmon from the Quinault River, have been limited or entirely unavailable in recent years. Further, several participants across tribal communities have expressed concern about having enough species through the year to meet their needs and desires. Additionally, hard shell clams and octopus, which were gathered traditionally by the Coastal Treaty Tribes, are reported to be less available.

Since time immemorial, the peoples of the Olympic Coast peninsula have relied upon the land and ocean for subsistence and survival. Many species are still used for subsistence by the Coastal Treaty Tribes today. However, current diets generally include fewer locally sourced species than they historically did. Changes in diet, use, and access to marine species are complex and may result from management decisions or policy changes (e.g., Marine Mammal Protection Act, fisheries management), social or societal changes, changes in species availability or distribution, and/or environmental changes. Poe (2021) found that at least 27 species of invertebrates, 34 species of fish, eight species of marine mammals, six types of kelp or algae, and nine species of birds are important for tribal subsistence today. These include, but are not limited to, salmon, halibut, clams, Dungeness crab, octopus, urchins, olive snails, gray and humpback whales, pinnipeds, bald eagles, gulls, bull kelp, as well as fish and bird eggs.

This condition report evaluates the status and trend of subsistence harvest since 2008. The majority of the indicators summarized here are dependent upon survey data of both people and the species used for subsistence harvest. Much of the literature available on subsistence makes a distinction between tribal and non-tribal subsistence harvest. Accordingly, when available, results are reported for tribal and non-tribal populations.

There are a handful of studies that have sought to quantify the value of subsistence; however, this is often focused on a market value one-to-one replacement in protein costs. This type of quantification does not fully capture the value of subsistence harvest and it should ultimately be left to tribes to determine if and how to approach quantifying this sensitive topic. These studies are limited, as they typically do not capture any of the spiritual or cultural significance associated with subsistence harvest, including the act of harvesting itself, sharing within the community, or any of the other numerous benefits that can't be traded in a marketplace.

Poe et al. (2015) analyzed data from Washington and California commercial fishing operations and found that zero to as much as 33% of catch was retained for personal use in a Puget Sound port. Roughly 85% (14.4 million kilograms) of the personal use harvest was from tribal landings in Washington state; the remaining 15% was from non-tribal Washington and California operators. Additionally, the study sought to determine whether the personal use of a species decreased when the market price of the fish increased. Of the top ten species kept for personal use by tribal fishers, only one, steelhead, fit the model for a price increase (Table ES.SH.1). This means that profit maximization is not a dependable predictor for subsistence behavior, and that some species have a greater value for consumption at home and as gifts than for revenue generation.

Table ES.SH.1. Top 10 species kept for personal use (1990–2010) (values are kilograms landed). Source: Poe et al., 2015

Rank	**Washington Tribal**	**Kilograms Kept for Personal Use**	**Washington Non-Tribal**	**Kilograms Kept for Personal Use**
1	Chum salmon	10,511,301	Albacore	303,627
2	Chinook salmon	2,206,729	Pacific halibut	233,171
3	Coho salmon	663,038	Chum salmon	113,579
4	Steelhead	262,007	Dungeness crab	84,640
5	Sockeye salmon	255,318	Chinook salmon	77,063
6	Geoduck	129,024	Coho salmon	46,760
7	Dungeness crab	120,897	Sockeye salmon	33,942
8	Pacific halibut	87,797	Lingcod	22,833
9	Pink salmon	74,638	Sablefish	20,307
10	White sturgeon	30,918	Rougheye rockfish	15,609

A separate study sought to understand the motivations for keeping a portion of the harvest for personal use. Analyzing four separate fishing communities in 2018, including non-tribal communities, the majority of respondents (69%) kept seafood for personal use (Figure ES.SH.1; Poe, 2019).

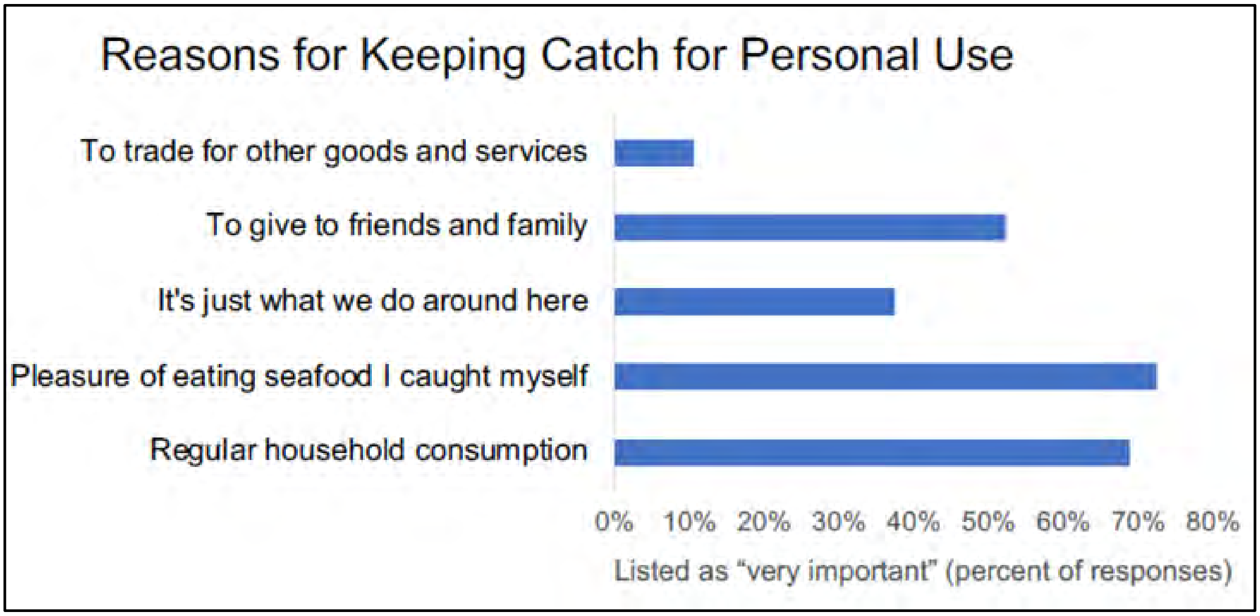

Figure ES.SH.1. Reasons fishers reported keeping catch for personal use. Source: Poe, 2019

Marine mammals are a historical and, for some communities, current important source of subsistence. Whales, seals, and other marine mammals were dietary staples for the Coastal Treaty Tribes for thousands of years. The Makah have hunted whales for subsistence purposes for at least 1,500 years (Renker, 2018). Whale and seal meat and oil are consumed; marine mammal pelts have been and are used for clothing, blankets, or other purposes (e.g., harbor seal skin used for whale floats); and bones are used for tools and handicrafts (and historically other utilitarian purposes like drainage). The Makah Tribe has been working through the international and domestic regulatory processes to reestablish their gray whale hunt since the 1990s, with a successful hunt in 1999. The ceremonial and subsistence importance of marine mammals cannot be understated and is just as relevant today as it was pre-contact with European and American settlers.

Shellfish harvested by treaty tribes in western Washington state in ceremonial and subsistence fisheries are a necessary part of tribal culture and traditional diet (Northwest Indian Fisheries Commission, 2020). Shellfish include native littleneck, Manila, razor, and geoduck clams; Pacific oysters; Dungeness crab; shrimp; and other shellfish. Shellfish, like razor clams, can provide a reliable source of high quality, nutrient-rich subsistence year-round (Crosman et al., 2019). The importance of certain species was highlighted in Crosman et al. (2019). The concept is illustrated by the idea of clam hunger, where the physical and emotional craving for traditional food is so strong that some may still eat them, despite warnings of health hazards (DeWeerdt, 2016).

It is hard to overstate the importance of razor clams for the Quinault Indian Nation. The topic has been featured in an *Earth is Blue* video (ONMS, 2016) and is featured occasionally in local media, such as when blooms of harmful algae cause harvest closures due to the increased presence of neurotoxins like domoic acid. While domoic acid events do not seem to affect the health of razor clams themselves or the Dungeness crab that prey on them, toxins can bioaccumulate in marine mammals and humans that consume toxic shellfish, resulting in injury, paralysis, or even death. One recent NPR story focused on the impacts of the latest coastal HAB event, capturing voices of tribal members and resource managers trying to convey the impacts of the closure on tribal and coastal communities (Pailthorp, 2020). These disruptions not only produce negative economic consequences but also preclude important cultural and social traditions that exist around these family-centric activities.

Sepez (2001) collected data in 1998 from a random sample of Makah households and found that over 80 species were used for personal use, including eight fish, three phyla of shellfish, and marine mammals. Finfish was the most common resource, followed by shellfish and marine mammals. Additionally, 76–100% of households reported using halibut, salmon, clams, and crab. In 1998, fish composed roughly 55% of the meat diet of Makah, compared to 7% in the average U.S. diet. The same study also considered attributes of subsistence. Common themes included tribal identity, work of subsistence (respect of self-reliance), fun/socialization, health (local subsistence is perceived to be healthier than other foods), freshness, and the idea that you are what you eat. Specifically, current traditions emerge from heritage, and when practicing subsistence, one connects to their historical and ecological legacy.

Other resources were collected for more utilitarian uses, such as mussel shells for knife blades, whaling harpoon heads, scrapers, split for awls, jewelry, and tattoo needles (Shaffer et al., 2004). Purple olive snails are still used in Makah ceremonial regalia. Historically, many grasses, roots, and tree barks were collected to build baskets (Wray, 2014). Treaty Tribes in Washington use kelp directly for ceremonial and subsistence purposes, including but not limited to consumptive, cultural, spiritual, medicinal, artistic, and utilitarian uses (Naar, 2020). Kelp habitats also support other cultural resources, like fish and invertebrates that are important for many tribes, and serve as navigational aids.

Changing resource conditions from year to year impact the ability to practice subsistence harvest of species. Climate change is also projected to impact access to subsistence resources (Dalton, 2016; Krueger, 2016; Shannon et al., 2016; Chang et al., 2020). There have been several fisheries disasters over the condition report study period (Table ES.CH.1) that have impacted various salmon populations and Dungeness crab. Sockeye in particular are often kept and canned for subsistence use throughout the year, so losing a season of sockeye can have a disproportionate impact on subsistence communities. Workshop participants expressed difficulty in accessing hard shell clams and octopus. Trends vary among other target subsistence species; razor clam populations have been stable or increasing since 2008, Pacific halibut are increasing in catch area 2A (waters off Washington, Oregon, and California), and salmon populations on the coast are mixed, with 56 stable runs; six increasing runs of Chinook, coho, and steelhead; and 19 declining runs. While populations of Dungeness crab have remained stable or increased coastwide (Richerson et al., 2020), Dungeness crab has declined north of Point Grenville since 2005. Many groundfish populations have recovered from being depleted. Olive snails have recently increased despite a mass mortality in 2014 in Makah Bay. Red urchin densities increased from 2015–2017 and decreased from 2017–2019 at multiple depths. The eastern North Pacific gray whale population has been increasing, and is currently around 27,000, despite an unusual mortality event that began in 2019 (NOAA Fisheries, 2021c).

Conclusion

Subsistence harvest was determined to be fair with a mixed trend, as some species abundances are increasing and others are decreasing. It is worth emphasizing that this rating reflects the 2008–2019 study period and does not consider subsistence use or changes since time immemorial. However, there is high consistency in the species used by the Coastal Treaty Tribes historically and at present. Coastal Treaty Tribe members and some non-tribal members rely on marine resources for subsistence. Recent fishery disaster declarations impact food security and highlight the vulnerability of species and communities in this region to changing conditions. At the same time, populations of some species, such as Pacific halibut and gray whales, have increased in OCNMS, and other species have remained fairly stable.

Ornamentals

Resources collected for decorative, aesthetic, and/or ceremonial purposes

Status Description: The capacity to provide the ecosystem service is compromised, but performance is acceptable.

Rationale: A wide variety of marine resources have been, and continue to be, collected from OCNMS for decorative, aesthetic, and ceremonial purposes. However, shifts in distribution and abundance have occurred for some ornamental species from 2008 to 2018. Data gaps are present regarding the status and trends of a number of ornamental species.

Ornamentals include items collected for decoration, display, or ceremonial purposes. Living and non-living resources from OCNMS are collected for a range of ornamental purposes. It is also worth noting that many items classified as ornamentals were historically produced for utilitarian purposes. This is especially true for basketry, which is discussed both here and in greater detail in the subsistence section.

The art of basketry reached a peak prior to the Great Depression, but has seen a resurgence in modern times among the Coastal Treaty Tribes. Common marine resources collected to make baskets include cattail, sweetgrass, other swamp grasses, and surf grass. While human-made dyes are more commonly used now, berries and seaweed were historically used to dye basket supplies, adding to the intricacy of the patterns used in weaving baskets. Basketry encompasses many forms, but ornamental baskets continue to be sold today at visitor centers and museums. For the Coastal Treaty Tribes, basketry has cultural meaning and provides a vital link between past, present, and future artists. However, due to restrictions on removing resources, and thus access to basket-making supplies, the ability to practice basketry has decreased (Wray, 2014).

Beachcombing for non-living resources (e.g., driftwood, sea glass) is popular in some areas of the sanctuary (Figure ES.O.1a; Washington Marine Spatial Planning, 2020). Similarly, shore-based collection and harvest of sea life also occurs in some parts of the sanctuary, but is generally less common than beachcombing (Figure ES.O.1b; Washington Marine Spatial Planning, 2020), and may include collection for non-ornamental purposes (e.g., subsistence harvest, consumptive recreation). Both beachcombing and harvest of sea life are regulated within Olympic National Park, and are, with few exceptions, prohibited (Olympic National Park, 2020). Beachcombing on tribal reservations is also prohibited.

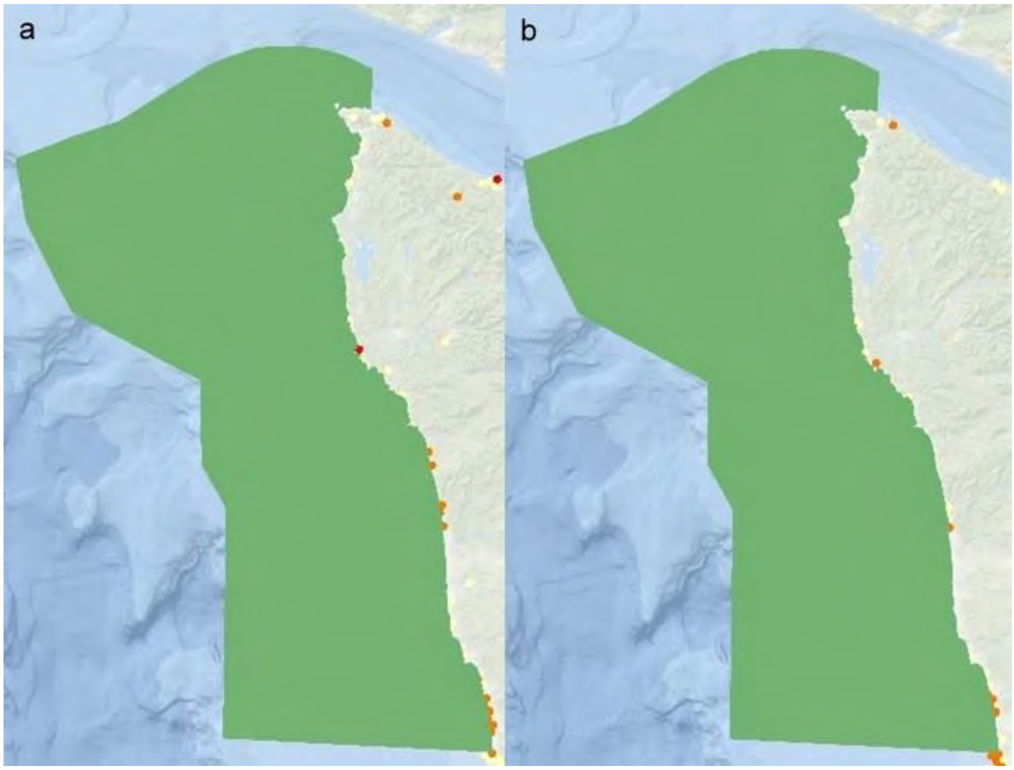

Figure ES.O.1. Spatial distribution of (a) beachcombing and (b) shore-based sea life collection and harvest activities in and adjacent to OCNMS. The green polygon represents OCNMS. Red points indicate high use, orange points indicate moderate use, and yellow points indicate low use. Image: Washington Marine Spatial Planning, 2020

Museums and festivals dedicated to beachcombing feature items collected adjacent to the sanctuary. These include John's Beachcombing Museum in Forks, founded in 1976, and the annual Beachcomber's Fun Fair in Ocean Shores.

Beyond beachcombing activities, which are popular among visitors and residents, workshop participants noted a number of resources that are collected from or adjacent to OCNMS for traditional ornamental and ceremonial use by Indigenous peoples of the Olympic Coast. These include kelp (used to make baskets and rattles) and shells from species such as blue mussels and olive snails (used to make clothing, jewelry, and regalia). Other shellfish, such as California mussels and acorn barnacles, are also used for ornamental purposes. Marine mammal products, including whale bone, sea otter teeth and pelts, and sea lion pelts, have also been used for traditional ornamental purposes.

Although many resources are still successfully harvested for ornamental purposes in OCNMS, some species are becoming scarce. Workshop participants noted that *Dentalium* (Shaffer et al., 2004) and abalone shells were historically used for ornamental purposes, but are now difficult to find. Interviews with tribal members and elders from the Olympic Coast indicate that kelp is also scarce on beaches compared to its historical abundance (Shaffer et al., 2004). A mass die-off of olive snails was observed in Makah Bay in 2014, but the population subsequently recovered (Akmajian et al., 2018).

The abundance of acorn barnacles and California mussels varied across sites within the sanctuary, but generally remained stable during the study period (see Figure S.H.10.2). However, some observations suggest that changes in intertidal zoning of these species are occurring (J. Waddell/NOAA, personal communication, January 16, 2020). Concerns exist regarding how changes in distribution or zonation may affect the ability of tribal communities to access these resources, as treaty rights only apply to specific locations, and would no longer apply if shellfish populations migrate outside treaty-delineated boundaries.

Conclusion

While information is available for some species and locations, workshop participants ultimately noted that data gaps are present for the vast majority of species harvested for ornamental purposes, resulting in few available resource indicators for this ecosystem service.

Response to Pressures

The Drivers and Pressures sections of this report describe a variety of issues and human activities occurring within and beyond OCNMS that warrant attention, tracking, study, and, in some cases, specific management actions. Addressing any of these issues requires participation by and coordination with a variety of agencies and organizations. OCNMS is fortunate to be able to work with many entities that contribute to managing human activities and addressing marine conservation issues. Central to that collaborative approach are the Olympic Coast IPC and the OCNMS Sanctuary Advisory Council.

The IPC was formed in 2007 to provide an effective and efficient forum for communication, exchange of information, and policy recommendations regarding the management of marine resources and activities within the boundaries of OCNMS. The IPC is a forum where sovereigns with regulatory jurisdiction over marine resources and activities within the boundaries of OCNMS meet to enhance their communication, policy coordination and resource management strategies. Membership includes the Hoh Tribe, Makah Tribe, Quileute Tribe, Quinault Indian Nation, and the state of Washington (The Hoh Indian Tribe et al., 2007).

The Sanctuary Advisory Council was established immediately after the sanctuary's 1994 designation, 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 (OCNMS, 2017b). The advisory council includes governmental (i.e., tribal, state, local, and federal agencies) and non-governmental (i.e., education, conservation, research, fishing, tourism, industry, marine resources committee, citizen at large) seats.

In addition to these groups, OCNMS also consults on a government-to-government basis with the Coastal Treaty Tribes individually.

For each of the main issues and human activities presented in the Drivers and Pressures sections 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 2022, OCNMS 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 actions that ONMS has taken, primarily since 2008, to address the issues and human activities that were described in the Drivers and Pressures sections of this report.

OCNMS Management Plan

The OCNMS management plan serves as a non-regulatory policy framework for addressing the issues facing the sanctuary over a five- to ten-year period. It lays the foundation for restoring and protecting the sanctuary's ecosystem, details the human pressures that threaten the qualities and resources of the sanctuary, and recommends actions that should be taken both now and, in the future, to better manage the area and resources.

The original management plan was drafted during the sanctuary designation process, completed in 1994. The completion of the 2008 OCNMS condition report kicked off a three-year management plan review process. The resulting management plan was the result of a collaboration between the OCNMS Sanctuary Advisory Council, the Olympic Coast IPC, and the public. The 20 action plans in the 2011 management plan (OCNMS, 2011) are grouped under five priorities:

- Achieve collaborative and coordinated management
- Conduct collaborative research, assessments, and monitoring to inform ecosystem-based management
- Improve ocean literacy
- Conserve natural resources in the sanctuary
- Understand the sanctuary's cultural, historical, and socioeconomic significance

In 2017, OCNMS conducted an internal assessment of the progress made toward implementing the management plan. Based on this review, it was determined that no immediate or urgent revisions to the management plan or regulations were needed at that time. The evaluation demonstrated the sustained relevance of the goals, objectives, and priorities of the existing management plan.

Changing Ocean Conditions

In 2013, OCNMS produced a report, *Climate Change and the Olympic Coast National Marine Sanctuary: Interpreting Potential Futures* (Miller et al., 2013), which summarized the best available science related to the implications of climate change for the resources in OCNMS. This climate change site scenario assessment was designed to assist OCNMS in adapting to climate change by bridging the gap between the global projections provided by the IPCC and the regional and local implications of climate change. Miller et al. (2013) considered the direct consequences of climate change on the physical environment in OCNMS and, where possible, the direction and magnitude of change was estimated. These physical effects were divided into seven categories: increasing ocean temperature, ocean acidification, sea level rise, increasing storminess, changing ocean current patterns (with a focus on upwelling), increasing hypoxia or anoxia, and altered hydrology in rivers draining into OCNMS. Following the completion of this climate change site scenario, work continued to refine a regional approach to address the issues identified.

Following the release of Miller et al. (2013), the Sanctuary Advisory Council and the IPC formed a joint Ocean Acidification Working Group. The working group was tasked with reviewing the recommendations of the Washington State Blue Ribbon Panel on Ocean Acidification, identifying recommendations most relevant to the outer coast of the Olympic Peninsula, and providing advice on potential responses and actions. The working group identified seven priority recommendations, including designating OCNMS as a NOAA sentinel site for ocean acidification and sea level rise. Building upon these efforts, in 2016, the Sanctuary Advisory Council established the Ocean Acidification Sentinel Site Working Group, whose purpose was to help develop and plan a workshop to assist OCNMS in becoming a sentinel site for ocean acidification. The workshop facilitated discussion, identified efficiencies, and highlighted potential collaborations, and began to collectively articulate the desired core components and capabilities of an ocean acidification sentinel site for the Olympic Coast.

On November 6, 2019, ONMS Director John Armor, working closely with tribal and state representatives on the IPC and a Sanctuary Advisory Council working group, designated OCNMS as a sentinel site for ocean acidification. The resulting sentinel site on the Olympic Coast of Washington state is focused on identifying trends in carbonate chemistry and hypoxia through collaborative monitoring, research, outreach, and public engagement efforts. The sentinel site is helping to inform resource managers and coastal communities by telling the story of ocean acidification and its impacts on Washington coastal marine resources, cultures, communities, and economies. The sentinel site works to ensure that the Olympic Coast is well prepared for changing ocean conditions, with research and information that supports management responses and actions.

OCNMS is currently piloting a process to better integrate climate change into its management planning process. Occurring in tandem with the condition report, OCNMS is drafting an addendum to Miller et al. (2013) and plans to develop a rapid vulnerability assessment, which will better inform the management plan review process with respect to climate impacts to sanctuary resources. These efforts will leverage existing reports (i.e., condition report, Miller et al. [2013]) to ensure consistency and share lessons learned with other sites. OCNMS aims to holistically integrate climate change into its management plan to address climate and non-climate stressors as mandated.

While changing climatic conditions likely cannot be managed at the level of the sanctuary, OCNMS can assist in documenting the direct effects of climatic changes by recording oceanographic properties such as water temperature and dissolved oxygen levels over time. Management actions will be considered during the sanctuary's next management plan review.

In order to understand and track how ocean conditions change on the Olympic Coast over time, OCNMS has maintained an oceanographic mooring program since 2000 to document basic physical and chemical properties of the coastal ocean along approximately 130 miles of coastline. For most of the assessment period (2008–2019), ten moorings were deployed during the upwelling season (May to October) between Makah Bay and Cape Elizabeth, with moorings placed at water depths of 15 m and 42 m. Although some nearshore sites record only temperature throughout the water column, OCNMS staff have continually worked to enhance these moorings with additional sensors and capabilities in an effort to collect similar data at all sites.

Data resulting from the OCNMS mooring program are utilized in a number of important ways, ranging from graduate student research and development of ocean temperature climatologies (Koehlinger, 2018) to synthesis into sophisticated regional ocean models that provide near-term and seasonal forecasts of ocean parameters like aragonite saturation state and other indications of ocean acidification (NANOOS, 2021b). The unusual, two-decade-long coastal time series generated by OCNMS will provide a foundation for future work, including activities prioritized by steering committee members and ocean acidification sentinel site working groups.

HABs are present on the Olympic Coast, and associated neurotoxins can produce drastic negative consequences for human and animal health and prompt cascading negative economic impacts from the closure of recreational, commercial, and subsistence harvest activities. HABs are addressed by OCNMS in a couple of ways, including as part of the mooring program. Working in partnership with Quileute Natural Resources, staff routinely collect surface water samples adjacent to OCNMS' ten mooring sites during every visit, or approximately 5–6 times per season. Samples are analyzed by Quileute Natural Resources and shared with partners, including the Olympic Region Harmful Algal Blooms partnership—a regional effort among tribal, state, and federal scientists and resource managers to coordinate and collaborate in support of a better understanding of HAB dynamics and impacts to fisheries and human health on the Olympic Coast.

Ocean Sound

Sound is a fundamental component of habitat that many ocean animals and ecosystems have evolved to rely on over millions of years. It is the most efficient means of communication over distance underwater. In just the last 100 years, human activity has increased along coasts, further offshore, and in deep ocean environments. Sound from human activities travels long distances underwater, leading to increases and changes in ocean noise levels.

Rising noise levels can negatively impact ocean animals and ecosystems in complex ways. Higher noise levels can reduce the ability of animals to communicate with potential mates, other group members, their offspring, or feeding partners. Noise can reduce an ocean animal's ability to hear environmental cues that are vital for survival, including those key to avoiding predators, finding food, and navigation among preferred habitats.

In 2010, NOAA developed an approach to managing ocean noise with the intention of reducing negative physical and behavioral impacts to living marine resources. This Ocean Noise Strategy is multi-faceted and includes studies on adverse physical and behavioral effects that exposure to certain noise types and levels can have on different species, as well as strategies to improve NOAA's ability to manage both species and the places they inhabit in the context of a changing acoustic environment (Gedamke et al., 2016b).

ONMS efforts in this area include a collaboration with the U.S. Navy on a program to characterize soundscapes within national marine sanctuaries, including three west coast sanctuaries: Olympic Coast, Monterey Bay, and Channel Islands. This program aims to measure and describe both comparable and site-specific underwater soundscape qualities within the

National Marine Sanctuary System, in order to develop the capacity to understand and protect acoustic habitats.

OCNMS has also actively engaged in the review of other federal agencies' actions that may include the use of acoustic sources that are likely to injure sanctuary resources (e.g., Navy testing and training activities, a National Science Foundation-funded seismic study of the Cascadia subduction zone).

Addressing Proposed Actions

Section 304(d) of the NMSA outlines the basic process by which federal agencies must consult with NOAA on certain activities. If a federal agency finds that a proposed action is likely to injure sanctuary resources, the agency is required to submit a "written statement" to ONMS describing the potential effects of the activity on sanctuary resources at the earliest practicable time, but no later than 45 days before the final approval of the action, unless the agencies agree upon another schedule.

If ONMS finds that a proposed action is likely to injure sanctuary resources, it must, within 45 days of receipt of complete information on the proposed action from the federal agency, develop and recommend "reasonable and prudent alternatives" for the agency to implement to protect sanctuary resources. Upon receipt of these alternatives, the agency is required to consult with ONMS regarding plans for incorporating these recommendations into the proposed action.

If the agency decides not to follow ONMS recommendations, it must provide a written explanation for that decision to ONMS. If the agency takes an action other than an alternative recommended by the ONMS and the action results in the destruction of, loss of, or injury to a sanctuary resource, the head of the agency must promptly prevent and mitigate further damage and restore or replace the sanctuary resource in a manner approved by ONMS (ONMS, 2020b).

Maritime Transportation

The sanctuary lies at the entrance to the Strait of Juan de Fuca, a major international waterway linking the important North American ports of Seattle, Tacoma, and Vancouver with trading partners all around the Pacific Rim. Maritime transportation is one of the most significant commercial uses of the sanctuary. The region benefits from robust international management by a Cooperative Vessel Traffic Service, jointly managed by the U.S. and Canadian Coast Guards. The purpose of the Cooperative Vessel Traffic Service is to provide for the safe and efficient movement of vessel traffic while preventing collisions and groundings, and therefore minimizing the risk of resulting environmental damage.

Washington state is also proactive in maritime transportation risk management and oil spill prevention, planning, and response. Most recently, the Washington State Legislature passed the 2018 Strengthening Oil Transportation Safety Act and the 2019 Reducing Threats to Southern Resident Killer Whales and Improving the Safety of Oil Transportation Act.

There are a number of groups that also participate in vessel traffic management and safety issues, including the Puget Sound Harbor Safety Committee, Salish Sea Shared Water Forum, and the Pacific States-British Columbia Oil Spill Task Force.

Ship Strikes

At present, there have been limited management actions taken to address the risks to marine mammals from ship strikes in OCNMS. Voluntary vessel slowdowns have been implemented in California waters and in nearby Canadian and U.S. waters. There are standard operating procedures that have been adopted by NOAA to minimize speeds in certain situations to minimize ship strike risk. Furthermore, the U.S. Navy and Coast Guard are required to report ship strikes.

Oil Spill Prevention

OCNMS works closely with the U.S. Coast Guard, Washington Department of Ecology, Makah Office of Marine Affairs, and other organizations on oil spill response and preparedness by participating in oil spill drills, supporting a rescue tug stationed in Neah Bay, participating in discussions of alternative response technologies, prioritizing allocation of oil spill restoration funds, and reviewing proposed legislation, regulations, and documentation. Since 1999, Washington state has funded a seasonal rescue tug stationed at Neah Bay to quickly respond to vessels that may need assistance. As of February 2020, the tug has escorted, stood by, or assisted 78 ships that were disabled or had reduced maneuvering or propulsion capability while fishing or transporting oil and other cargo through the sanctuary, along the Strait of Juan de Fuca, and even in Canadian waters (Washington State Department of Ecology, 2020d).

Area To Be Avoided Monitoring and Compliance

At the time of designation, to mitigate potential oil spills, NOAA worked with the U.S. Coast Guard and the U.S. delegation to the IMO to establish an ATBA as a buffer to improve response time to assist foundering vessels along the rocky and environmentally sensitive Olympic Coast. The ATBA was designated in 1995 and modified in 2002 and 2012. The ATBA originally applied to all vessels transiting with cargoes of oil or hazardous materials. Effective December 1, 2012, applicability was extended to also include all vessels over 400 gross tons. All ships meeting these criteria must comply with the ATBA. The sanctuary has monitored ATBA compliance since 1998 and has reported monitoring results annually since 2004.

Letters signed by the sanctuary superintendent and the Coast Guard Captain of the Port are sent to non-complying vessels observed within the ATBA. The response by the maritime industry has been favorable, with an estimated compliance rate of 95.5% in 2019.

Vessel Discharge and Ballast Water

There are risks from vessel discharges in addition to oil spills. Interest in water quality and the effects of vessel discharges in the sanctuary were expressed during the management plan review public scoping period and during subsequent public comment periods at Sanctuary Advisory Council meetings. Regulations on vessel discharges were considered, including a ban on the discharge of invasive species in the sanctuary through ballast water discharges. In one case, discharges from cruise ships were addressed through OCNMS rule-making and are discussed in the following section.

In reviewing alternatives for an OCNMS Water Quality Protection Action Plan, modifications to sanctuary regulations were considered for both cruise ships and vessels 300 gross tons and above. OCNMS considered regulation banning all discharges (except when limited by sewage or graywater holding capacity) from vessels 300 gross tons and above into waters of the sanctuary, except clean vessel engine cooling water, clean vessel generator cooling water, clean bilge water, and anchor wash (OCNMS, 2011). The sanctuary did not pursue the regulation for vessels 300 gross tons and above, deciding to focus instead on the estimated higher volumes from cruise ships. OCNMS has been working with local marinas to improve access to pump out stations to address sewage discharge and may be able to expand these efforts to include oily bilge discharge.

In reviewing alternatives for a Habitat Protection Action Plan, a modification to OCNMS regulations to ban the discharge of invasive species in the sanctuary was considered. The Washington Invasive Species Council's definition and list of invasive species was adopted for the analysis. After reviewing existing state and regional regulations and policies related to invasive species, an OCNMS regulation related to invasive, non-native species was determined to be unnecessary. This position may need to be reevaluated based on the results of the EPA's proposed rulemaking on Vessel Incidental Discharge National Standards of Performance (85 FR 67818). The rule is intended to reduce the environmental impact of discharges, such as ballast water, that are incidental to the normal operation of commercial vessels; however, this rule may also preempt existing state regulations in federal waters.

Cruise Ship Discharges

As part of the 2011 management plan review, regulations banning discharges from cruise ships in the sanctuary were promulgated. The related analysis found that cruise ships generated a variety of wastewater discharges, on the scale of a small municipality, that could potentially harm the marine environment. The discharges of highest concern to OCNMS based on volume and potential contaminant loading were sewage, graywater, and bilge water. Sewage discharges from ships, particularly those not using advanced water treatment systems, contain nutrients that create biological and chemical oxygen demand and could contribute to algae blooms that, in turn, could intensify low dissolved oxygen levels known to occur in the sanctuary. Pathogens from sewage have the potential to contaminate commercial or recreational shellfish beds (a human health risk) and harm wildlife and humans directly (OCNMS, 2011).

The final rule (76 FR 67348) created a regulatory ban on all discharges from cruise ships within OCNMS (except clean vessel deck wash down, clean vessel engine cooling water, clean vessel generator cooling water, clean bilge water, or anchor wash). This ban will have a direct, long-term, beneficial, less-than-significant impact on physical resources (i.e., water quality) because it prohibits potentially harmful discharges that may include pollutants, such as bacteria, viruses, solids, pharmaceuticals, organics, nutrients, and metals.

Exhaust Gas Cleaning Systems

Illegally discharged exhaust gas cleaning system effluents from cruise ships in OCNMS could have an adverse effect on sanctuary resources or qualities. There have been a number of self-reported violations of the cruise ship discharge regulation that have resulted in civil penalties.

Submarine Cables

Two submarine cables were installed by plow burial in the OCNMS seafloor for the Pacific Crossing fiber optic telecommunications system in 1999 and 2000. At the time, there were no published studies on impacts of submarine cable installation to seafloor habitats or biological communities. As a result, the authorization to install the cable in OCNMS required a post-installation field study to monitor the impact of cable installation on benthic habitats and biological communities and recovery over time.

A cable inspection survey contracted by the cable owners in 2001 revealed that significant portions of each cable were not buried to the required 0.6 meter depth, and considerable lengths of cable were unburied or suspended above the seafloor. Protracted negotiations between the cable owner, cable installer, OCNMS, U.S. Army Corps of Engineers, and the Makah Tribe resulted in an agreement requiring cable reinstallation throughout the sanctuary. Reinstallation of the PC-1 cables was completed in 2006.

Antrim et al. (2018) analyzed cable surveys completed between 2000 and 2004. This analysis provided useful scientific information about the sanctuary's benthic habitats, as well as management implications and monitoring recommendations for cable installations. Effective cable route planning can help identify areas susceptible to significant or persistent impacts that could be avoided during project construction. In areas where user conflicts are clearly identified, such as where bottom contact fisheries are conducted, post-installation surveys of submarine cables were recommended to identify where exposed cables put fishers at risk of snagging gear or damaging submarine cables. The current permit end date, and the anticipated end of life for the cable network, is in 2025. Monitoring of the cable continues and will inform the actions to be taken in 2025.

Fishing

OCNMS does not directly manage fisheries within sanctuary waters; however, sanctuary research may inform fisheries management entities, particularly with regard to habitats within sanctuary boundaries. In 2013, OCNMS and WDFW jointly responded to a request for proposals from the Pacific Fishery Management Council as part of its five-year review of groundfish essential fish habitat along the West Coast. The OCNMS and WDFW submission, "Options for Potential Modifications to Olympic 2 Groundfish Essential Fish Habitat Conservation Area in Washington State," contained three options, applicable to non-tribal fisheries, to increase protection of sensitive biogenic and rocky reef habitats both within and adjacent to the existing Olympic 2 Essential Fish Habitat Conservation Area.

Based on concerns expressed by the Coastal Treaty Tribes regarding how essential fish habitat protections might impact their U&A fishing areas, and for the purposes of broader ecosystem protection and the application of precautionary management principles, OCNMS and WDFW agreed to an alternative process to address broader ecosystem protection in OCNMS. These efforts have resulted in an IPC Habitat Framework initiative, which is based on a need for a common understanding of all information sources regarding habitat and its role in supporting marine ecosystems.

Habitat

Information on habitat is required for both fisheries and national marine sanctuary management and is a logical nexus for collaboration. OCNMS met a substantial milestone in 2015 with the release of the Washington State Seafloor Atlas (Figure R.1), which shows the primary surficial substrate types from the Washington state shoreline to 700 fathoms. The atlas was developed through a partnership among OCNMS, the Washington State Department of Natural Resources, and Oregon State University. Thirty-five OCNMS surveys, conducted over 15 years, were reprocessed and edgematched by the Oregon State University Active Tectonics and Seafloor Mapping Lab.

Data from the atlas were also utilized by the IPC's Habitat Framework. The Habitat Framework is a joint effort by the IPC and OCNMS to build a comprehensive catalog of marine and coastal data that will improve management initiatives, such as ecosystem based management, marine spatial planning, and habitat protection, and contribute to integrated ecosystem assessments. Moreover, the Habitat Framework—based on the NOAA CMECS—can help identify knowledge gaps and coalesce multi-agency partners with shared priorities and available resources to address timely research and management issues. OCNMS is providing technical support and linkages with state and federal agencies and academic institutions. To date, OCNMS and the IPC have held focus group meetings in which academic and agency experts provided observed and modeled data. Seafloor sediment data have also been classified using the CMECS scheme, bringing current and historic ocean bottom surveys into the Habitat Framework. More than 25 unique data sets have been identified for shoreline, nearshore, shelf, and offshore classification in CMECS. Since the Habitat Framework is one of the most significant applications of CMECS since its approval by the Federal Geographic Data Committee in 2012, OCNMS is currently networked with NOAA Fisheries and NOAA's Office of Coastal Management for ongoing support through the development, implementation, and distribution phases of the project.

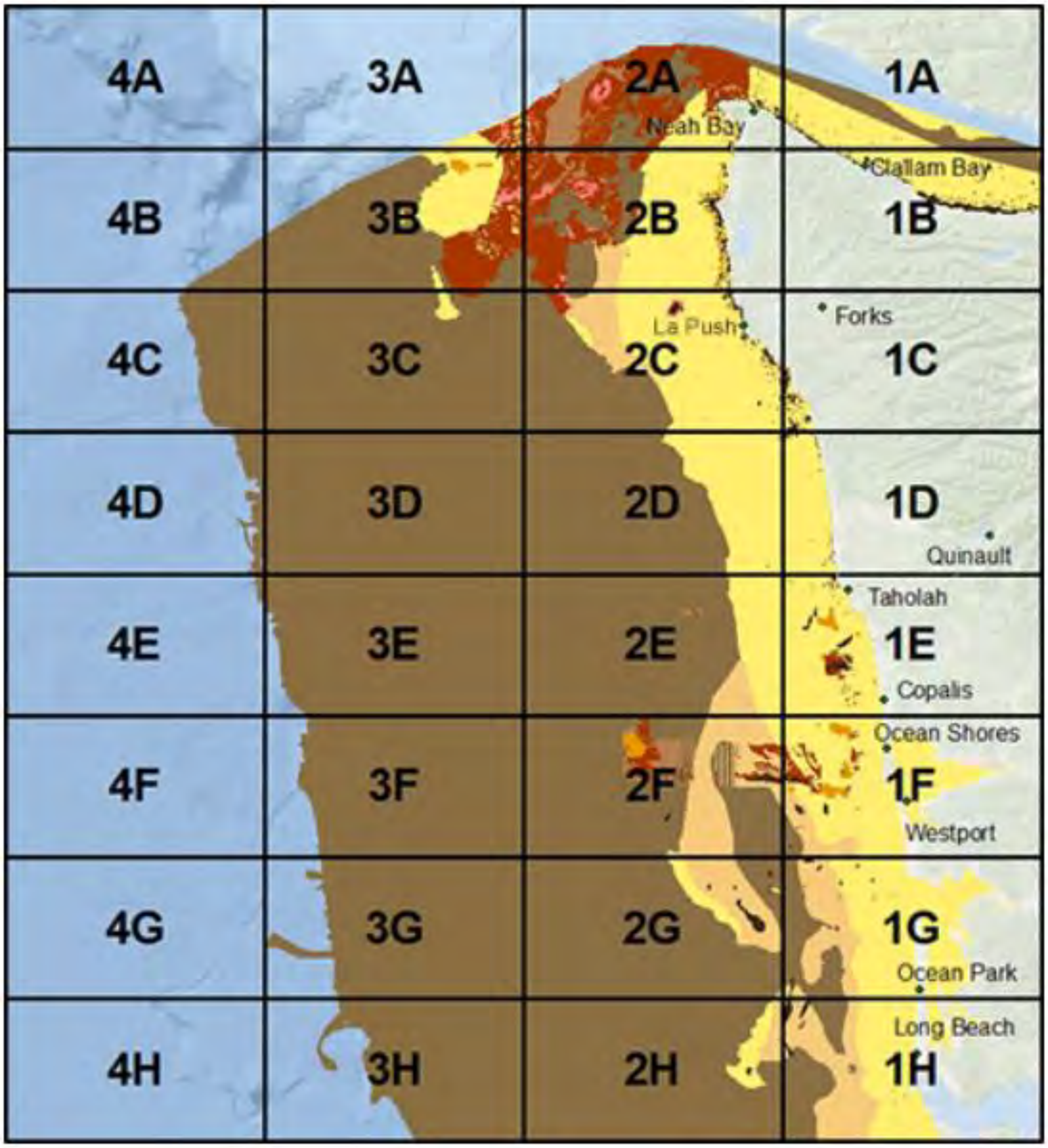

Figure R.1. Geographic extent of the Washington State Seafloor Atlas. The atlas overlays fine-scale seafloor data from OCNMS (2000–2013) on coarser-scale surficial geologic habitat data from multiple sources compiled by the Oregon State University Active Tectonics and Seafloor Mapping Lab (2003–2015).

Whale Entanglement

In response to a large increase in reported marine mammal entanglements during the assessment period, natural resource agencies have studied the problem and taken action. NOAA Fisheries has a West Coast Large Whale Entanglement Response Program that works to reduce the number of large whale entanglements and minimize the likelihood of large whales becoming entangled in fishing gear to promote the conservation of healthy whale populations along the U.S. West Coast (NOAA Fisheries, 2020c). The NOAA Fisheries West Coast Region Protected Resources Division oversees the Large Whale Entanglement Response Network and maintains entanglement records through the West Coast Marine Mammal Stranding Network.

Washington state and the Coastal Treaty Tribes are responsible for co-management of the commercial Dungeness crab fishery and have considered management measures to address the entanglement issue. WDFW held workshops with coastal Dungeness crab fishers and discussed potential management measure alternatives that resulted in new rules for Dungeness crab in an effort to reduce the potential for humpback whale entanglements on Washington's coast. Rule changes included requiring only the amount of line reasonably necessary, reducing the pot limit, requiring a summer buoy tag, replacing buoy tags, and requiring line marking specific to Washington.

Overfished and Depleted Stocks

Groundfish are managed through a variety of management measures, including quotas, trip and landing limits, temporal and spatial restrictions or closures, gear restrictions, and harvest guidelines. OCNMS does not have a fisheries management mandate, but has engaged in relevant research, developed recommendations for physical and biogenic habitat characterization, and provided staff support for the Habitat Framework initiative that could be used to inform management decisions, especially those that pertain to essential fish habitat.

Significant conservation actions applied to the West Coast over the past two decades have enhanced sustainable fisheries management and include the establishment of conservation areas to protect groundfish habitat and minimize the bycatch of overfished species. Since 2000, the state of Washington has prohibited bottom trawling in state waters. In 2006, the Pacific Fishery Management Council and NOAA Fisheries designated multiple areas along the West Coast as essential fish habitat. Essential fish habitat areas are characterized by specific fishing restrictions designed to freeze the footprint of bottom trawling and rebuild overfished stocks. Essential fish habitat is habitat necessary to fish for spawning, breeding, feeding, or growth to maturity. Five essential fish habitat areas were adopted off the coast of Washington that are closed to non-tribal bottom trawl fishing. One essential fish habitat area, the Olympic 2 Essential Fish Habitat Conservation Area, is located within the boundary of OCNMS and is closed to all types of non-tribal bottom trawl fishing gear, but not all types of bottom-contact gear, such as longline gear. Olympic 2 Essential Fish Habitat Conservation Area covers 7% of the sanctuary's area. The essential fish habitat measures also included a prohibition of bottom trawl activity deeper than 700 fathoms across the entire West Coast. The essential fish habitat areas were implemented through Amendment 19 to the Pacific Coast Groundfish Fisheries Management Plan and went into effect in 2006. The 2007 reauthorization of the Magnuson-Stevens Fishery Conservation and Management Act provided regional fishery management councils with discretionary authority to restrict fishing activities, protect deep-sea corals, and take other management actions.

In addition, trawl rockfish conservation areas, temporary, large-scale closed areas that extend along the entire length of the U.S. West Coast, were enacted and are expected to be in place until key overfished rockfish species recover. Commercial trawl rockfish conservation area boundaries approximate particular depth contours that can change during the year and are designed to minimize opportunities for vessels to incidentally take overfished rockfish by eliminating fishing in areas where and when those species are likely to co-occur with healthier stocks of groundfish. In addition, there are specific closed areas within the sanctuary that are permanent in nature and pertain to specific fisheries. These include the North Coast Commercial Yelloweye Rockfish Conservation Area (closed to fixed gear [e.g., longlines, pots] and recreational groundfish and halibut fisheries), the North Coast Recreational Yelloweye Rockfish Conservation Area, and the Salmon Troll Yelloweye Rockfish Conservation Area, a smaller area that lies within the North Coast Recreational Yelloweye Rockfish Conservation Area.

In 2011, NOAA Fisheries and the Pacific Fishery Management Council also implemented Amendment 20, establishing "catch shares" management for portions of the commercial groundfish fishery, which allocates shares of allowable catch to each fisher. The implementation of essential fish habitat areas, catch shares, and other fisheries management measures have led to the recovery of nearly every groundfish species listed as overfished; some species recovered a decade or more earlier than predicted (Table R.1).

Table R.1. Declaration and recovery years for depleted West Coast groundfish species. Source: Pacific Fishery Management Council, 2019

West Coast Groundfish Species	Declared Overfished	Declared Recovered
Bocaccio rockfish	1999	2017
Canary rockfish	2000	2015
Cowcod	1999	2019
Darkblotched rockfish	2000	2017
Lingcod	1999	2005
Pacific ocean perch	1999	2017
Pacific whiting (hake)	2002	2004
Petrale sole	2009	2015
Widow rockfish	2001	2012
Yelloweye rockfish	2002	Not yet recovered

A review of essential fish habitat established under Amendment 19 took place from 2010–2014. The Pacific Fishery Management Council decided to combine essential fish habitat and trawl rockfish conservation area modifications into a single action. In 2018, Amendment 28 was approved to be implemented in 2020. Amendment 28 adjusted many essential fish habitat areas, with the exception of those within the tribal U&A fishing areas off the Washington coast (which overlaps OCNMS) until completion of the Habitat Framework initiative, except for the expansion of the Grays Canyon Essential Fish Habitat Conservation Area with agreement from the Quinault Indian Nation. Elsewhere, Amendment 28 closed new areas to bottom contact fishing gear, reopened some areas that were previously closed to bottom trawling, and closed waters deeper than 3,500 m to bottom-contact gear, but did not affect essential fish habitat areas located within or adjacent to OCNMS. Under Amendment 28, essential fish habitat closures cover approximately 33,670 km^2 of the area covered by the Groundfish Fishery Management Plan, and approximately 7,770 km^2 have been reopened to bottom trawling.

OCNMS has been working since 2006 to characterize and map the abundance, diversity, and distribution of deep-sea corals and sponges, especially within and adjacent to essential fish habitat areas, through several research cruises (Table ES.S.1). In 2018, NOAA launched the West Coast Deep-Sea Coral Initiative, a four-year effort that aims to characterize and study deep-sea coral and sponge ecosystems offshore of the West Coast. This initiative focuses on essential fish habitat areas that closed or reopened as a result of Amendment 28, areas of high coral and sponge bycatch in research trawls, and national marine sanctuaries (Caldow et al., 2019).

Offshore Seafood Processing

The EPA recently issued a National Pollutant Discharge Elimination System General Permit to seafood processing vessels that discharge in federal waters off the coast of Washington and Oregon (Permit Number WAG520000). The general permit authorizes discharges of seafood processing waste from the vessels. This is the first time this general permit has been issued and the first time this sector has received National Pollutant Discharge Elimination System permit coverage off the coast of Oregon and Washington (84 FR 9794).

The permit does not specify a target species or type of seafood processing to be covered; however, the sector seeking permit coverage is known to process Pacific hake (or Pacific whiting, *Merluccius productus*). The EPA rule is independent from the management of the Pacific whiting fishery, which is managed under the authority of the Pacific Coast Groundfish Fishery Management Plan, the Magnuson-Stevens Fishery Conservation and Management Act, and the Pacific Whiting Act of 2006. Each year a U.S. total allowable catch is determined and allocated between tribal and non-tribal sectors. The 2019 Pacific whiting allocation by sector is provided in Table R.2 (84 FR 20578).

Table R.2. 2019 Pacific whiting allocations (84 FR 20578).

Sector	2019 Pacific Whiting Allocation (mt)
Tribal	77,251
Catcher/processor coop program	123,312
Mothership coop program	87,044
Shorebased individual fishing quota program	152,326.5

The general permit is applicable to two of the four sectors: at-sea mothership processors and catcher/processors.

The permit was originally proposed in 2015, and based on public comments and consultations, was re-proposed in 2017 and finalized in 2019. Under the requirements of the NMSA section 304(d), the EPA consulted with OCNMS on this permit and accepted a recommendation that permittees must provide a copy of a required annual report (Figure R.2) to OCNMS if they operate within the sanctuary boundaries. Among other items, the report will include:

- Reports of noncompliance;
- Maps of processing areas;
- Clearly labeled representative pictures;
- Dates of discharge by month; and
- Type and amount (pounds) of discharged seafood processing waste residues by month.

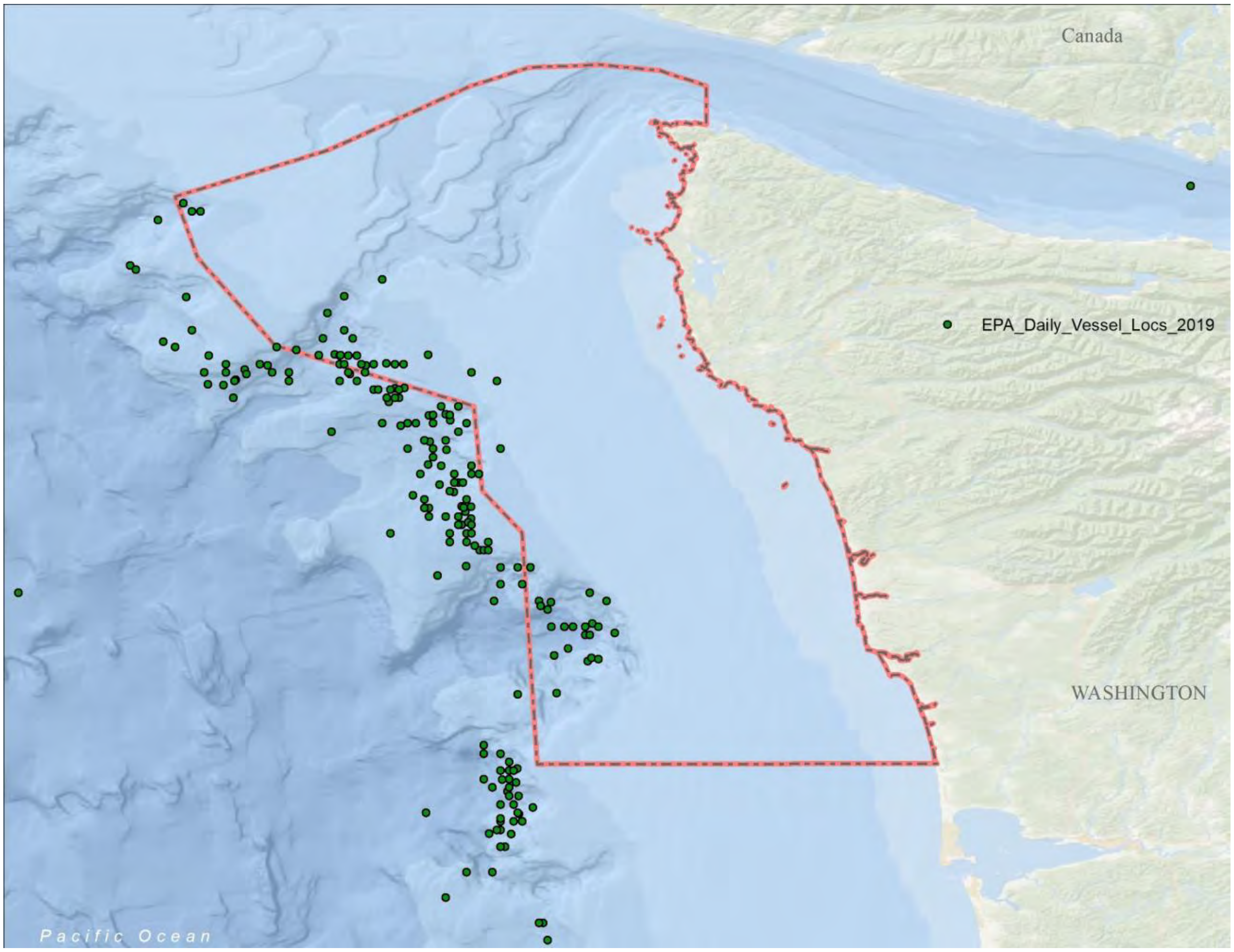

Figure R.2. EPA compilation of 2019 discharges of seafood processing vessels reported by industry. Each location is a single reported daily position for days when discharges occurred (discharges occur over a larger area then shown on map). Source: EPA; Image: NOAA

Derelict Gear

In 2009, WDFW initiated two efforts to recover abandoned crab-fishing gear off the Washington coast. WDFW administered a grant from the NOAA Marine Debris Program. Commercial vessels were hired to sweep two large areas near Grays Harbor and the mouth of the Columbia River and remove all abandoned pots. In addition, WDFW developed a permit program that allows crab fishers to recover all of the abandoned gear remaining at fishing grounds at the close of the commercial crabbing season. These permits allow fishers to keep the pots they recover, including those owned by other fishers licensed by Washington state (WDFW, 2019).

Some of the Coastal Treaty Tribes conduct similar crab pot recovery for their fisheries with support from the NOAA Marine Debris Program. Quinault Indian Nation (beginning in 2014) and the Quileute Tribe (beginning in 2015) both partnered with the Nature Conservancy to develop their community-based derelict crab gear removal programs. The Makah Tribe (beginning in 2018) is in the process of developing a community-based derelict crab gear removal program. These efforts aim to remove existing derelict crab gear and establish management measures to reduce the accumulation of future derelict gear.

Military Activities

The Navy and OCNMS recognize the significance of each other's value to the country and have committed to work together to support each organization's respective mandates. The Navy's use of the waters and airspace of the Olympic Coast for training and testing pre-dates the establishment of OCNMS, and was recognized during the sanctuary designation process. The Department of Defense is required to carry out its activities in a manner that avoids, to the maximum extent practicable, any adverse impact on sanctuary resources and qualities.

Between 2008 and 2020, under the requirements of the NMSA section 304(d), the Navy consulted with OCNMS on three occasions in 2011, 2015, and 2020. On a fourth occasion in 2010, the sanctuary requested a section 304(d) consultation regarding the Navy's proposed action related to the Northwest Training Range Complex. While the Navy did not initially concur that a consultation was required, they did respond to OCNMS comments on the subject.

In addition to consultations, the Navy provides a representative to the OCNMS Sanctuary Advisory Council and meets annually with sanctuary staff to discuss topics of mutual interest. As a result of this working relationship, OCNMS began to include special conditions on permits, requiring permit holders to notify the Navy of certain underwater operations, such as ROV dives, 48 hours in advance. The Navy also sponsors a variety of marine species monitoring efforts in the Pacific Northwest and across the country, primarily to address potential impacts to species and habitats in areas of naval operations (U.S. Navy Marine Species Monitoring, 2021).

Marine Debris

OCNMS's response to marine debris has followed a number of approaches, including support for beach cleanups; crab pot recovery efforts; investigating and responding to large, discrete events; and monitoring.

Beach Cleanups

OCNMS's involvement in Olympic Coast beach cleanups efforts has evolved over time. Current efforts to involve the public in this important volunteer stewardship program are currently managed by the Washington CoastSavers. Washington CoastSavers is made up of thousands of volunteers, an executive committee, a steering committee, and a program coordinator. The steering committee is comprised of representatives from private and non-profit organizations and government agencies, including individuals from Lions Club International, Discover Your Northwest, Grass Roots Garbage Gang, Surfrider Foundation, OCNMS, Clallam County Waste Management, Pacific Shellfish Growers Association, Clallam County Marine Resources

Committee, NOAA Marine Debris Program, Olympic National Park, Washington State Parks and Recreation Commission, Coastal Treaty Tribes, and Olympic Coast National Marine Sanctuary Foundation. Olympic Coast National Marine Sanctuary Foundation currently serves as the fiscal agent for Washington CoastSavers (Washington CoastSavers, 2020).

Incident Response

In addition to working with volunteer-supported beach cleanups on persistent marine litter, OCNMS and other agencies must occasionally deal with larger, more episodic incidents, such as sunken or grounded vessels (Figure R.3). The U.S. Coast Guard and Washington State Department of Ecology are the leads for dealing with oil spills, but once human and environmental impacts are mitigated, vessels may be abandoned. In addition to responding to the release of pollutants, OCNMS is concerned with the abandonment of wrecked vessels, which is prohibited by sanctuary regulations.

Since 2008, 21 vessels have been lost in the sanctuary; some were salvaged and some were lost, with many still sitting on the seafloor. When first notified of an ongoing vessel incident, OCNMS coordinates with other agencies and the responsible party on an appropriate response, including the removal of the vessel from the sanctuary.

Figure R.3. On October 6, 2016, the USCG responded to the S/V *Soteria*, which was disabled and taking on water in heavy weather, 17 nm off the coast. The USCG determined it was not safe to tow the vessel and evacuated the three-person crew. The vessel was abandoned and was later sighted by the sanctuary vessel R/V *Tatoosh* grounded on Sand Point in Olympic National Park on October 9, 2016. The vessel subsequently broke apart, resulting in a debris field north of Sand Point and the original grounding location. Global Diving & Salvage, Inc. was contracted by the vessel owner to remove any fuel and hazardous materials; the wreck was subsequently removed by helicopter. Photo: NOAA

While responding to vessel incidents is the most common episodic marine debris response, there have been other significant responses, including the 2012 grounding of a large dock and reports of crushed cars fouling the trawl nets of Makah fishers. Each of these unusual incidents resulted in significant responses by OCNMS and partners.

On December 14, 2012, a floating dock, one of four washed out from Misawa harbor by the devastating tsunami that hit Japan on March 11, 2011, was spotted off the Washington coast and reported to the USCG. Federal and state agencies and Coastal Treaty Tribes responded quickly and collaboratively, and prepared for a response at sea or on shore. NOAA generated trajectories to estimate the dock's movement and possible landfall. The USCG launched overflights to search for the dock, locating it on December 18, 2012 at a remote beach in Washington state, within Olympic National Park and OCNMS.

State and federal agencies convened in Forks, Washington and, along with aquatic invasive species experts, conducted a site visit to assess the dock and attach a tracking buoy to it. In later visits, the agencies removed all visible growth, greatly reducing further risk of aquatic invasive species introduction. Once it was on shore, responsibility for removal of the dock shifted to the landowners, NOAA and National Park Service, who put together a funding package and managed contracting efforts to remove the dock (Figure R.4). Communication and outreach work continued throughout the response, with the state website serving as a conduit for information on the dock removal efforts.

On March 16, the removal contractor deployed equipment and supplies to the dock's location. Using concrete saws and mini excavators, the contractor cut the dock to pieces and flew concrete and foamed plastic by helicopters to a nearby landing site accessible to trucks, which hauled the dock pieces to a landfill for disposal and recycling. On March 26, all removal operations ended successfully, and the response to the floating dock was completed (Barnea et al., 2013).

Figure R.4. A dock dislodged during the Japan tsunami, washed ashore in Washington. As of the date of the photo (March 21, 2013), 87% of foam and 25% of concrete had been removed by helicopter. Photo: NOAA

Makah fishermen recovered crushed cars in their nets on four occasions in 2011, 2013, 2016, and 2017. A recovered license plate was researched and the registered owner reported delivering the car to a metal recycling yard in New Westminster, British Columbia, Canada in October 2007. OCNMS identified additional documented cases of scrap metal being lost from open deck barges. OCNMS reviewed vessel monitoring data and attempted to identify the transit that could have been involved in the loss of the vehicle delivered to the recycling yard in October 2007. Several potential transits were identified. OCNMS also identified additional transits with the same profile. This analysis identified 44 southbound transits between the New Westminster and Portland recycling yards in the period between October 2007 and February 2013.

In order to better assess the extent of the problem, OCNMS chartered a survey off Cape Flattery in September, 2015. The survey area was developed to take into account the locations of the cars snagged by Makah fishers. Using a combination of sidescan sonar and an ROV, a debris field of approximately 13 cars was identified (Figure R.5).

In consultation with OCNMS and Transport Canada, Coast Guard Sector Seattle and Coast Guard Sector Columbia River initiated Operation Jalopy in 2018. This included hand-delivered correspondence to all potentially involved facilities and surveillance of the waterways looking for potentially overloaded and unsecured open hopper barges carrying scrap metal.

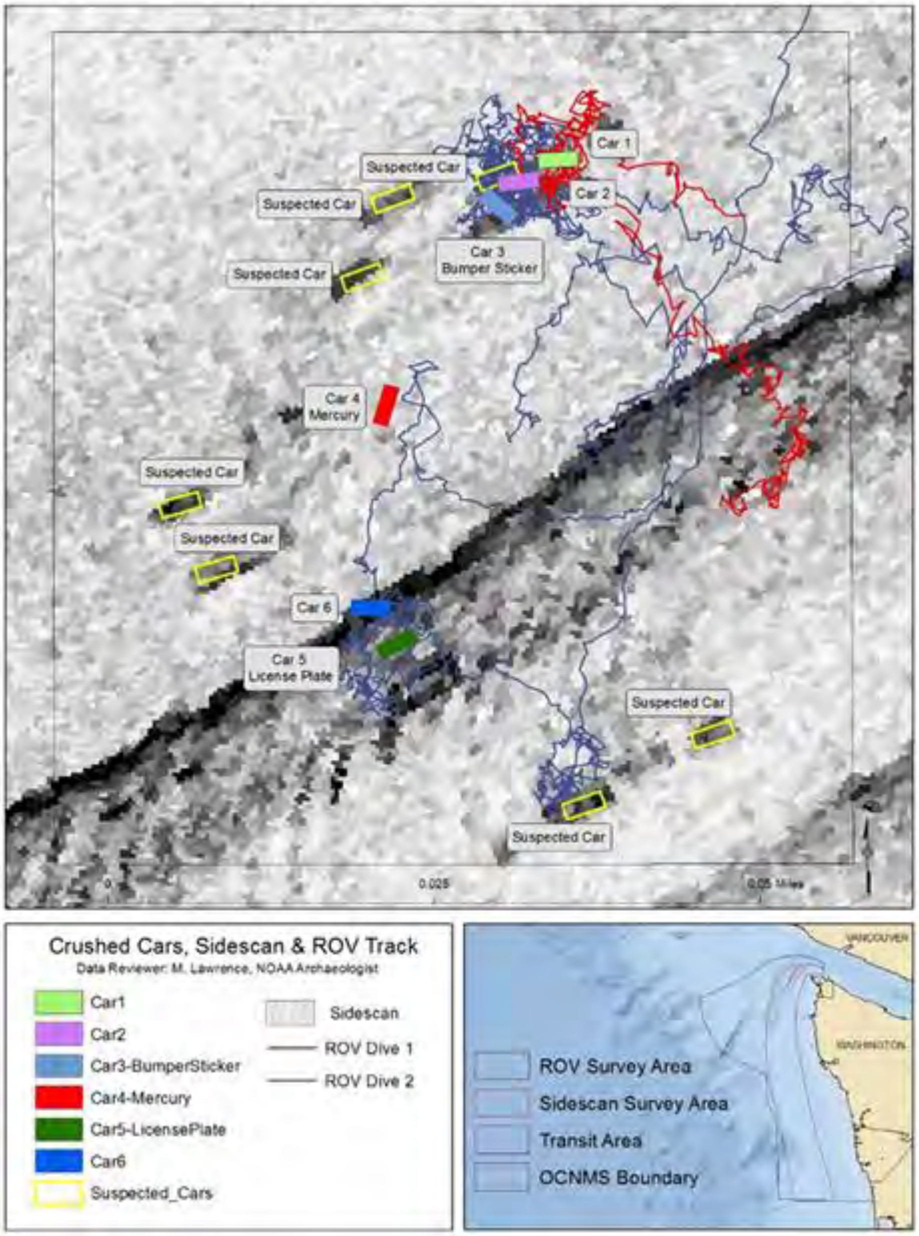

Figure R.5. Scaled map of the distribution and orientation of crushed cars located in OCNMS. Six car locations were derived from the review of video data. Symbols outlined in yellow mark the location of suspected additional cars. Image: NOAA

Lost Vessels

In 2017, OCNMS conducted a review of the circumstances of vessels that have sunk, grounded, or capsized since sanctuary designation. The resulting report focused on incidents that resulted in vessels lost in or near the sanctuary. This included vessels that sunk, grounded, or capsized, regardless of whether the vessel was salvaged or remnants of the wreck remain in the marine environment. Out of all incident records, 46 vessels (Figure R.6) were identified for further analysis. Data collected on those incidents were summarized to determine whether there were commonalities based on cause and vessel characteristics (Galasso, 2017).

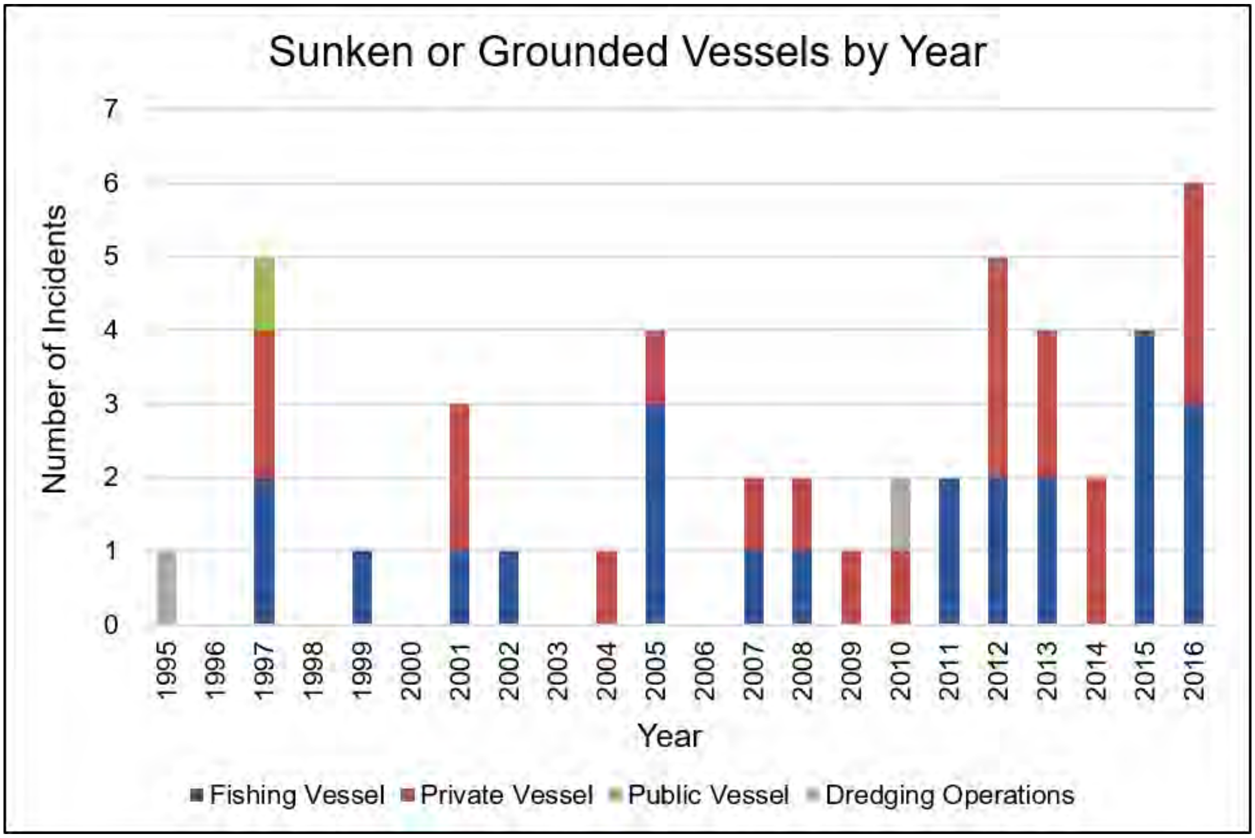

Figure R.6. Number of documented lost vessels in or near OCNMS by vessel type and by year. Image: Galasso, 2017

Following the completion of the report, the Sanctuary Advisory Council chartered the Vessel Incident Working Group, which was tasked with reviewing causes leading to the loss of vessels in the sanctuary and providing recommendations to the sanctuary superintendent on the prevention of, documentation of, and response to future incidents of lost vessels. The working group's report to the sanctuary superintendent (Olympic Coast National Marine Sanctuary Advisory Council, 2017) expressed concern about the loss of life, loss of property, and damage to resources within the sanctuary that result from vessels that are lost in OCNMS. They recognized that many of the contributing factors that resulted in vessel loss were beyond OCNMS's control, but offered nine recommendations for a responsible response to the issue by the sanctuary (Olympic Coast National Marine Sanctuary Advisory Council, 2017). One recommendation was for OCNMS to meet with regional marinas to investigate the potential of establishing kiosks or signage to educate mariners on safe boating practices and local conditions (Figure R.7).

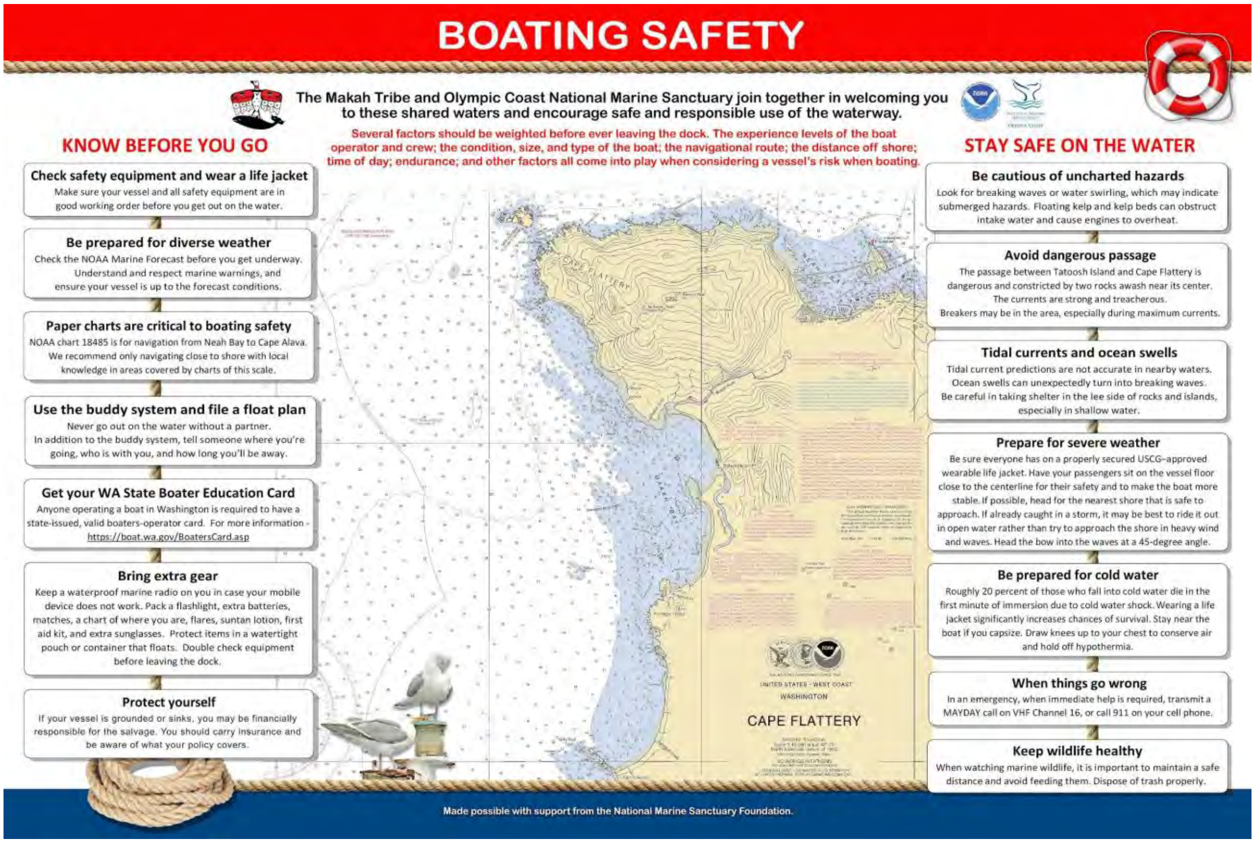

Figure R.7. In response to a recommendation from the Vessel Incident Working Group, OCNMS staff collaborated with the Makah Tribe and Washington Sea Grant to create this sign, which will be posted at the Makah Marina.

Monitoring

OCNMS had a marine debris monitoring program from 2001 through 2019. Protocols changed in 2012 to better assess the accumulation of tsunami debris on the Washington coast following a March 2011 earthquake and resulting tsunami in Japan. Using the revised protocols, between 2012 and 2019, community scientist volunteers regularly identified the types and quantities of shoreline marine debris found at 26 locations adjacent to the sanctuary along the outer coast of Washington and the Strait of Juan de Fuca.

Data were gathered to identify whether marine debris loads were noticeably higher as a result of the 2011 tsunami, in line with modeled predictions for high-windage items and early reported observations. Volunteers utilized protocols developed by the NOAA Marine Debris Program to conduct monthly shoreline surveys along 100-meter transects placed at selected beaches. Plastic was the most common type of debris; plastic items found ranged from large polystyrene buoys to inch-sized fragments. Although volunteers encountered tsunami-related debris, cyclic, oceanic, weather-related patterns, such as ENSO and beach aspect, appeared to have a greater influence on depositions, indicating an ongoing need for public outreach to stem the flow of debris into marine environments (Butler-Minor, 2021).

Non-indigenous and Invasive Species

As mentioned previously, OCNMS considered regulations on invasive, non-native species during its most recent management plan review, but did not pursue the effort based on the adequacy of state regulations. However, direct management intervention did occur during the floating dock incident response, including the collection of samples, consultation with aquatic invasive species experts, scraping visible growth on the sides and deck of the dock, hauling 400 lbs of biota up the bluff and away from water access, and sterilizing the surface with a bleach solution, used sparingly and under a permit from OCNMS. Vertical and horizontal bumpers, which provided shelter to living organisms, were removed and cleaned (Barnea et al., 2013).

In 2017, European green crabs were found in two estuaries on the Makah reservation, adjacent to OCNMS (Figure P.13). Several aquatic invasive species experts, along with agency and tribal government staff, consulted and supported a dedicated trapping effort by the Makah Fisheries Management Department. This effort resulted in the removal of over 2,500 green crabs between 2017 and 2019, the most anywhere in Washington state until 2020, when a new invasion was discovered near the Lummi Reservation in Puget Sound.

Contaminants

Despite the fact that there are no direct discharges of contaminants from land-based sources adjacent to OCNMS, contaminants have been documented in sanctuary resources (Southern Resident Orca Task Force, 2018).

There is currently one active EPA Superfund site on the National Priorities List that lies adjacent to the sanctuary: the Warmhouse Beach Dump, located on the Makah Reservation. The site includes a former open dump on top of a ridge about three miles northwest of Neah Bay, and the two streams that originate within the dump flow to East Beach and Warmhouse Beach, and presumably into the sanctuary.

Municipal and household solid and hazardous wastes were disposed of at the dump from the 1970s until 2012, when the Makah Tribe began operating a solid waste transfer station on the reservation. Access to the 7-acre dump was then restricted by a locked gate on the unpaved road leading up to the dump, and signs were posted to discourage the community from entering the dump.

Elevated levels of metals, perchlorate, and PCBs have been found in soil at the dump and in sediment in both creeks. Mussels at the beach also contain elevated concentrations of lead; however, it has not been determined whether this is from the dump, creeks, or ambient seawater. The Warmhouse Beach Dump site was added to the Superfund National Priorities List in December 2013. The EPA is in the early stages of the Superfund cleanup process (i.e., remedial investigation/feasibility study). During this stage, the EPA consolidates data previously collected from the site, determines if there are any data gaps, and collects any missing data (EPA, 2021).

One significant regional response to the issue of marine contaminants was the construction of a tertiary sewage treatment plan for the Canadian municipalities of Victoria, Esquimalt, Saanich, Oak Bay, View Royal, Langford, and Colwood, as well as the Esquimalt and Songhees Nations

(Capital Regional District, 2014), which are located on the portion of Vancouver Island that borders the Strait of Juan de Fuca. This action followed decades of debate and four years of construction. The topic was a source of cross-border conflict, including calls for travel boycotts, as well as “one of the best protest mascots in recent history” (Banse, 2017; Figure R.8).

Figure R.8. Victoria Mayor Lisa Helps and Mr. Floatie board a seaplane to fly to Seattle for the sewage treatment mascot's official retirement party. Photo: KNKX/Lisa Helps/Facebook

Research Activities

OCNMS issues permits for a variety of research activities that could involve impacts to the seafloor, discharge within OCNMS (including ROVs and autonomous underwater vehicles), or low overflights. OCNMS consults with the Coastal Treaty Tribes on each permit application to ensure their awareness of the proposal and to identify any potential concerns or conflicts. When potential conflicts do arise, OCNMS works directly with the tribe and the permit applicant to resolve issues and reduce conflicts (e.g., by changing locations or timing of activities). For example, researchers worked directly with the Makah Fisheries Department and Makah fishers to identify locations for three SoundTrap acoustic recorders that were proposed to be deployed within their U&A fishing area. Doing so reduced potential interactions or conflicts with tribal fisheries activities and improved the project by leveraging the Makah fishers’ extensive local knowledge of ship movements in the area. In addition, OCNMS is increasingly scrutinizing projects that involve abandonment of anchors on the seafloor. OCNMS mooring operations have been adjusted to reduce or eliminate anchor abandonment, and permit applicants are now required to pursue alternatives to anchor abandonment, including the use of anchor recovery systems or substitution of metal anchors with sandbags or other biodegradable materials.

Offshore Aquaculture

In 2011, NOAA Fisheries developed aquaculture policies that encouraged and fostered sustainable aquaculture development that provides domestic jobs, products, and services and is also in harmony with healthy, productive, and resilient marine ecosystems; compatible with other uses of the marine environment; and consistent with the National Policy for the Stewardship of the Ocean, our Coasts, and the Great Lakes (NOAA Fisheries, 2011).

The policy cited the statutory basis for NOAA's aquaculture activities as the Magnuson-Stevens Fishery Conservation and Management Act, the Marine Mammal Protection Act, the ESA, the Coastal Zone Management Act, the NMSA, and the Fish and Wildlife Coordination Act. Under these laws, in addition to the National Environmental Policy Act, NOAA is responsible for considering and preventing and/or mitigating the potential adverse environmental impacts of planned and existing marine aquaculture facilities through the development of fishery management plans, sanctuary management plans, permit actions, proper siting, and consultations with other regulatory agencies at the federal, state, and local levels.

In 2008, during the management plan public scoping period, ONMS received comments requesting aquaculture be banned in the sanctuary. Some comments focused on the potential adverse impacts associated with farming Atlantic salmon, a non-native species. Since sanctuary designation, no aquaculture permit applications have been received or issued by the OCNMS superintendent, and no aquaculture activities are known to occur within sanctuary boundaries.

ONMS addressed one aspect of the aquaculture issue in alternative C (not preferred) of the 2011 OCNMS management plan. This alternative included the consideration of a regulatory ban on the introduction of invasive species in the sanctuary. Atlantic salmon and a few other cultured organisms are classified as invasive species by the state of Washington and, as such, project proposals with these species would receive rigorous scrutiny and facilities would require effective containment, as is the current practice in Washington state.

Similar to proposed alternative energy projects discussed in the next section, ONMS would treat any future aquaculture proposal as an offshore commercial development project that would likely be subject to the ONMS permitting process. It can be assumed that any aquaculture project proposed in the sanctuary would require an ONMS permit based on OCNMS regulations related to seabed disturbance (for anchoring/mooring aquaculture structures) and discharge. During review of an aquaculture project's permit application, ONMS would consider all the potential impacts of any proposed aquaculture operation. Therefore, ONMS did not pursue specific regulatory actions related to aquaculture in any of the 2011 management plan alternatives (OCNMS, 2011).

Offshore Energy

Offshore energy development was a major issue during the sanctuary designation process and was analyzed in the original *OCNMS Final Environmental Impact Statement/Management Plan, Volume 1* (Sanctuaries and Reserves Division, 1993). The analysis found that oil and gas development would generate conflicts that could harm sanctuary resources. Alternative energy development was briefly discussed during management plan review as a subject that came up in scoping, however an alternative was not developed. This topic was flagged for future analysis.

Oil and Gas Exploration

In 1992, outer continental shelf oil and gas leasing within the boundaries of the (at the time) proposed sanctuary was under consideration by the U.S. Department of Interior's Minerals Management Service.[23] The Minerals Management Service had planned to conduct lease sale #132 in April 1992 for exploration and development off the Washington and Oregon coasts. The 1992 reauthorization of the NMSA prohibited oil and gas leasing and development within the boundaries of OCNMS (Pub. L. 102-587).

Marine Renewable Energy

In March 2010, the Washington State Legislature enacted the Marine Waters Management and Planning Act (Wash. Rev. Code § Chapter 43.372), a marine planning law to foster integrated coastal decision-making and ecosystem-based management. One of the requirements of the act was the development of a marine spatial plan, which included a series of maps identifying locations with high potential for marine renewable energy production that have minimal potential for conflicts with other existing uses or sensitive environments. OCNMS staff supported the development of the plan and were asked to evaluate whether marine renewable energy projects could be sited in the sanctuary.

As a result of those discussions, the Washington State Department of Ecology determined that the presence of OCNMS along the northern half of the coast lowered the likelihood for marine renewable energy projects, particularly for commercial-scale developments. However, marine renewable energy projects that are owned by a tribe could possibly be permitted within OCNMS (15 CFR § 922). Tribes must still go through all applicable federal permit processes (Washington State Department of Ecology, 2017b).

Any proposed offshore energy project in OCNMS would be analyzed through the permitting process, in addition to being vetted through the state's marine spatial plan.

Increased Visitation

Concerns related to visitor impacts on the Olympic Coast are not new. In 1969, "the Quinault Indian [Nation] Tribal Council closed 25 miles of ocean beaches to [non-Indigenous peoples], an action taken to protest vandalism, theft, and land damage caused by tourists, teenagers, and

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[23] In 2011, the Minerals Management Service was renamed the Bureau of Ocean Energy Management, Regulation and Enforcement and placed within the newly established Bureau of Ocean Energy Management.

real-estate developers" (Caldbick, 2011). Today, controlling access remains the major means of controlling impacts from visitors. With the exception of its role in ATBA compliance (see previous discussion), OCNMS has no control over access within the sanctuary; however, adjacent land managers and tribal governments do exert such controls through permitting.

Other management approaches to reduce impacts of increased visitation include coastal interpretive programs at Olympic National Park and the Makah Cultural and Research Center, both of which are supported by the sanctuary. OCNMS also supports efforts to promote sustainable tourism and voluntourism, such as Get Into Your Sanctuary and Washington CoastSavers beach cleanup events. While there are limited at-sea whale watching opportunities, the Whale Trail promotes shore-based whale watching, with several sites along the Washington coast. These programs provide visitors with information that includes proper etiquette during visits.

Sanctuary Operations and Research Activities

OCNMS staff are not exempt from sanctuary regulations, permitting, or other environmental compliance requirements. There are two environmental assessments that have recently reviewed sanctuary operations, the 2011 management plan (OCNMS, 2011) and the 2018 *Programmatic Environmental Assessment of Field Operations in the West Coast National Marine Sanctuaries* (ONMS, 2018). These analyses include sanctuary operations that are both allowed and prohibited under sanctuary regulations (15 C.F.R. § 922.152).

Tribal Consultation

Working on a government-to-government basis with the Coastal Treaty Tribes is a fundamental aspect of OCNMS management. OCNMS works to accomplish this through a number of means, including, but not limited to, methods described in *NOAA Procedures for Government-to-Government Consultation with Federally Recognized Indian Tribes and Alaska Native Corporations* (NOAA, 2013). In addition to NOAA procedures, when requested, OCNMS has developed more specific consultation protocols with individual tribes.

Permitting/Research

A valid permit is required from OCNMS when an individual wishes to conduct an activity within the sanctuary that is otherwise prohibited. Prohibited activities are defined in OCNMS regulations and are generally restrictive of seafloor disturbance, discharges, and overflights in certain areas that may disturb wildlife—all activities that require a permit regardless of who conducts the work.

A permit is required when an individual, including a staff member, wishes to conduct an activity within a national marine sanctuary that is otherwise prohibited. Permits may be issued if a proposed activity will not substantially injure sanctuary resources and qualities, and will further certain sanctuary values such as research, education, resource protection, and tribal self-determination. Most sanctuary permits are related to research projects; proposed research activities are analyzed and special conditions are imposed to mitigate impacts as appropriate. The Coastal Treaty Tribes are consulted to minimize conflicts with access to treaty-protected resources.

Programmatic Environmental Assessment

In 2018, as part of ONMS's environmental compliance policy, four programmatic environmental assessments were drafted to describe and account for ONMS field operations. The *Programmatic Environmental Assessment of Field Operations in the West Coast National Marine Sanctuaries* (ONMS, 2018) includes OCNMS operations.

The purpose of the programmatic environmental assessment is to fulfill the requirements outlined in the NMSA to protect and manage the resources of each national marine sanctuary. Sanctuary field operations are one aspect of resource management that assists with the accomplishment of the goals, objectives, and priorities of each sanctuary. Field operations are activities on, in, or above the water that support the NMSA's primary objective of resource protection through direct management, research, and education. These field operations can include vessel, aircraft, and scuba diving operations, as well as deployment of instrumentation and presence of personnel. Field operations are evaluated on a regional basis, taking into consideration the protected resources that may be present at each sanctuary.

Maritime Heritage

During the 2011 management plan review, the Washington State Department of Archeology and Historic Preservation requested that OCNMS enter into a National Historic Preservation Act section 106 programmatic agreement. Following the completion of the management plan, OCNMS, the ONMS Maritime Heritage Program, and the Washington State Department of Archeology and Historic Preservation held a number of discussions on the subject. As a result, OCNMS drafted a document, *Maritime Heritage Resource Management Guidance for Olympic Coast National Marine Sanctuary* (OCNMS, 2018b). The primary purpose of the document is to ensure the sanctuary's compliance with the National Historic Preservation Act. The document details how OCNMS complies with its federally mandated responsibilities regarding maritime heritage resource management by collaborating with partner agencies and tribes. Whereas the primary focus of the document is the responsibility of OCNMS under the National Historic Preservation Act, other aspects of OCNMS's maritime heritage are also discussed.

Concluding Remarks

This condition report for OCNMS is a comprehensive update to the 2008 condition report. We have made numerous improvements and changes to the report in order to enhance its utility for not only the sanctuary, but the Coastal Treaty Tribes, federal and state agency partners, scientists, resource managers, stakeholders, and the general public. For example, we improved the ONMS framework to expand the ecosystem services assessed, adding subsistence harvest due to its high importance for communities within our region. Furthermore, we have enhanced the process to better represent the reciprocal relationship between humans and the ocean and to weave Indigenous voices and perspectives more prominently into our report.

While many aspects of the sanctuary, including water quality, seafloor habitat, many fish and marine mammal species, the condition of maritime archaeological resources, and several ecosystem services appear healthy and stable, we believe that current and projected impacts from climate change pose significant threats to the sanctuary. During this assessment period, starting in 2008, we have observed impacts from climate change that have influenced many of the status and trends presented throughout the report. These include marine heatwaves like "the blob," increased intensity and frequency of HABs, epizootic diseases like the widespread sea star wasting disease, impacts from ocean acidification, and an increase in the severity and duration of seasonal hypoxic events. Multi-stressor impacts to the ecosystem that may occur when two or more of these disruptions overlap in space and time present additional complexity that is challenging to understand and anticipate.

The threat of climate change is real and is already felt on the Olympic Coast. As such, the sanctuary is piloting a process to better understand projected conditions and the vulnerability of sanctuary resources to these changes. New information generated from these efforts will be invaluable as we update our sanctuary management plan and adjust our priorities for the coming years.

This report also highlights important information gaps that will help guide OCNMS's future collaborative research and monitoring efforts. For example, the report notes potential benefits from increased characterization and monitoring within understudied habitats like sandy beach, sandy seafloor, and deep sea habitats and their associated communities. Additionally, new information on changing subsurface ocean conditions; changes to upwelling strength, duration, and timing; and changes in the volume and timing of freshwater inputs to sanctuary waters will aid in understanding and managing sanctuary resources. With respect to living marine resources, OCNMS would benefit from additional information on the status and trends of keystone and focal species, more comprehensive and consistent biodiversity metrics and methods for tracking changes in biodiversity, and expanded monitoring programs for tracking variability in the abundance and composition of species within critical trophic levels, notably zooplankton, larval fish, and forage fish species that largely fuel the high productivity of the region. Recent efforts to record underwater sound at four sites along the Olympic Coast inspire us to continue to seek an enhanced understanding of acoustic impacts to living resources, in addition to climate impacts stemming from changes in the ocean environment. The recent arrival of our new research vessel, *Storm Petrel*, increases our capacity to conduct research on the Olympic Coast, and we hope its use will deepen existing partnerships and establish new ones.

We would like to express our deepest appreciation to members and staff of the Hoh Tribe, Makah Tribe, Quileute Tribe, and Quinault Indian Nation for providing data, information, traditional knowledge, and expertise throughout the condition report process. The Coastal Treaty Tribes have inhabited this region for thousands of years and their traditional knowledge deepens our understanding of the Olympic Coast. We are grateful that they have challenged us all to think more deeply about human connections with the ocean and to view ocean conservation in a more holistic manner and over a much longer time frame.

This report would not have been possible without the dedicated support and input of numerous contributors and reviewers. On behalf of ONMS, we want to express our sincerest gratitude for those who contributed their time, knowledge, data, and information in telling the story of the Olympic Coast.

George Galasso, Deputy Superintendent
Jenny Waddell, Research Ecologist
Katie Wrubel, Resource Protection Specialist

The expanded capabilities of OCNMS's new research vessel, *Storm Petrel*, will greatly enhance collaborative research at OCNMS. The new vessel was delivered to OCNMS in August 2021. Photo: Jenny Waddell/NOAA

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Appendix A: Questions and Rating Schemes for State of Sanctuary Resources

The purpose of this rating scheme is to clarify the questions and possible responses used to report the condition of sanctuary resources in condition reports for all national marine sanctuaries. ONMS and subject matter experts used this guidance, as well as their own understanding of the condition of resources, to make judgments about the status and trends of sanctuary resources.

The questions derive from the National Marine Sanctuary System's mission, and a system-wide monitoring framework developed to ensure the timely flow of data and information to those responsible for managing and protecting resources in the ocean and coastal zone, and to those that use, depend on, and study sanctuary resources. The questions are being used to guide ONMS and its partners at each of the sanctuary system's 14 units in the development of periodic sanctuary condition reports. Evaluations of status and trends were based on interpretation of quantitative and, when necessary, non-quantitative assessments and observations of scientists, managers, and users.

In 2012, ONMS led an effort to review and edit the set of questions and their possible responses that were developed for the first round of condition reports (drafted between 2007 and 2014) (National Marine Sanctuary Program, 2004). The questions that follow are revised and improved versions of those original questions. Although all questions have been edited to some degree, both in their description and status ratings, the nature and intent of most questions have not changed. Five questions, however, are either new or are significantly altered and therefore, are not directly comparable to the original questions. For these, a new baseline will need to be established.

- Among the Water Quality questions, one was added on climate change. This was necessary to address the constantly increasing awareness and attention to the issue following the original design of the condition report process, which began in 2002. It also removed the need to combine climate change discussions with other questions.
- Two Habitat Quality questions were combined due to feedback received during the development of the first round of reports. A single question regarding the "integrity of major habitat types" has been created and combines prior questions that separately inquired about non-biogenic and biogenic habitats. Our experience showed that species constituting biogenic habitat (e.g., kelp, corals, seagrass, etc.) were considered adequately within questions about living resources, and need not be covered twice in the reports.
- Among the Living Resource Quality questions, one used in the first round of condition reports was removed entirely. It asked about "the status of environmentally sustainable fishing." It was removed for a variety of reasons—it was the only question focused on a single, specific human activity and because fishing activity discussions were already included in the question regarding "human activities that may influence living resource

quality." In addition, living resource quality that would provide a basis for judgement for this question was typically considered as part of other living resource questions, and need not be covered twice. Another change to the Living Resource Quality questions pertains to the question about the "health of key species" which was previously addressed in a single question, but is now split into two. The first asks specifically about the status of "keystone and foundation" species, the second about "other focal species." In either case, the health of any species of interest can be considered in judgement of status and trends.

One of the initial maritime archaeology questions addressed potential environmental hazards presented by heritage resources like shipwrecks. While the assessment of such threats is important, it was decided that the question should actually address environmental hazards in general rather than apply specifically to historic maritime properties. Therefore, the question was removed from the maritime heritage resources section of the report and the subject is discussed in the context of other questions.

Ratings for a number of questions depend on judgments of the "ecological integrity" within a national marine sanctuary. This is because one of the foundational principles behind the establishment of sanctuaries is to protect ocean ecosystems. The term ecological integrity is used to imply "the presence of naturally occurring species, populations and communities, and ecological processes functioning at appropriate rates, scales, and levels of natural variation, as well as the environmental conditions that support these attributes" (modified from the National Park Service's Vital Signs Monitoring Program). Sanctuaries have ecological integrity when they have their native components intact, including abiotic components (i.e., the physical forces and chemical elements, such as water), biotic elements (such as habitats), biodiversity (i.e., the composition and abundance of species and communities), and ecological processes (e.g., competition, predation, symbioses). For purposes of this report, the level of integrity that is judged to exist is based on the extent to which humans have altered specific components of the system, and the effect of that change on the ability of an ecosystem to resist continued change and recover from it. The statements for many questions are intended to reflect this judgment. Reference is made in the rating system to "near-pristine" conditions, for which this report would imply a status as near to an unaltered ecosystem as can reasonably be presumed to exist, recognizing that there are virtually no ecosystems on Earth completely free from human influence.

Not all questions, however, use ecological integrity as a basis for judgment. One focuses on the impacts of water quality factors on human health. Two questions rate the status of keystone and key species compared with that expected in an unaltered ecosystem. One rates maritime heritage resources based on their historical, archaeological, scientific, and educational value. Finally, four ask specifically about the levels of ongoing human activities (i.e., Pressures) that could affect resource condition.

During workshops in which status and trends are rated, subject matter experts discuss each question and available data, literature (e.g., published scientific studies, reports), and experience associated with the topic. They then discuss the statements provided as options for judgments about status; these statements have been customized for each question. Once a particular statement is agreed upon, a color code and status rating (e.g., good, fair, poor) is assigned. Experts can also decide that the most appropriate rating is "N/A" (i.e., the question does not apply) or "Undetermined" (i.e., resource status is undetermined due to a paucity of relevant information).

A subsequent discussion is then held about the trend. Conditions are determined to be improving, remaining the same, or worsening in comparison to the results found in the first round of condition reports. Symbols used to indicate trends are the same for all questions: "▲"—conditions appear to be improving; "**▬**"—conditions do not appear to be changing; "▼"—conditions appear to be worsening; and "**?**"—trend is undetermined.

Human Dimension

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

Driving forces are those characteristics of human societies that influence the nature and extent of pressures on resources. They are the underlying cause of change in coastal marine ecosystems, as they determine human use. Drivers are influenced by demographics (e.g., age structure, population, etc.), demand, economic circumstances, industrial development patterns, business trends, and societal values. They operate at global, regional, and local scales. Examples include increasing global demand for agricultural commodities, which increases the use of chemicals that degrade coastal water quality; difficult economic times that reduce fishing efforts for a period of time within certain regions; or local construction booms that alter recreational visitation trends. Other drivers could be the demands that govern trends, such as global greenhouse gas generation, regional shipping or offshore industrial development, local recreation and tourism, fishing, port improvement, manufacturing, and age-specific services (e.g., retirement). Each of these, in turn, influences certain pressures on natural and cultural resources.

Integrated into this question should be consideration of societal values, which include such matters as levels of conservation awareness, political leanings, opinion about environmental issues relative to other concerns, or changing opinions about the acceptability of specific behaviors (e.g., littering, fishing). Understanding these values gives one a better understanding of the likely future trends in drivers and pressures, as well as the nature of the societal tradeoffs in different uses of the ecosystem resources (e.g., the effects of multiple changing drivers on each other and the resources they affect). This can better inform policy and management responses and education and outreach efforts that are designed to change societal values with the intention to change drivers and reduce pressures.

In rating the status and trends for drivers, the following should be considered:

- the main driving forces behind each pressure affecting natural resources and the environment
- the best available indicators of each driving force
- the status and trend of each driving force
- societal values behind each driving force
- the best indicators of societal values
- the status and trend of societal values

Rating	Status Description
Good	Few or no drivers occur that have the potential to influence pressures in ways that will negatively affect resource qualities.
Good/Fair	Some drivers exist that may influence pressures in ways expected to degrade some attributes of resource quality.
Fair	Selected drivers are influencing pressures in ways that cause measurable resource impacts.
Fair/Poor	Selected drivers are influencing pressures in ways that result in severe impacts that are either widespread or persistent.
Poor	Selected drivers are influencing pressures in ways that result in severe, persistent, and widespread impacts.

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

Among the human activities in or near sanctuaries that affect water quality are those involving direct discharges and spills (vessels, onshore and offshore industrial facilities, public wastewater facilities), those that contribute contaminants to groundwater, stream, river, and water control discharges (agriculture, runoff from impermeable surfaces through storm drains, conversion of land use), and those releasing airborne chemicals that subsequently deposit via particulates at sea (vessels, land-based traffic, power plants, manufacturing facilities, refineries). In addition, dredging and trawling can cause resuspension of contaminants in sediments. Many of these activities can be controlled through management actions in order to limit their impact on protected resources.

Rating	Status Description
Good	Few or no activities occur that are likely to negatively affect water quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade water quality.
Fair	Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

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

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 (e.g., trawls, traps, dredges, longlines, and even hook-and-line in some habitats), dredging of channels and harbors, dumping dredge spoil, grounding of vessels, anchoring, laying pipelines and cables, installing offshore structures, discharging drill cuttings, dragging tow cables, and placing artificial reefs. Removal or alteration of critical biological components of habitats can occur due to several of the above activities, most notably trawling, groundings, and cable drags. Marine debris, particularly in large quantities (e.g., lost gill nets and other types of fishing gear), can degrade both biological and structural habitat components. Changes in water circulation often occur when channels are dredged, fill is added, coastlines are armored or other construction takes place. Management actions such as beach wrack removal or sand replenishment on high public-use beaches, may impact the integrity of the natural ecosystem. Alterations in circulations can lead to changes in food delivery, waste removal, water quality (e.g., salinity, clarity and sedimentation), recruitment patterns, and a host of other ecological processes. Chemical alterations most commonly occur following spills and can have both acute and chronic impacts. Many of these activities can be controlled through management actions in order to limit their impact on protected resources.

Rating	Status Description
Good	Few or no activities occur that are likely to negatively affect habitat quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade habitat quality.
Fair	Selected activities have caused measurable resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

4. What are the levels of human activities that may adversely influence living resources and how are they changing?

Human activities that degrade the condition of living resources do so by causing a loss or reduction of one or more species, by disrupting critical life stages, by impairing various physiological processes, or by promoting the introduction of non-indigenous species or pathogens. (Note: Activities that impact habitat and water quality may also affect living resources. These activities are dealt with in the following human activity questions, and some may be repeated here as they also directly affect living resources).

For most sanctuaries, recreational or commercial fishing and collecting have direct effects on animal or plant populations, either through removal or injury of organisms. Related to this, lost fishing gear can cause extended periods of loss for some species through entanglement and "ghost fishing." In addition, some fishing techniques are size-selective, resulting in impacts to particular life stages. High levels of visitor use in some places also cause localized depletion, particularly in intertidal areas or on shallow coral reefs, where collecting and trampling can be chronic problems.

Mortality and injury to living resources has also been documented from cable drags (e.g., towed barge operations), dumping spoil or drill cuttings, vessel groundings, or repeated anchoring. Contamination caused by acute or chronic spills or increased sedimentation to nearshore ecosystems from road developments in watersheds (including runoff from coastal construction or highly built coastal areas), discharges by vessels, or municipal and industrial facilities can make habitats unsuitable for recruitment or other ecosystem services (e.g., as nurseries or spawning grounds). And while coastal armoring and construction can increase the availability of surfaces suitable for hard bottom species, the activity may disrupt recruitment patterns for other species (e.g., intertidal soft bottom animals), and natural habitat may be lost.

Oil spills (and spill response actions), discharges, and contaminants released from sediments (e.g., by dredging and dumping) can all cause physiological impairment and tissue contamination. Such activities can affect all life stages by direct mortality, reducing fecundity, reducing disease resistance, loss as prey and disruption of predator-prey relationships, and increasing susceptibility to predation. Furthermore, bioaccumulation results in some contaminants moving upward through the food chain, disproportionately affecting certain species.

Activities that promote the introduction of non-indigenous species include bilge discharges and ballast water exchange, commercial shipping and vessel transportation. Intentional or accidental releases of aquarium fish and plants can also lead to introductions of non-indigenous species.

Many of these activities are controlled through management actions in order to limit their impact on protected resources.

Rating	Status Description
Good	Few or no activities occur that are likely to negatively affect living resource quality.
Good/Fair	Some potentially harmful activities exist, but they have not been shown to degrade living resource quality.
Fair	Selected activities have caused measurable living resource impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

5. What are the levels of human activities that may adversely affect maritime heritage resources and how are they changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas.

Some human activities threaten the archaeological or historical condition of maritime heritage resources. Archaeological or historical condition is compromised when elements are moved, removed, or otherwise damaged. Threats come from looting, inadvertent damage by recreational divers, improper research methods, vessel anchorings and groundings, and commercial and recreational fishing activities, among others. Other human activities may alter or damage heritage resources by impacting the landscape or viewshed of culturally significant places or locations. Many of these activities can be controlled through management actions in order to limit their impact to maritime heritage resources.

Rating	Status Description
Good	Few or no activities occur at maritime heritage resource sites that are likely to adversely affect their condition.
Good/Fair	Some potentially damaging activities exist, but they have not been shown to degrade maritime heritage resource condition.
Fair	Selected activities have caused measurable impacts to maritime heritage resources, but effects are localized and not widespread or persistent.
Fair/Poor	Selected activities have caused severe impacts that are either widespread or persistent.
Poor	Selected activities have caused severe, persistent, and widespread impacts.

Water Quality

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

Eutrophication is the accelerated production of organic matter, particularly algae, in a water body. It is usually caused by an increase in the amount of nutrients (largely nitrogen and phosphorus) being discharged to the water body. As a result of accelerated algal production, a variety of interrelated impacts may occur, including nuisance and toxic algal blooms, depleted dissolved oxygen, and loss of submerged aquatic vegetation (Bricker et al., 1999). Indicators commonly used to detect eutrophication and associated problems include nutrient concentrations, chlorophyll content, rates of water column or benthic primary production, benthic algae cover, algae bloom frequency and intensity, oxygen levels, and light penetration.

Eutrophication of sanctuary waters can impact the condition of other sanctuary resources. Nutrient enrichment often leads to plankton and/or algae blooms. Blooms of benthic algae can affect benthic communities directly through space competition. Indirect effects of overgrowth and other competitive interactions (e.g., accumulation of algal-sediment mats) often lead to shifts in dominance in the benthic assemblage, oxygen depletion, etc. Disease incidence and frequency can also be affected by algae competition and changes in the chemical environment along competitive boundaries. Blooms can also affect water column conditions, including light penetration and plankton availability, which can alter pelagic food webs. HABs, some of which are exacerbated by eutrophic conditions, often affect other living resources, as biotoxins are consumed or released into the water and air, or decomposition depletes oxygen concentrations.

Rating	Status Description
Good	Eutrophication has not been documented, or does not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Eutrophication is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Fair	Eutrophication has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Eutrophication has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Eutrophication has caused severe degradation in most if not all attributes of ecological integrity.

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

Human health concerns are generally aroused by evidence of contamination (usually bacterial or chemical) in bathing waters or seafood intended for consumption. They also arise when harmful algal blooms are reported or when cases of respiratory distress or other disorders attributable to harmful algal blooms increase dramatically. Any of these conditions should be considered in the course of judging the risk to humans posed by waters in a marine sanctuary.

Some sanctuaries may have access to specific information about beach closures and seafood contamination. In particular, beaches may be closed when criteria for water safety are exceeded. Shellfish harvesting and fishing may be prohibited when contaminant or biotoxin loads or infection rates exceed certain levels. Alternatively, seafood advisories may also be issued, recommending that people avoid or limit intake of particular types of seafood from certain areas (e.g., when ciguatera poisoning is reported). Any of these conditions, along with changing frequencies or intensities, can be important indicators of human health problems and can be characterized using the descriptions below.

Rating	Status Description
Good	Water quality does not appear to have the potential to negatively affect human health.
Good/Fair	One or more water quality indicators suggest the potential for human health impacts but human health impacts have not been reported.
Fair	Water quality problems have caused measurable human impacts, but effects are localized and not widespread or persistent.
Fair/Poor	Water quality problems have caused severe impacts that are either widespread or persistent.
Poor	Water quality problems have caused severe, persistent, and widespread human impacts.

8. Have recent, accelerated changes in climate altered water conditions and how are they changing?

The purpose of this question is to capture shifts in water quality, and associated impacts on sanctuary resources, due to climate change. Though temporal changes in climate have always occurred on Earth, evidence is strong that changes over the last century have been accelerated by human activities. Indicators of climate change in sanctuary waters include water temperature, acidity, sea level, upwelling intensity and timing, storm intensity and frequency, changes in erosion and sedimentation patterns, and freshwater delivery (e.g., rainfall patterns). Climate-related changes in one or more of these indicators can impact the condition of habitats, living resources, and maritime archaeological resources in sanctuaries.

Increasing water temperature has been linked to changing growth rates, reduced disease resistance, and disruptions in symbiotic relationships (e.g., bleaching on coral reefs), and changes in water temperature exposure may affect a species' resistance or the capacity to adapt to disturbances. Acidification can affect the survival and growth of organisms throughout the food web, as well as the persistence of skeletal material after death (through changes in rates of dissolution and bioerosion). Recent findings also suggest acidification impacts at sensory and behavioral levels, which can alter vitality and species interactions. Sea level change alters habitats, as well as their use and persistence. Variations in the timing and intensity of upwelling is known to change water quality through factors such as oxygen content and nutrient flow, further disrupting food webs and the natural functioning of ecosystems. Changing patterns and intensities of storms alter community resistance and resilience within ecosystems that have, over long periods of time, adapted to such disturbances. Altered rates and volumes of freshwater delivery to coastal ecosystems affects salinity and turbidity regimes and can disrupt reproduction, recruitment, growth, disease incidence, phenology, and other important processes.

Rating	Status Description
Good	Climate-related changes in water conditions have not been documented or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Climate-related changes are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Climate-related changes have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Climate-related changes have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Climate-related changes have caused severe degradation in most if not all attributes of ecological integrity.

9. Are other stressors, individually or in combination, affecting water quality, and how are they changing?

The purpose of this question is to capture shifts in water quality due to anthropogenic stressors not addressed in other questions. For example, localized changes in circulation or sedimentation resulting from coastal construction or dredge spoil disposal can affect light penetration, salinity regimes, oxygen levels, productivity, waste transport, and other aspects of water quality that in turn influence the condition of habitats and living resources. Human inputs, generally in the form of contaminants from point or non-point sources, including fertilizers, pesticides, hydrocarbons, heavy metals, and sewage, are common causes of environmental degradation. When present in the water column, any of these contaminants can affect marine life by direct contact or ingestion, or through bioaccumulation via the food chain.

(Note: Over time, accumulation in sediments can sequester and concentrate contaminants. Their effects may manifest only when the sediments are resuspended during storm or other energetic events. In such cases, reports of status should be made under Question 11 — Habitat contaminants.)

Rating	Status Description
Good	Other stressors on water quality have not been documented, or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Selected stressors are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Selected stressors have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected stressors have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected stressors have caused severe degradation in most if not all attributes of ecological integrity.

Habitat

10. What is the integrity of major habitat types and how are they changing?

Ocean habitats can be categorized in many different ways, including water column characteristics, benthic assemblages, substrate types, and structural character. There are intertidal and subtidal habitats. The water column itself is one habitat type (Federal Geographic Data Committee, 2012). There are habitats composed of substrates formed by rocks or sand that originate from purely physical processes. And, there are certain animals and plants that create, in life or after their death, substrates that attract or support other organisms (e.g., corals, kelp, beach wrack, drift algae). These are commonly called biogenic habitats.

Regardless of the habitat type, change and loss of habitat is of paramount concern when it comes to protecting marine and terrestrial ecosystems. Of greatest concern to sanctuaries are changes to habitats caused, either directly or indirectly, by human activities. Human activities like coastal development alter the distribution of habitat types along the shoreline. Changes in water conditions in estuaries, bays, and nearshore waters can negatively affect biogenic habitat formed by submerged aquatic vegetation. Intertidal habitats can be affected for long periods by oil spills or by chronic pollutant exposure. Marine debris, such trash and lost fishing gear, can degrade the quality of many different marine habitats including beaches, subtidal benthic habitats, and the water column. Sandy seafloor and hard bottom habitats, even rocky areas several hundred meters deep, can be disturbed or destroyed by certain types of fishing gear, including bottom trawls, shellfish dredges, bottom longlines, and fish traps. Groundings, anchors, and irresponsible diving practices damage submerged reefs. Cables and pipelines disturb corridors across numerous habitat types and can be destructive if they become mobile.

Integrity of biogenic habitats depends on the condition of particular living organisms. Coral, sponges, and kelp are well known examples of biogenic habitat-forming organisms. The diverse assemblages residing within these habitats depend on and interact with each other in tightly linked food webs. They may also depend on each other for the recycling of wastes, hygiene, and the maintenance of water quality. Other communities that are dependent on biogenic habitat include intertidal communities structured by mussels, barnacles, and algae and subtidal hard-bottom communities structured by bivalves, corals, or coralline algae. In numerous open ocean areas drift algal mats provide food and cover for juvenile fish, turtles, and other organisms. The integrity of these communities depends largely on the condition of species that provide structure for them.

This question is intended to address acute or chronic changes in both the extent of habitat available to organisms and the quality of that habitat, whether non-living or biogenic. It asks about the quality of habitats compared to those that would be expected in near-pristine conditions (see definition above).

Rating	Status Description
Good	Habitats are in near-pristine condition.
Good/Fair	Selected habitat loss or alteration is suspected and may degrade some attributes of ecological integrity, but has not yet caused measurable degradation.
Fair	Selected habitat loss or alteration has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected habitat loss or alteration has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected habitat loss or alteration has caused severe degradation in most if not all attributes of ecological integrity.

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

Habitat contaminants result from the introduction of unnatural levels of chemicals or other harmful material into the environment. Contaminants may be introduced through discrete entry locations, called point sources (e.g., rivers, pipes, or ships) and those with diffuse origins, called non-point sources (e.g., groundwater and urban runoff). Chemical contaminants themselves can be very specific, as in a spill from a containment facility or vessel grounding, or a complex mix, as with urban runoff. Familiar chemical contaminants include pesticides, hydrocarbons, heavy metals, and nutrients. Contaminants may also arrive in the form of materials that alter turbidity or smother plants or animals, therefore affecting metabolism and production.

This question is focused on risks posed primarily by contaminants within benthic formations, such as soft sediments, hard bottoms, or structure-forming organisms (see notes below). Not only are contaminants within benthic formations consumed or absorbed by benthic fauna, but resuspension due to benthic disturbance makes the contaminants available to water column organisms. In both cases contaminants can be passed upwards through the food chain. While the contaminants of most common concern to sanctuaries are generally pesticides, hydrocarbons, and nutrients, the specific concerns of individual sanctuaries may differ substantially.

Notes: 1) Contaminants in the water column addressed in the water quality section of this report should be cited, but details need not be repeated here; 2) many consider noise a pollutant, but in the interest of focusing here on more traditional forms of habitat degradation caused by contaminants, ONMS recommends addressing the impacts of acoustic pollution within the living resource section, most likely as it impacts key species.

Rating	Status Description
Good	Contaminants have not been documented, or do not appear to have the potential to negatively affect ecological integrity.
Good/Fair	Selected contaminants are suspected and may degrade some attributes of ecological integrity, but have not yet caused measurable degradation.
Fair	Selected contaminants have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected contaminants have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected contaminants have caused severe degradation in most if not all attributes of ecological integrity.

Living Resources

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

Certain species are defined as “keystone” within ecosystems, meaning they are species on which the persistence of a large number of other species in the ecosystem depends (Paine, 1966). They are the pillars of community stability (among other things, they strongly affect both resistance and resilience) and their contribution to ecosystem function is disproportionate to their numerical abundance or biomass. Their impact is therefore important at the community or ecosystem level. Keystone species are often called “ecosystem engineers” and can include habitat creators (e.g., corals, kelp), predators that control food web structure (e.g., Humboldt squid, sea otters), herbivores that regulate benthic recruitment (e.g., certain sea urchins), and those involved in critical symbiotic relationships (e.g., cleaning or co-habitating species).

“Foundation” species are single species that define much of the structure of a community by creating locally stable conditions for other species, and by modulating and stabilizing fundamental ecosystem processes (Dayton, 1972). These are typically dominant biomass producers in an ecosystem and strongly influence the abundance and biomass of many other species. Examples include krill and other zooplankton, kelp, forage fish, such as rockfish anchovy, sardine, and coral. Foundation species exhibit similar control over ecosystems as keystone species, but their high abundance distinguishes them.

Changes in either keystone or foundation species may transform ecosystem structure through disappearances of or dramatic increases in the abundance of dependent species. Not only do the abundances of keystone and foundation species affect ecosystem integrity, but measures of condition can also be important to determining the likelihood that these species will persist and continue to provide vital ecosystem functions. Measures of condition may include growth rates, fecundity, recruitment, age-specific survival, contaminant loads, pathologies (e.g., disease incidence, tumors, deformities), the presence and abundance of critical symbionts, or parasite loads.

Rating	Status Description
Good	The status of keystone and foundation species appears to reflect near-pristine conditions and may promote ecological integrity (full community development and function).
Good/Fair	The status of keystone or foundation species may preclude full community development and function, but has not yet led to measurable degradation.
Fair	The status of keystone or foundation species suggests measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	The status of keystone and foundation species suggests severe degradation in some but not all attributes of ecological integrity.
Poor	The status of keystone and foundation species suggests severe degradation in most if not all attributes of ecological integrity.

13. What is the status of other focal species and how is it changing?

This question targets other species of particular interest from the perspective of sanctuary management. These “focal species” may not be abundant or provide high value to ecosystem function, but their presence and health is important for the provision of other services, whether conservation, economic, or strategic. Examples include species targeted for special protection (e.g., threatened or endangered species), species for which specific regulations exist to minimize perturbations from human disturbance (e.g., touching corals, riding manta rays or whale sharks, disturbing white sharks, disturbing nesting birds), or indicator species (e.g., common murres as indicators of oil pollution). This category could also include so-called “flagship” species, which include charismatic or iconic species associated with specific locations, ecosystems or are in need of specific management actions, are highly popular and attract visitors or business, have marketing appeal, or represent rallying points for conservation action (e.g., humpback and blue whales, Dungeness crab).

Status of these other focal species can be assessed through measures of abundance, relative abundance, or condition, as described for keystone species. In contrast to keystone and foundation species, however, the impact of changes in the abundance or condition of focal species is more likely to be observed at the population or individual level, and less likely to result in ecosystem or community effects.

Rating	Status Description
Good	Selected focal species appear to reflect near-pristine conditions.
Good/Fair	Reduced abundances in selected focal species are suspected but have not yet been measured.
Fair	Selected focal species are at reduced levels, but recovery is possible.
Fair/Poor	Selected focal species are at substantially reduced levels, and prospects for recovery are uncertain.
Poor	Selected focal species are at severely reduced levels, and recovery is unlikely.

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

This question allows sanctuaries to report on the threat posed and impacts caused by non-indigenous species. Also called alien, exotic, non-native, or introduced species, these are animals or plants living outside their native distributional range, having arrived there by human activity, either deliberate or accidental. Activities that commonly facilitate invasions include vessel ballast water exchange, restaurant waste disposal, and trade in exotic species for aquaria. In some cases, climate change has resulted in water temperature fluctuations that have allowed range extensions for certain species.

Non-indigenous species that have damaging effects on ecosystems are called "invasive" species. Some can be extremely destructive, and because of this potential, non-indigenous species are usually considered problematic and warrant rapid response after invasion. For those that become established, however, their impacts can sometimes be assessed by quantifying changes in affected native species. In some cases, the presence of a species alone constitutes a significant threat (e.g., certain invasive algae and invertebrates). In other cases, impacts have been measured, and may or may not significantly affect ecosystem integrity.

Evaluating the potential impacts of non-indigenous species may require consideration of how climate change may enhance the recruitment, establishment, and/or severity of impacts of non-indigenous species. Altered temperature or salinity conditions, for example, may facilitate the range expansion, establishment and survival of non-indigenous species while stressing native species, thus reducing ecosystem resistance. This will also make management response decisions difficult, as changing conditions will make new areas even more hospitable for non-indigenous species targeted for removal.

Rating	Status Description
Good	Non-indigenous species are not suspected to be present or do not appear to affect ecological integrity (full community development and function).
Good/Fair	Non-indigenous species are present and may preclude full community development and function, but have not yet caused measurable degradation.
Fair	Non-indigenous species have caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Non-indigenous species have caused severe degradation in some but not all attributes of ecological integrity.
Poor	Non-indigenous species have caused severe degradation in most if not all attributes of ecological integrity.

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

Broadly defined, biodiversity refers to the variety of life on Earth, and includes the diversity of ecosystems, species and genes, and the ecological processes that support them (United Nations Convention on Biological Diversity). This question is intended as an overall assessment of biodiversity compared to that expected in a near-pristine system (one as near to an unaltered ecosystem as people can reasonably expect, given that there are virtually no ecosystems completely free from human influence). It may include consideration of measures of biodiversity (usually aspects of species richness and evenness) and the status of functional interactions between species (e.g., trophic relationships and symbioses). Intact ecosystems require that all parts not only exist, but that they function together, resulting in natural symbioses, competition, predator-prey relationships, and redundancies (e.g., multiple species capable of performing the same ecological role). Intact structural elements, processes, and natural spatial and temporal variability are essential characteristics of community integrity and provide a natural adaptive capacity through resistance and resilience.

The response to this question will depend largely on changes in biodiversity that have occurred as a result of human activities that cause depletion, extirpation or extinction, illness, contamination, disturbance, and changes in environmental quality. Examples include collection of organisms, excessive visitation (e.g., trampling), industrial activities, coastal development, pollution, activities creating noise in the marine environment, and those that promote the spread of non-indigenous species.

Loss of species or changing relative abundances can be mediated through selective mortality or changing fecundity, either of which can influence ecosystem shifts. Human activities of particular interest in this regard are commercial and recreational harvesting. Both can be highly selective and disruptive activities, with a limited number of targeted species, and often result in the removal of high proportions of the populations, as well as large amounts of untargeted species (bycatch). Extraction removes biomass from the ecosystem, reducing its availability to other consumers. When too much extraction occurs, ecosystem stability can be compromised through long-term disruptions to food web structure, as well as changes in species relationships and related functions and services (e.g. cleaning symbioses). This has been defined as "ecologically unsustainable" extraction (Zabel et al., 2003).

Rating	Status Description
Good	Biodiversity appears to reflect near-pristine conditions and promotes ecological integrity (full community development and function).
Good/Fair	Selected biodiversity loss or change is suspected and may preclude full community development and function, but has not yet caused measurable degradation.
Fair	Selected biodiversity loss or change has caused measurable but not severe degradation in some attributes of ecological integrity.
Fair/Poor	Selected biodiversity loss or change has caused severe degradation in some but not all attributes of ecological integrity.
Poor	Selected biodiversity loss or change has caused severe degradation in most if not all attributes of ecological integrity.

Maritime Heritage Resources

16. What is the condition of known maritime heritage resources and how is it changing?

Maritime heritage resources are the wide variety of tangible and intangible elements (archaeological, cultural, historical properties) that reflect our human connections to Great Lakes and ocean areas.

Maritime heritage resources include archaeological and historical properties, and material evidence of past human activities, including vessels, aircraft, structures, habitation sites, and objects created or modified by humans. The condition of these resources in a marine sanctuary significantly affects their value for science and education, as well as the resource's eligibility for listing in the National Register of Historic Places. The "integrity" of archaeological/historical resources, as defined within the National Register criteria, refers to their ability to help scientists answer questions about the past through archaeological research. Historical significance of an archaeological resource depends on its integrity and/or its representativeness of past events that made a significant contribution to the broad patterns of history, its association with important persons, or its embodiment of a distinctive type or architecture.

Maritime heritage resources also include certain culturally significant resources, locations and viewsheds, the condition of which may change over time. Such resources, often more intangible in nature, may still be central to traditional practices and maintenance of cultural identity. The integrity of both cultural resources and cultural locations are included within the National Register criteria.

Section 110 of the National Historic Preservation Act requires federal agencies to inventory, assess, and nominate appropriate maritime heritage resources ("historic properties") to the National Register. The Maritime Cultural Landscape approach, adopted by the sanctuary system, provides a comprehensive tool for the assessment of archaeological, historical and cultural (maritime heritage) resources.

Assessments of heritage resources include evaluation of the apparent condition, which results from deterioration caused by human and natural forces (unlike questions about water, habitat, and living resources, the non-renewable nature of many heritage resources makes any reduction in integrity and condition, even if caused by natural forces, permanent). While maritime heritage resources have intrinsic value, these values may be diminished by changes to their condition.

Rating	Status Description
Good	Known maritime heritage resources appear to reflect little or no unexpected natural or human disturbance.
Good/Fair	Selected maritime heritage resources exhibit indications of natural or human disturbance, but there appears to have been little or no reduction in aesthetic, cultural, historical, archaeological, scientific, or educational value.
Fair	The diminished condition of selected maritime heritage resources has reduced, to some extent, their aesthetic, cultural, historical, archaeological, scientific, or educational value, and may affect the eligibility of some sites for listing in the National Register of Historic Places.
Fair/Poor	The diminished condition of selected maritime heritage resources has substantially reduced their aesthetic, cultural, historical, archaeological, scientific, or educational value, and is likely to affect their eligibility for listing in the National Register of Historic Places.
Poor	The degraded condition of known maritime heritage resources in general makes them ineffective in terms of aesthetic, cultural, historical, archaeological, scientific, or educational value, and precludes their listing in the National Register of Historic Places.

Appendix B: Definitions and Rating Scheme for State of Ecosystem Services

The following provides descriptions of the various ecosystem services considered in sanctuary condition reports and the process for rating them. ONMS defines ecosystem services in a slightly more restrictive way than some other experts. Specifically, ecosystem services are defined herein as the benefits people obtain from nature through use, consumption, enjoyment, and/or simply knowing these resources exist (non-use). The descriptions below reflect this definition, and therefore, only those ecosystem services are evaluated in sanctuary conditions reports. In contrast, there are some supporting services, such as biodiversity, decomposition, and carbon storage, that are included in the State section of these reports instead. Specifically, these services are critical to ecosystem function and considered "intermediate" ecosystem services that are not directly used, consumed, or enjoyed by humans to meet the ONMS condition report definition of ecosystem services. In other words, these secondary or intermediate services support ecosystems and are not final ecosystem services in and of themselves.

As an example, biodiversity is often considered an ecosystem service, but ONMS recognizes biodiversity as an *attribute* of the ecosystem on which many “final” ecosystem services depend (e.g., recreation and food supply/commercial fishing). For this reason, it is considered a secondary ecosystem service and it is evaluated in the State section of the report.

In addition, ONMS does not consider climate regulation or stabilization in condition reports. The impacts of climate change on water quality and biodiversity, however, are considered separately in the State section of the report. While sanctuaries are not large enough to influence climate stability, they may locally buffer climate-related factors, such as temperature change and ocean acidity; thus, the extent to which they may locally buffer climate-related factors is reflected in resource conditions in the State section.

Certain other ecosystem services may not be assessed by individual sanctuaries because the activities required to achieve them are prohibited (e.g., collection of ornamentals) or there is simply no related activity underway or expected (e.g., energy production).

Below are brief descriptions of the ecosystem services considered within each sanctuary condition report (more complete descriptions are provided below the list).

***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 demands for seafood products
8. Subsistence Harvest — The capacity to support non-commercial harvesting of food and utilitarian products
9. Drinking water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash
10. Ornamentals — Resources collected for decorative, aesthetic, ceremonial purposes
11. Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use
12. Renewable 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

Sanctuaries vary with regard to the ecosystem services they support, so each sanctuary is likely to have a different mix of services and information to support its assessment. To rate the status and trends for each relevant ecosystem service, the following was considered:

- the ecosystem services relevant to the sanctuary
- the best available indicators for each ecosystem service (economic, non-economic human dimensions, and ecological)
- the status and direction of change of each ecosystem service
- whether economic and non-economic human dimensions indicators yield the same conclusions about the status and trend for each ecosystem service
- whether economic indicators send a false signal about the status and trend of an ecosystem service (namely, conflicting ecological and economic indicators, suggesting that people are sacrificing natural capital for short-term economic gain)

The steps used to rate ecosystem services were adapted from the multi-year study, "Marine and Estuarine Goal Setting for South Florida," of three south Florida marine ecosystems, including Florida Keys National Marine Sanctuary. It used Integrated Conceptual Ecosystem Models for each ecosystem under the DPSER Model (Nuttle & Fletcher, 2013) and evaluation of three types of indicators: 1) economic; 2) human dimension non-economic (Lovelace et al., 2013); and 3) resource for each ecosystem service.

The discussion of ecosystem services should consider whether economic and non-economic indicators yield the same conclusions as resource indicators; this will enable consideration of the sometimes conflicting relationship between economic gain and the preservation of natural capital. For example, economic indicators (e.g., dive operator income) may suggest improving recreational services while resource indicators (e.g., anchor damage) suggest that natural resource qualities are being sacrificed for short-term gain, making the activity unsustainable.

ONMS recognizes that the ecosystem services model is intentionally anthropocentric, designed to elicit a selected type of service-oriented rating useful in resource management decision making. Connections between ecosystems and culture and resource management are often more complex, beyond the scope of the condition report. Collectively, stakeholders may have multiple worldviews and ecosystem values equally important to consider, and some ecosystem elements may not be appropriate to rate in the ecosystem services approach (e.g., aspects of heritage and sense of place). Sites may want to consider the option of including a "context-specific perspective" or narrative (as proposed Diaz et al., 2018), without assigning a rating, for the purpose of providing appropriate information for management purposes. Cultural (non-material) ecosystem services are particularly intricate and have been undervalued in the past. Evaluators should remember that deliberative processes engaging local stakeholders and subject matter experts are critical, and adherence to the process demands both flexibility and creativity.

Rating Scheme for Ecosystem Services

Rating	Status Description
Good	The capacity to provide the ecosystem service has remained unaffected or has been restored.
Good/Fair	The capacity to provide the ecosystem service is compromised, but performance is acceptable.
Fair	The capacity to provide the ecosystem service is compromised, and existing management would require enhancement to enable acceptable performance.
Fair/Poor	The capacity to provide the ecosystem service is compromised, and substantial new or enhanced management is required to restore it.
Poor	The capacity to provide the ecosystem service is compromised, and it is doubtful that new or enhanced management would restore it.

The discussion of ecosystem services ratings within the written report should focus on the influence of drivers and societal values considered responsible for the ratings. This discussion may also consideration of whether economic and non-economic indicators yield the same conclusions; this will enable consideration of the sometimes conflicting relationship between economic gain and the preservation of natural capital. For example, economic indicators (e.g., dive operator income) may suggest improving recreational services while resource indicators (e.g., anchor damage) suggest that natural resource qualities are being sacrificed for short-term gain, making the activity unsustainable.

Descriptions of Ecosystem Services

Cultural (non-material benefits)

Consumptive recreation — Recreational activities that result in the removal of or harm to natural or cultural resources

Perhaps the most popular activity that involves consumptive recreation is sport fishing from private boats and for-hire operations. Targeted species and bycatch are removed from the environment, and those that must be released due to regulations and prohibitions (e.g., undersized or out of season) sometimes die due to stress or predation. Nonetheless, fishing for consumptive purposes is a highly valued cultural tradition for many people, as well as a popular recreational activity. Other consumptive recreational activities include beachcombing, clam digs and shell collecting.

Indicators of status and trends for consumptive recreation often include levels of use (direct counts or estimates made from commercial vessel records and catch levels, and fishing license registrations) and production of economic value through job creation, income, spending, and tax revenue. Public polls can also be used to assess non-market indicators, such as importance and satisfaction, social values, willingness to pay, and facility and service availability.

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

Recreational activities, including ecotourism and outdoor sports, are often considered a non-consumptive ecosystem service that provides desirable experiential opportunities. Non-consumptive recreational activities include those on shore or from private boats and for-hire operations, such as relaxing, exploring, diving and snorkeling, kayaking, birdwatching, surfing, sailing, and wildlife viewing. Activities that may have unintentional impacts on habitats or wildlife including catch-and-release fishing and tidepooling which could result in mortality or trampling, respectively, are also considered in this category.

It should be noted that private boating often includes both non-consumptive and consumptive recreational activities (e.g., snorkeling and fishing during a single trip). Thus, field and survey data can be ambiguous, reflecting the heterogeneous preferences of boaters. This also has implications for interpretations of data regarding attitudes and perceptions of management strategies and regulations to protect and restore natural and cultural resources.

Indicators used to assess status and trends in market values for recreation can include direct measures of use (e.g., person-days of use by type of activity) that result in spending, income, jobs, gross regional product, and tax revenues. They can also be non-market economic values (the difference between what people pay to use a good/service and what they would be willing to pay). The data can be used to estimate the value a consumer receives when using a good or service over and above what they pay to obtain the good or service. Indirect measures are also used. For example, populations and per capita incomes at numerous scales influence demand for recreational products and services. Fuel prices can even serve as indirect measures of recreational demand because the levels of use by some recreational users tracks fuel prices.

Science — The capacity to acquire and contribute information and knowledge

Sanctuaries serve as natural laboratories that can advance science and education. NOAA provides vessel support, facilities, and information that is valuable to the research community, including academic, corporate, non-governmental and government agency scientists, citizen scientists, and educators that instruct others using research. Sanctuaries serve as long-term monitoring sites, provide minimally disturbed focal areas for many studies, and provide opportunities to restore or maintain natural systems.

Status and trends for science can be assessed by counting and characterizing the number of research permits and tracking the accomplishments and growth of partnerships, activity levels of citizen monitoring, and participation of the research community in sanctuary management. The number and types of research cruises and other expeditions conducted can also provide useful indicators. Indirect indicators, such as per capita income and gross regional or national product, may be helpful as higher incomes and better economic conditions often result in higher investments in research and monitoring.

Education — The capacity to acquire and provide intellectual enrichment

As with science, national marine sanctuaries' protected natural systems and cultural resources attract educators at many levels for both formal and informal education. Students and teachers often either visit sanctuaries or use curricula and information provided by sanctuary educators.

The status and trends for education can be tracked by evaluating the number of educators and students visiting the sanctuary and visitor centers, the number of teacher trainings, use of sanctuary-related curricula in the classroom, and levels of activity in volunteer docent programs. The number of outreach offerings provided during sanctuary research and education expeditions can also be a good indicator. Education can also follow trends in populations and per capita income locally, regionally, and nationally. Populations create demand for services, and higher incomes lead to investment, making these useful indirect indicators.

Heritage — Recognition of historical and heritage legacy and cultural practices

The iconic nature of many national marine sanctuaries or particular places within them generally means that they have long been recognized, used, and valued. Communities developed around them, traveled through them, and depended on their resources. This shared history and heritage creates the unique cultural character of many present-day coastal communities, and can also be an important part of the current economy. Recognition of the past, including exhibits, artifacts, records, stories, songs, and chants provide not only a link to the history of these areas, but a way to better understand the maritime and cultural heritage within the environment itself. Tangible and intangible aspects of heritage blend together to contribute to the history and legacy of the place.

For some marine sanctuaries, vibrant and active indigenous cultures remain a defining and dominant element of the cultural heritage of these places. Not only are they a direct and priceless connection to the past, but they frame and influence modern-day economies, cultural landscapes, and conservation ethics and practices. Their very existence is intrinsic to the heritage of these places.

Given this broad range of cultural expression, benefits of heritage may take many forms. Additionally, cultural heritage resources will often be part of, or overlap with, other ecosystem service categories, and may be understood from multiple perspectives (such as, a living resource keystone species that may also be identified as a "cultural" keystone species, one of exceptional significance to a culture or a people). The Heritage ecosystem service category defines benefits from resources primarily attached to historical and heritage legacy and culture. Heritage resources, including certain living resources and traditional medicines, may also provide other benefits that can be addressed in other ecosystem service categories.

Economic indicators that reflect status and trends for heritage value as an ecosystem service may include spending, income, jobs, and other revenues generated from visitation, whether it is to dive on wreck sites or patronize museums and visitor centers where artifacts are displayed and interpreted. Non-market indicators, such as willingness to pay for protection of resources, activity levels for training and docent interpretation, and changes in threat levels (looting and damage caused by fishing), may also be considered. Sites may determine that some aspects of Heritage may simply not be ratable using the framework of condition reports.

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

A wide range of intangible meanings can be attributed to a specific place by people, both individually and collectively. Aesthetic attraction, spiritual significance, and location identity all influence our recognition and appreciation for a place, as well as efforts to protect its iconic elements.

Marine environments serve as places of aesthetic attraction for many people, and inspire works of art, music, architecture, and tradition. Many people also value particular places as sources of therapeutic rejuvenation and to offer a change of perspective. Aesthetic aspects are often reflected as motifs in books, film, artworks, and folklore and as part of national symbols, architecture, and advertising efforts. These elements of "place attachment" may develop and change over the short and long term.

Many people, families, and communities consider places as defining parts of their "self identity," especially if they have lived there during or since childhood. The relationship between self/family/community and place can run very deep, particularly where lineage is place-based, with genealogy going back many generations. "Place identity" develops over the long term, and is often expressed in reciprocal human-ecosystem relationships, and locations associated with spiritual significance. The recognition of very long term place-based stewardship, sometimes in excess of 10,000 years, provides a unique aspect of place identity.

Many people even incorporate water or water-related activities as habitual or significant parts of their lives and cultures. Different factors are considered to measure/assess sense of place, including level of uniqueness, recognition, reputation, reliance, and appreciation for a place. Accounting for sense of place can provide strong incentives for conservation, preservation, and restoration efforts.

Despite its value as a cultural ecosystem service, it is difficult to quantify sense of place with direct measures. Examples of indicators may include the quality and availability of opportunities to support rituals, ceremonies and narratives and the level of satisfaction knowing that a place exists. Polls or surveys are often used to evaluate public opinions regarding economic and non-economic values of a place. Non-economic values may include existence or bequest value, which use surveys to estimate the value people would be willing to pay for resources to stay in a certain condition even though they may never actually use them. To comprehensively evaluate sense of place, sites may find it useful to consider subcategories such as place attachment and place identity. Furthermore, sites may determine that some aspects of Sense of Place may simply not be ratable using the framework of condition reports.

Provisioning (material benefits)

Commercial Harvest - The capacity to support commercial market demands for seafood products

Humans consume a large variety and abundance of products originating from the oceans and Great Lakes for nutrition or for use in other sectors. This includes fish, shellfish, other invertebrates, roe, and algae. Seafood is one of the largest traded food commodities in the world. Commercial fishing provides food for domestic and export markets, sold as wholesale and retail for household, restaurant and institutional meals. Seafood based industries include those that fish and harvest directly from wild capture and cultivated resources, as well as other businesses with functions throughout the supply chain including production of commercial gear, processors, storage facilities, buyers, transport and market outlets.

Within this category we also include what many call artisanal fishing, which can include commercial sale, but is also conducted by individuals or small groups who live near their harvest sites and use small scale, low technology, low cost fishing practices. Their catch is usually not processed (although it may be smoked or canned), and is mainly for local consumption or sale. Artisanal fishing uses traditional fishing techniques such as rod and tackle, fishing arrows and harpoons, cast nets, and sometimes small traditional fishing boats.

Fisheries located in national marine sanctuaries are usually encompassed by larger regional fisheries that are regulated by fisheries management plans. Fisheries management plans may include sanctuary-specific restrictions to protect sanctuary habitats, living resources, and archaeological resources, and to fulfill treaty obligations. Data that can be used to assess status and trends for this ecosystem service include: catch levels by species and species groups; and economic contributions in the form of sector-related jobs, income, sales, and tax revenue. Indirect measures include data on licensing, fleet size, fishing vessel types and sizes, days at sea, and commodity prices.

Subsistence Harvest – The capacity to support non-commercial harvesting of food and utilitarian products

Subsistence harvesting is the practice of collecting marine resources (e.g., fish, shellfish, marine mammals, seabirds, roe, and algae) either for food or for creating products that are utilitarian in nature (e.g., traditional medicine, shelter, clothing, fuel and tools) that are not for sale or income generation. Subsistence is conducted principally for personal and family use, and sometimes for community use, and may be distributed through ceremony, sharing, gifting, and bartering. Some people depend on subsistence fishing for food security and may have few other sources of income to provision their food and nutrition needs. Harvesting for subsistence is also a cultural or traditional practice for some people. It typically operates on a smaller and more local scale than commercial fishing. Natural resources that support subsistence harvest may also be used as ceremonial regalia or for cultural traditions, and therefore support other ecosystem services, including Heritage, Sense of Place, and Ornamentals. Data from surveys, tribal and indigenous knowledge and the status of fishery stocks can be used to assess the status and trends of this service.

Drinking water — Providing water for human use by minimizing pollution, including nutrients, sediments, pathogens, chemicals, and trash

Clean water is considered a final ecosystem service when the natural environment is improving water quality for human consumption or other direct use (e.g., irrigation). Although sanctuary ecosystems often function to improve water quality, most do not result in the final ecosystem service of clean water for human use. For most natural resources, improving water quality in a sanctuary is a supporting or intermediate ecosystem service that may, for example, result in better water quality for fish species that are then enjoyed by commercial or recreational anglers, safer water in which to swim, or improved water clarity for diving. These are aspects of other final ecosystem services and the water quality itself is an indicator that is inherently important to them; however, ONMS does not include this aspect of clean water in condition reports because it would result in a double counting of its ecosystem service value. Instead, ONMS evaluates clean water as a final ecosystem service, where the natural environment is improving water for human consumption, such as drinking water, or for irrigation (e.g., through filtration or suitability for desalination). In this way, the benefits of management policies and actions that improve water quality are captured separately, but in relation to the relevant final ecosystem services they support.

Ornamentals — Resources collected for decorative, aesthetic, or ceremonial purposes

In sanctuaries where the collection of ornamental products is not prohibited or is allowed under permit, they are taken for their aesthetic or material value for artwork, souvenirs, fashion, handicrafts, jewelry, or display. This includes live animals for aquaria and trade, pearls, shells, corals, sea stars, furs, feathers, ivory, and more. Some, particularly animals for the aquarium trade, are sold commercially and can be valued like other commodities; others cannot. Some products may be decorative and relatively non-functional, others culturally significant and specifically functional, such as ceremonial regalia. Status and trends for the use of ornamentals can also be evaluated using indicators such as the number of permitted or other collectors, frequency and intensity of collection operations, and sales.

Biotechnology — Medicinal and other products derived or manufactured from sanctuary animals or plants for commercial use

Biochemical and genetic resources, medicines, chemical models, and test organisms are all potential products that can be derived or sourced from national marine sanctuaries. Biochemical resources include compounds extracted from marine animals and plants and used to develop or manufacture foods, pharmaceuticals, cosmetics, and other products (e.g., omega-3 fatty acids from fish oil, or microbes for spill or waste bioremediation). Genetic resources are the genetic content of marine organisms used for animal and plant breeding and for biotechnology. Natural resources can also be used as a model for new products (e.g., the development of fiber optic technology, based on the properties of sponge spicules). Items harvested for food consumption are evaluated in Commercial and Subsistence Harvest.

Collections of products for biotechnology applications may be allowed under permit, and sanctuary permit databases can also be used to gauge demand and collection activity within a given national marine sanctuary. The value of commercially sold products associated with biotechnology may also be available.

Renewable energy — Use of ecosystem-derived materials or processes for the production of energy

In the offshore environment, energy production sources are considered to be either non-renewable (oil and gas) or renewable (wind, solar, tidal, wave, or thermal). While oil and gas technically are ecosystem-sourced and may be renewable over a time frame measured in millions of years, as an ecosystem service, they are not subject to management decisions in human time frames; therefore, they are not considered an ecosystem service in this section. The activities and management actions related to hydrocarbon production are, however, considered elsewhere in condition reports, primarily with regard to resource threats, impacts, and protection measures.

In contrast, "renewable" forms of energy that depend on ecosystem materials and processes operating over shorter time periods are evaluated. Indicators of status and trends for these energy sources include the types and number of permitted or licensed experimental or permanent operations, energy production, revenues generated, and jobs created. Indirect indicators that inform trends and provide some predictive value include social and market trends, energy costs, and expected demand based on service market populations trends.

Regulating (buffers to change)

Coastal protection — Natural features that control water movement and/or wind energy, thus protecting habitat, property, heritage resources and coastlines

Coastal and estuarine ecosystems can buffer the potentially destructive energy of environmental disturbances, such as floods, tidal surges and storm waves, and wind. Wetlands, kelp forests, mangroves, seagrass beds, and reefs of various types all absorb some of the energy of local disturbances, protecting themselves, submerged habitats closer to shore, intertidal ecosystems, and emergent land masses. They also can trap sediments and promote future protection through shoaling. They can also become sources of sediments for coastal dunes and beaches that control flooding and protect coastal properties from wave energy and the impacts of sea-level rise.

The value of coastal protection can be estimated by evaluating the basis of the value of vulnerable coastal properties and infrastructure and modeled estimates of losses expected under different qualities of coastal ecosystems (replacement cost). Levels of historical change under different energy scenarios can be used to support these estimates. Public polls can also reveal information on willingness to pay that is used to value this service.

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. OCNMS'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 ecosystem 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 OCNMS condition report process is available in the Acknowledgements section of this report.

First, on May 2, 2019, a one-day workshop was convened in which a group of natural science experts was asked to assist in the selection of indicators that would be assessed to determine status and trends of sanctuary resources. Specifically, experts were asked to review information compiled by NOAA staff on indicators of condition of waters, habitats, and living resources in the sanctuary; propose additional indicators to explore, including identifying data, information, and TK that supported proposed indicators; and identify specific indicators that could not be used in this round of condition reporting (per selection criteria) but are a high priority for inclusion in the next round of reporting.

Second, a three-day workshop was held January 14–16, 2020 to discuss and evaluate the series of questions about each resource and ecosystem service: human activities (Questions 2–4), water quality (Questions 6–9), habitat (Questions 10 and 11), living resources (Questions 12–15), maritime heritage resources (Question 16), and ecosystem services (consumptive recreation, non-consumptive recreation, science, education, heritage, sense of place, commercial harvest, subsistence harvest, and ornamentals). During the workshop, 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 meeting. 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. 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 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 Table App.C.1 below.

Table App.C.1. Criteria used to determine confidence levels for condition report status and trend ratings.

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.

Evidence Scores		
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

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 new 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 April and May 2021, a draft final report was sent to five regional science 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.[24] Furthermore, OMB Bulletin guidelines require that reviewer comments, names, and affiliations be posted on the agency website. 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.

Olympic Coast National Marine Sanctuary
Confidence Ratings from January 14–16, 2020 Expert Workshop

Question	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
1. Drivers/Human Activities	Rating not assigned			
2. Water/Human Activities	Status: Good/Fair	Limited	High	Medium
	Trend: Not Changing	Limited	High	Medium
3. Habitat/Human Activities	Status: Fair	Medium	Medium	Medium

[24] See footnotes in Table App.C.2 noting that the ratings that were determined during the expert workshop for Questions 10 and 15 were changed following comments received from peer reviewers. In addition, during the January 2020 workshop an undetermined trend was assigned for questions 12, 13, consumptive recreation, and subsistence harvest due to instances of variable trends (i.e., some indicators are improving while others are worsening), however, through the editing process it was agreed by ONMS staff that the trend ratings for these two questions and two ecosystem services should be modified and instead assigned a mixed trend rating in order to better reflect sanctuary dynamics.

Question	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
	Trend: Undetermined	Limited	High	Medium
4. Living Resources/Human Activities	Status: Good/Fair	Medium	High	High
	Trend: Improving	Medium	Medium	Medium
5. Maritime Heritage Resources/Human Activities	Status: Fair	Medium	Medium	Medium
	Trend: Undetermined	Medium	High	High
6. Water/Eutrophic Condition	Status: Good	Medium	High	High
	Trend: Not Changing	Medium	High	High
7. Water/Human Health	Status: Fair	Medium	High	High
	Trend: Not Changing	Medium	Medium	Medium
8. Water/Climate Change	Status: Fair/Poor	Robust	High	Very High
	Trend: Worsening	Robust	High	Very High
9. Water/Other Stressors	Status: Good/Fair	Limited	High	Medium
	Trend: Worsening	Limited	High	Medium
10. Habitat/Integrity[25]	Status: Good/Fair	Limited	Medium	Low
	Trend: Not Changing	Limited	Low	Very Low
11. Habitat/Contaminants	Status: Good	Limited	High	Medium
	Trend	Limited	High	Medium
12. Living	Status: Fair	Medium	Medium	Medium

[25] Experts at the January 2020 workshop rated Question 10 regarding the integrity of major habitat types as good/fair (low confidence) and not changing (very low confidence). Subsequently, peer reviewers suggested that the pelagic zone was not adequately considered during the workshop and recommended a rating change to reflect the impacts of climate change on OCNMS. Sanctuary staff considered this suggestion, reviewed relevant data, and agreed that the rating should be changed to fair (medium confidence) and worsening (medium confidence).

Question	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
Resources/Keystone and Foundation Species	Trend: Undetermined	Medium	High	High
13. Living Resources/Other Focal Species	Status: Fair	Medium	High	High
	Trend: Undetermined	Medium	High	High
14. Living Resources/Non-Indigenous Species	Status: Good/Fair	Medium	High	High
	Trend: Worsening	Medium	High	High
15. Living Resources/Biodiversity [26]	Status: Good/Fair	Limited	Medium	Low
	Trend	Limited	High	Medium
16. Maritime Heritage Resources/Condition	Status: Good/Fair	Limited	Medium	Low
	Trend: Undetermined	Limited	Medium	Low

Ecosystem Services	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
Consumptive Recreation	Status: Fair	Medium	High	High
	Trend: Undetermined	Medium*	Low	Low
Non-Consumptive Recreation	Status: Fair	Medium	Low	Low
	Trend: Undetermined	Medium	High	High
Science	Status: Fair	Robust	Medium	High

[26] Experts at the January 2020 workshop rated Question 15 about the status of biodiversity as good/fair (low confidence) and not changing (medium confidence). Peer reviewers suggested that key species, like groundfish and plankton, and the significant impacts related to sea star wasting disease were not adequately considered during the workshop and recommended a change to the rating. Sanctuary staff considered this suggestion, reviewed relevant data sets, including additional, recently acquired groundfish biodiversity data, and agreed that the trend rating should be changed to worsening (low confidence).

Ecosystem Services	Rating	Evidence (Limited, Medium, Robust)	Agreement (Low, Medium, High)	Confidence (Very Low, Low, Medium, High, Very High)
	Trend: Improving	Robust	High	Very High
Education	Status: Good/Fair	Medium	Medium	Medium
	Trend: Improving	Robust	High	Very High
Heritage	Status: Good/Fair	Medium	Medium	Medium
	Trend: Worsening	Medium	High	High
Sense of Place	Rating not assigned			
Commercial Harvest	Rating not assigned			
Subsistence Harvest	Status: Fair	Limited	High	Medium
	Trend: Undetermined	Limited	High	Medium
Ornamentals	Status: Good/Fair	Medium	High	High
	Trend: Undetermined	Limited	High	Medium

Appendix D:
Additional Water Quality Figures

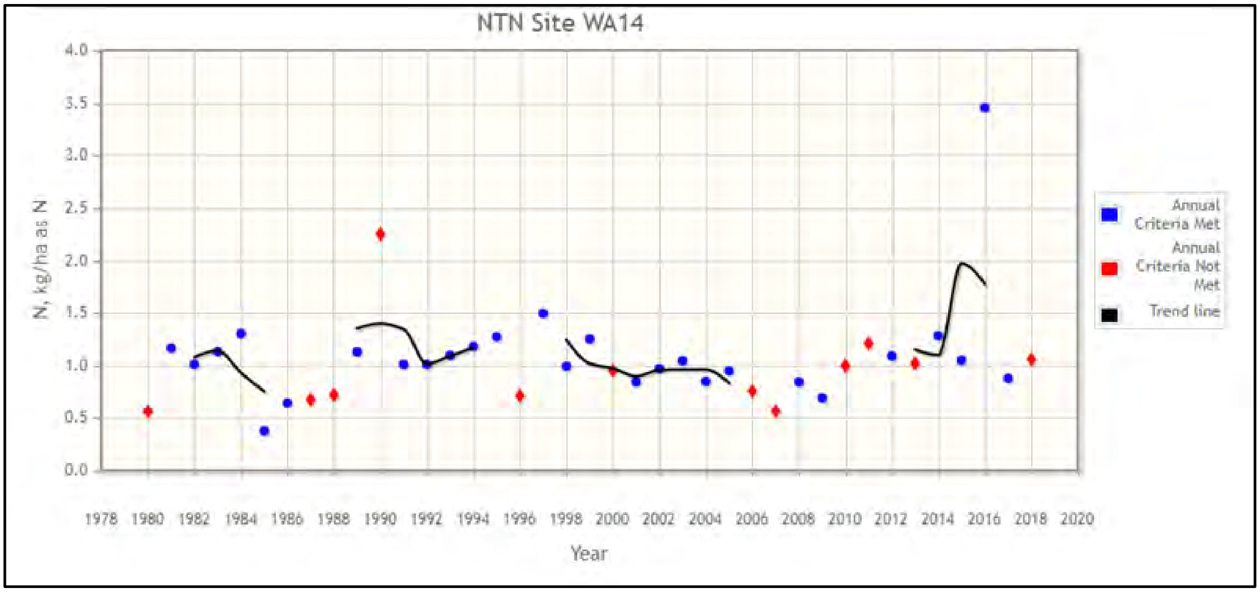


Figure App.S.WQ.6.1. Total nitrogen (nitrate plus ammonium) concentration in deposition (1980–2018), in Kg/ha at the Hoh River Ranger Station in Olympic National Park (elevation 182 m). Trend lines show the trend for at least 3 years when criteria were met. Image: NADP, 2020

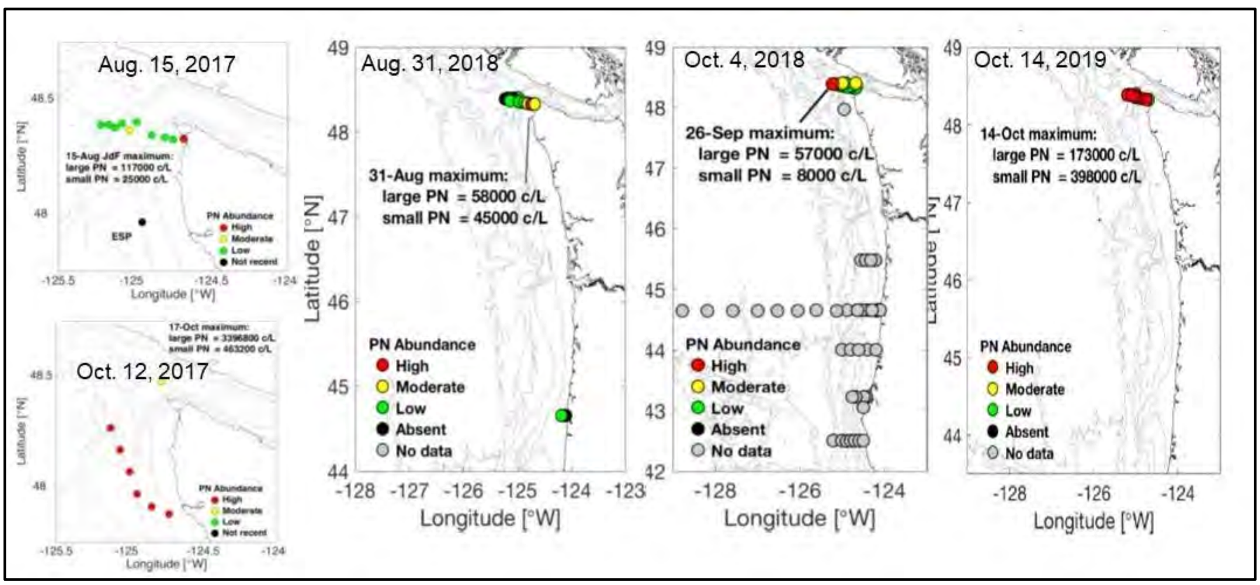


Figure App.S.WQ.7.1. *Pseudo-nitzschia* abundance levels for Washington and Oregon offshore sampling sites. High: abundance exceeded threshold values (50,000 cells/L for large *Pseudo-nitzschia*; 1,000,000 cells/L for small *Pseudo-nitzschia*) for either cell morphology; Moderate: abundance exceeded 1/3 of threshold value; Low: abundance did not exceed 1/3 threshold. “Absent” denotes absence or non-detection. “No data” indicates that there were no data reported within the previous 15 days. Source: NANOOS, 2020

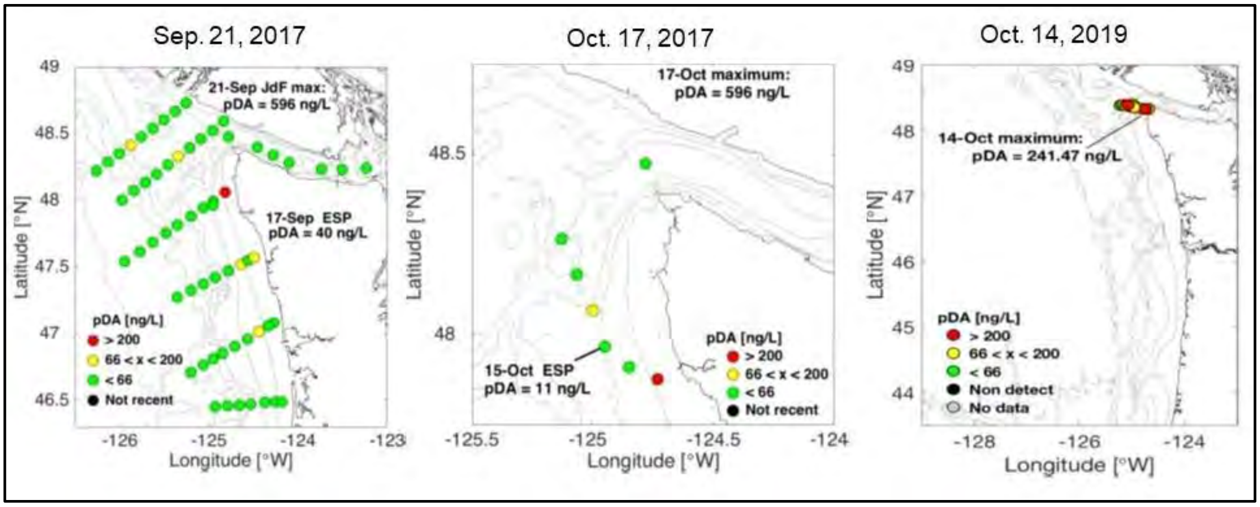


Figure App.S.WQ.7.2. Particulate domoic acid (pDA) levels for Washington and Oregon offshore sampling sites. High values indicate pDA > 200 ng/l; moderate values ranged from 66-200 ng/l; low values indicated pDA < 66 ng/l. “Not recent” indicates that there were no data reported within the previous 15 days. Source: NANOOS, 2020

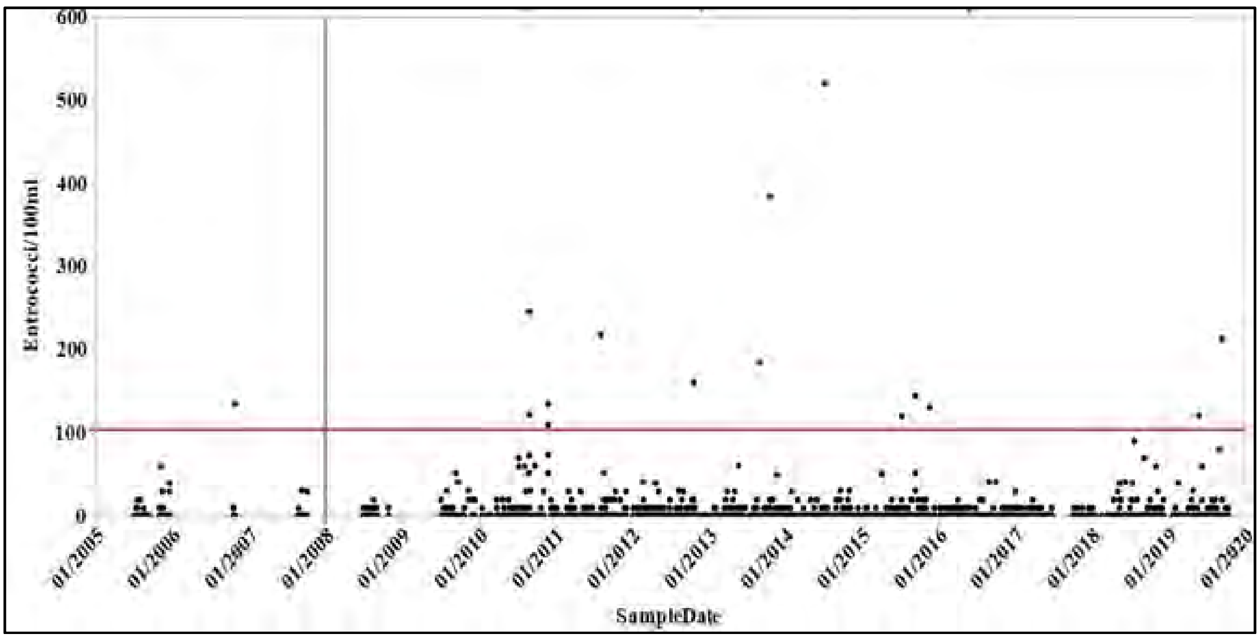


Figure App.S.WQ.7.3. Beach bacteria concentrations (enterococci/100 ml) for Hobuck Beach, Makah Bay, 2005–2019. Source: Washington State Department of Ecology, 2020b; Image: A. Mabrouk/NOAA

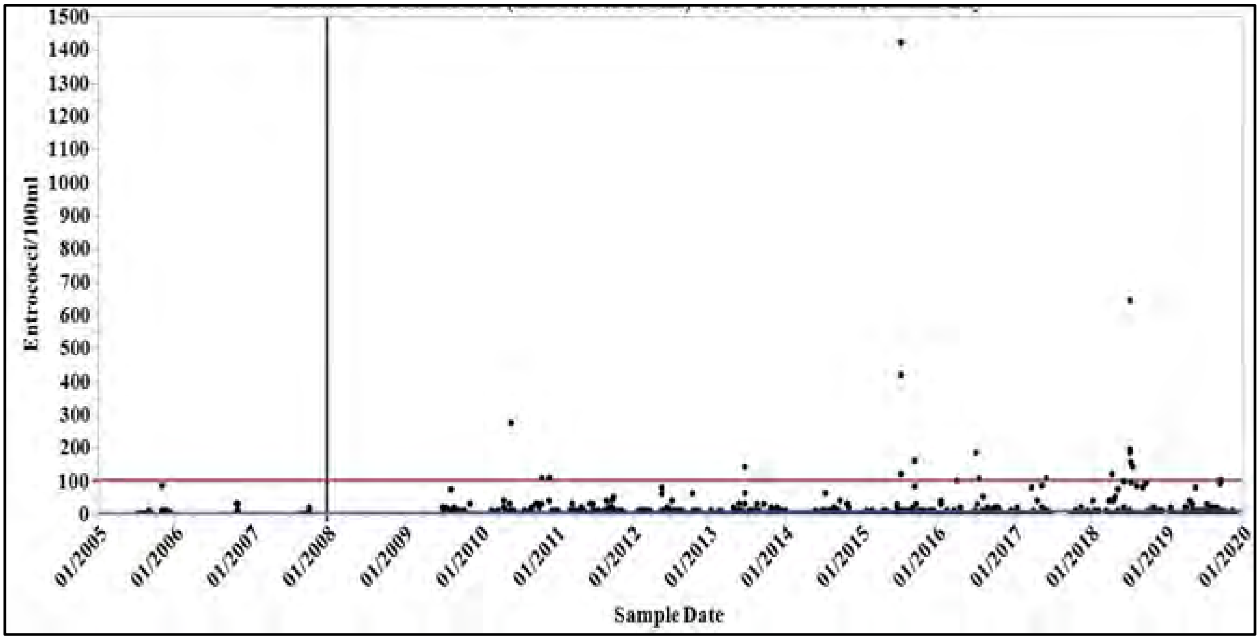
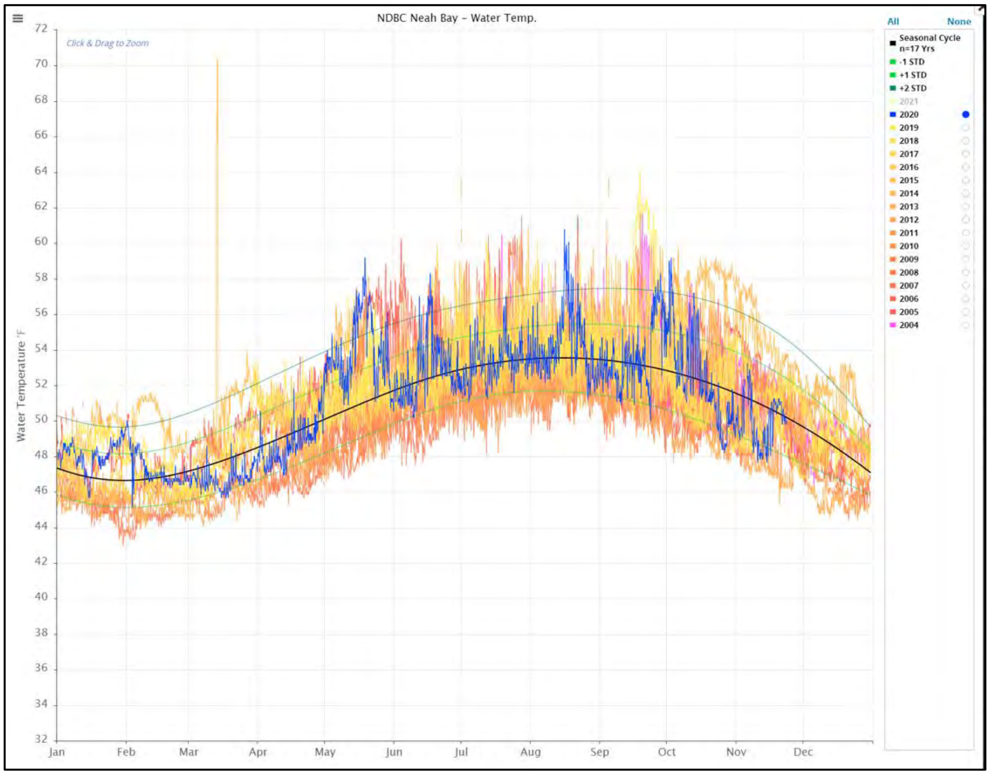


Figure App.S.WQ.7.4. Beach bacteria concentrations (enterococci/100ml) for Tsoo-Yess Beach, Makah Bay, 2005–2019. Source: Washington State Department of Ecology, 2020b; Image: A. Mabrouk/NOAA



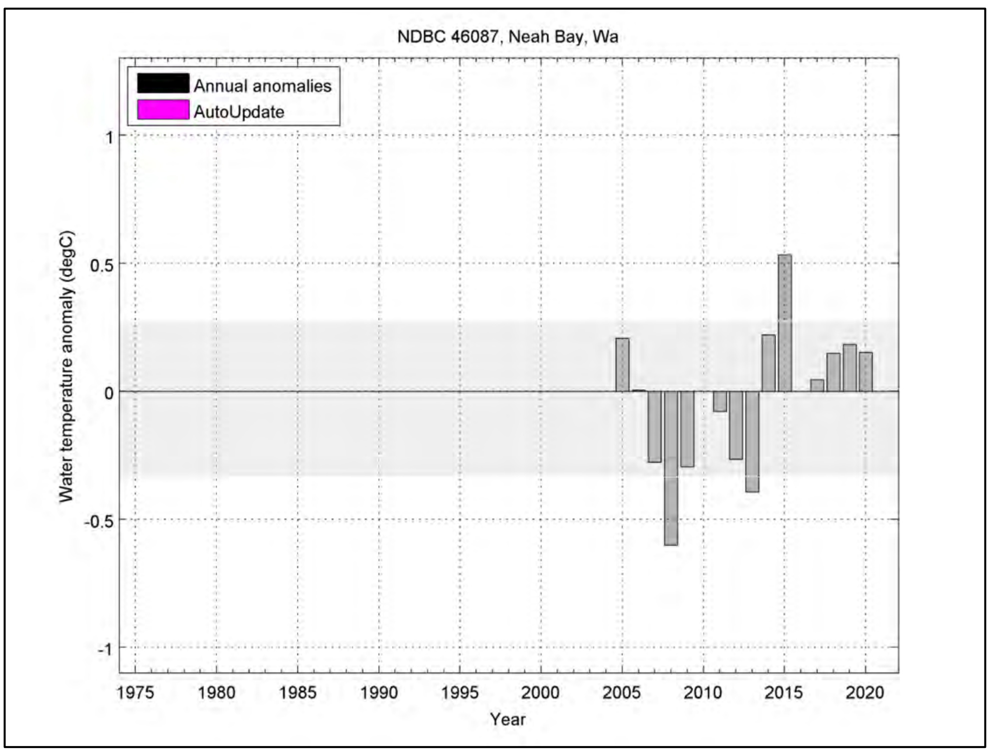
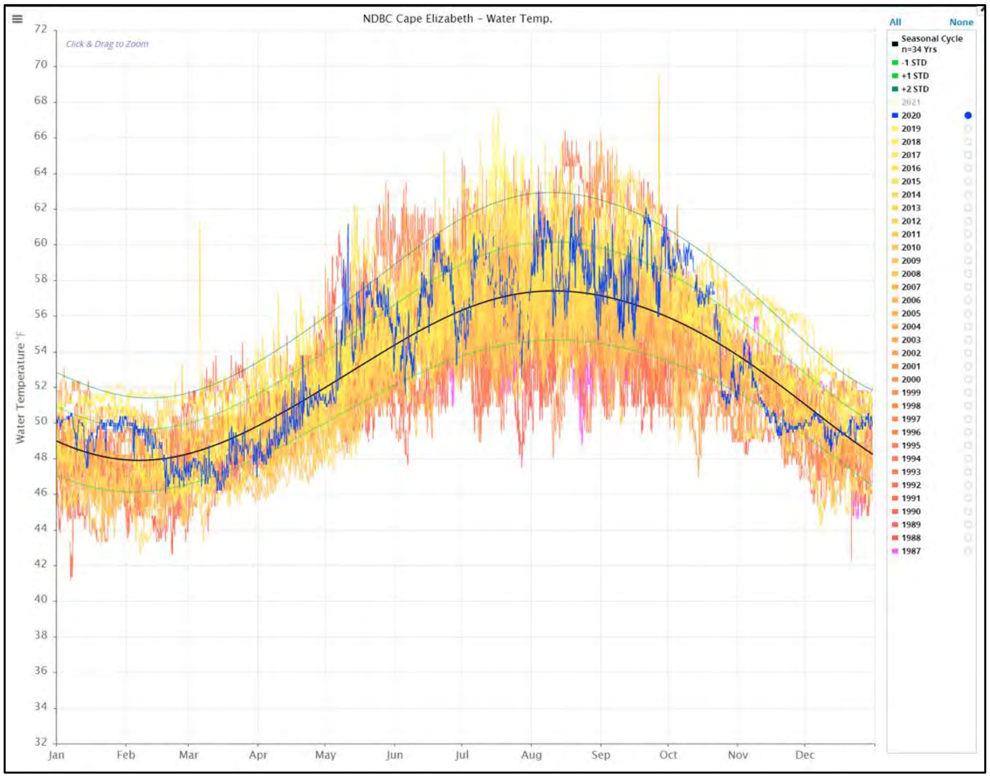


Figure App.S.WQ.8.1. Neah Bay (NDBC 46087) SST seasonal variability (left) and annual anomalies (right) in OCNMS, 2004–2020. In the left panel, data from 2020 are shown in red for comparison to previous data, with more recent years shown in blue transitioning to green for earlier years. The black line denotes mean daily value over the complete time series, blue lines depict one standard deviation, and the pink line represents +2 standard deviations. Source: NDBC; Image: NANOOS, 2020



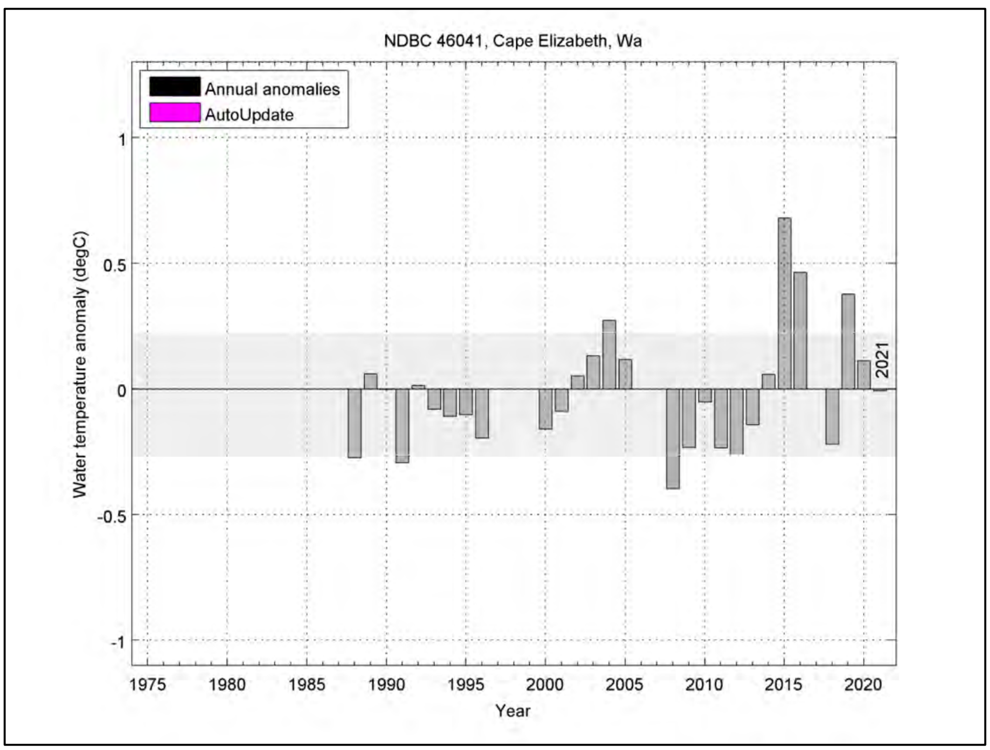
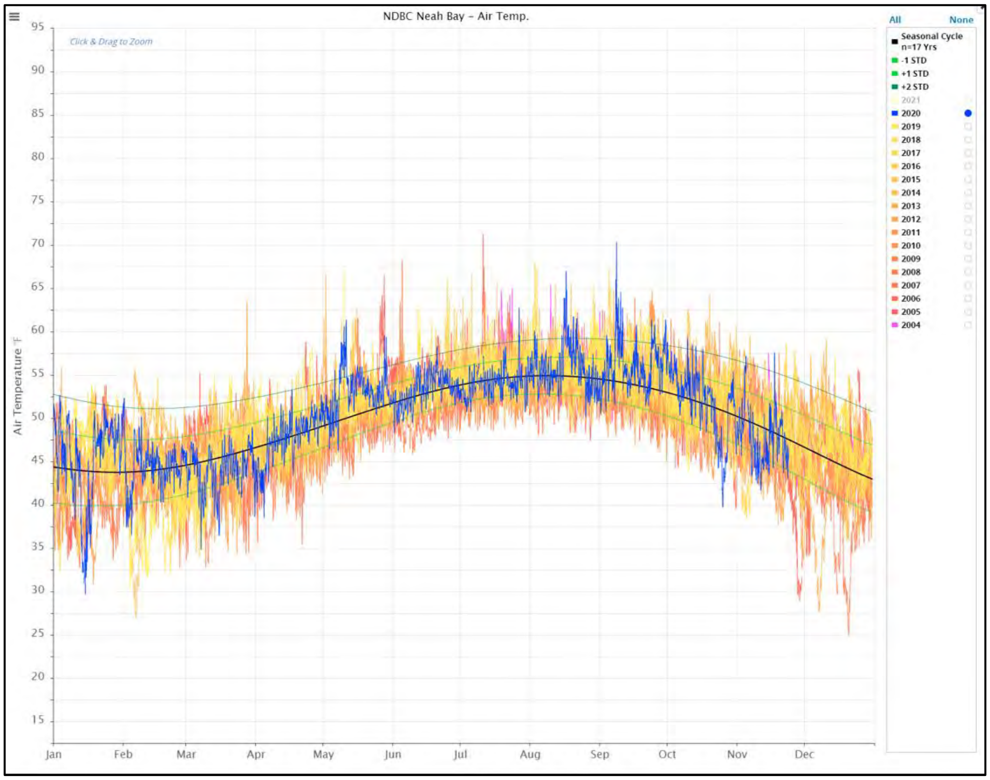


Figure App.S.WQ.8.2. Cape Elizabeth (NDBC 46041) SST seasonal variability (left) and annual anomalies (right) in OCNMS, 1987–2020. In the left panel, data from 2020 are shown in red for comparison to previous data, with more recent years shown in blue transitioning to green for earlier years. The black line denotes mean daily value over the complete time series, blue lines depict one standard deviation, and the pink line represents +2 standard deviations. Source: NDBC; Image: NANOOS, 2020



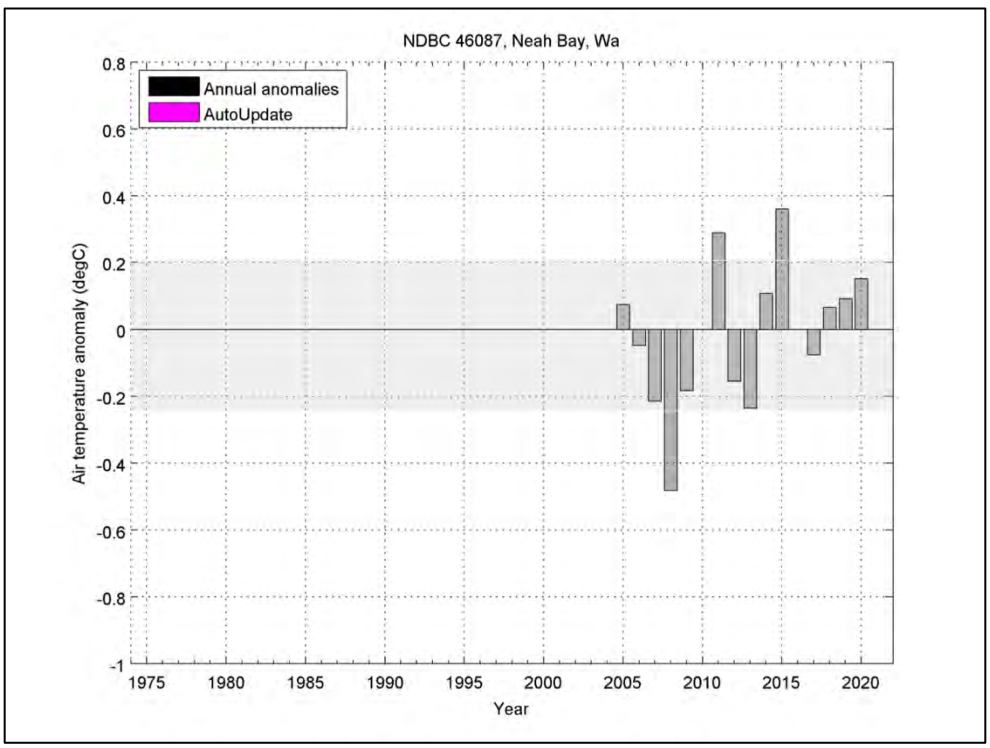
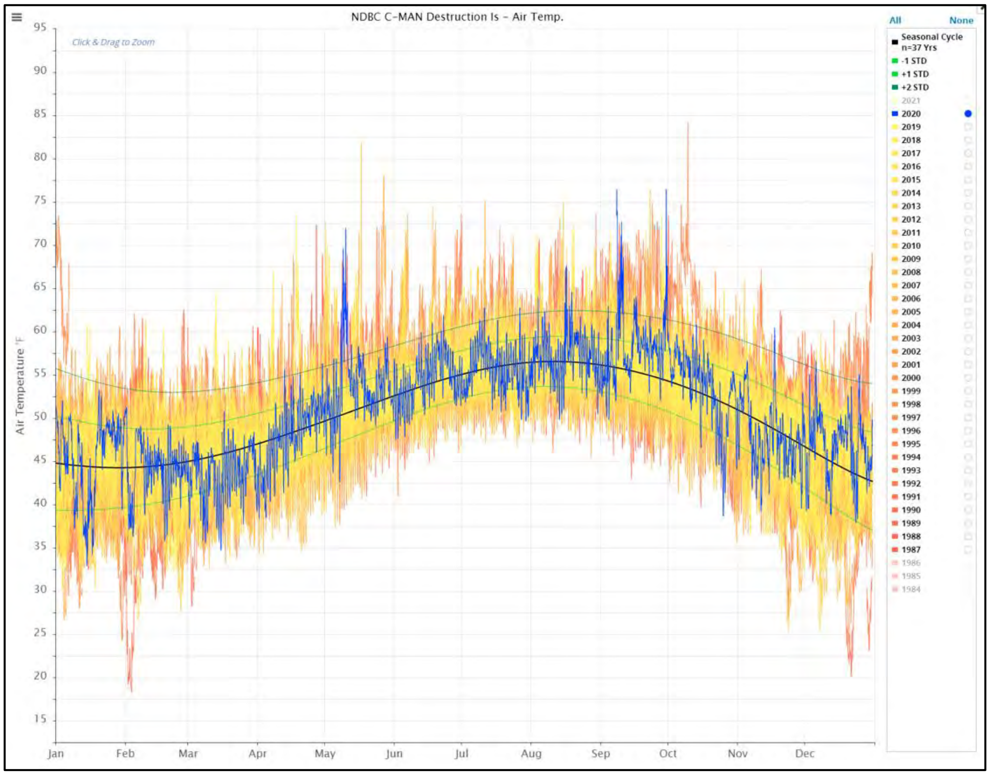


Figure App.S.WQ.8.3. Neah Bay (NDBC 46087) air temperature seasonal variability (left) and annual anomalies (right) in OCNMS, 2004–2020. In the left panel, data from 2020 are shown in red for comparison to previous data, with more recent years shown in blue transitioning to green for earlier years. The black line denotes mean daily value over the complete time series, blue lines depict one standard deviation, and the pink line represents +2 standard deviations. Source: NDBC; Image: NANOOS, 2020



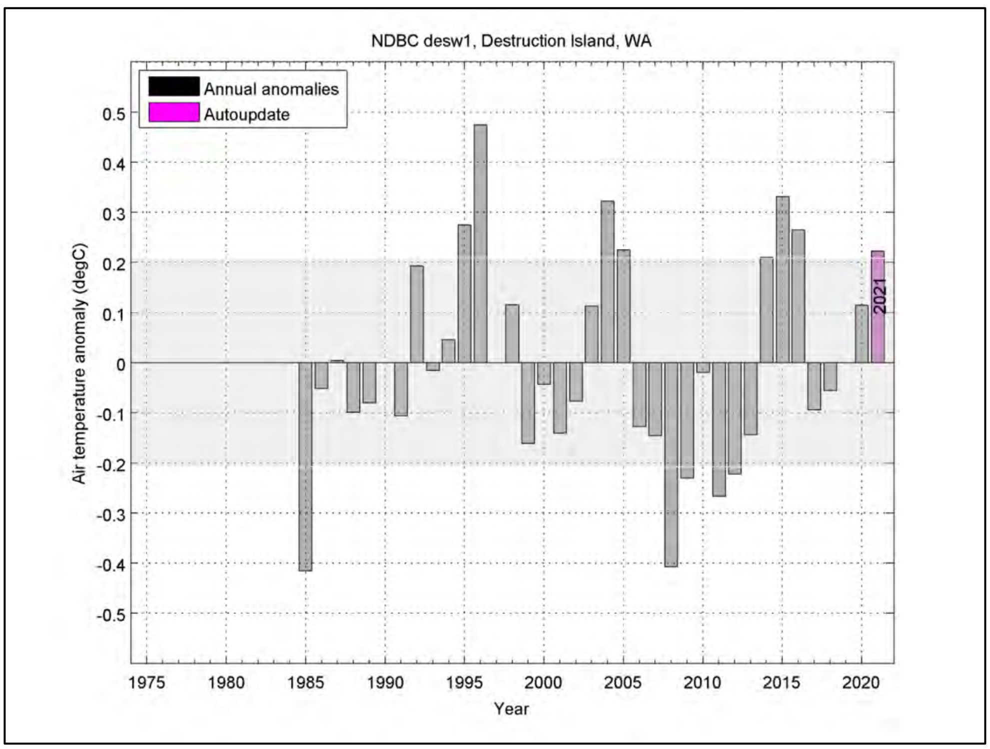


Figure App.S.WQ.8.4. C-MAN Destruction Island (NDBC desw1) air temperature seasonal variability (left) and annual anomalies (right) in OCNMS, 1987–2020. In the left panel, data from 2020 are shown in red for comparison to previous data, with more recent years shown in blue transitioning to green for earlier years. The black line denotes mean daily value over the complete time series, blue lines depict one standard deviation, and the pink line represents +2 standard deviations. Source: NDBC; Image: NANOOS, 2020

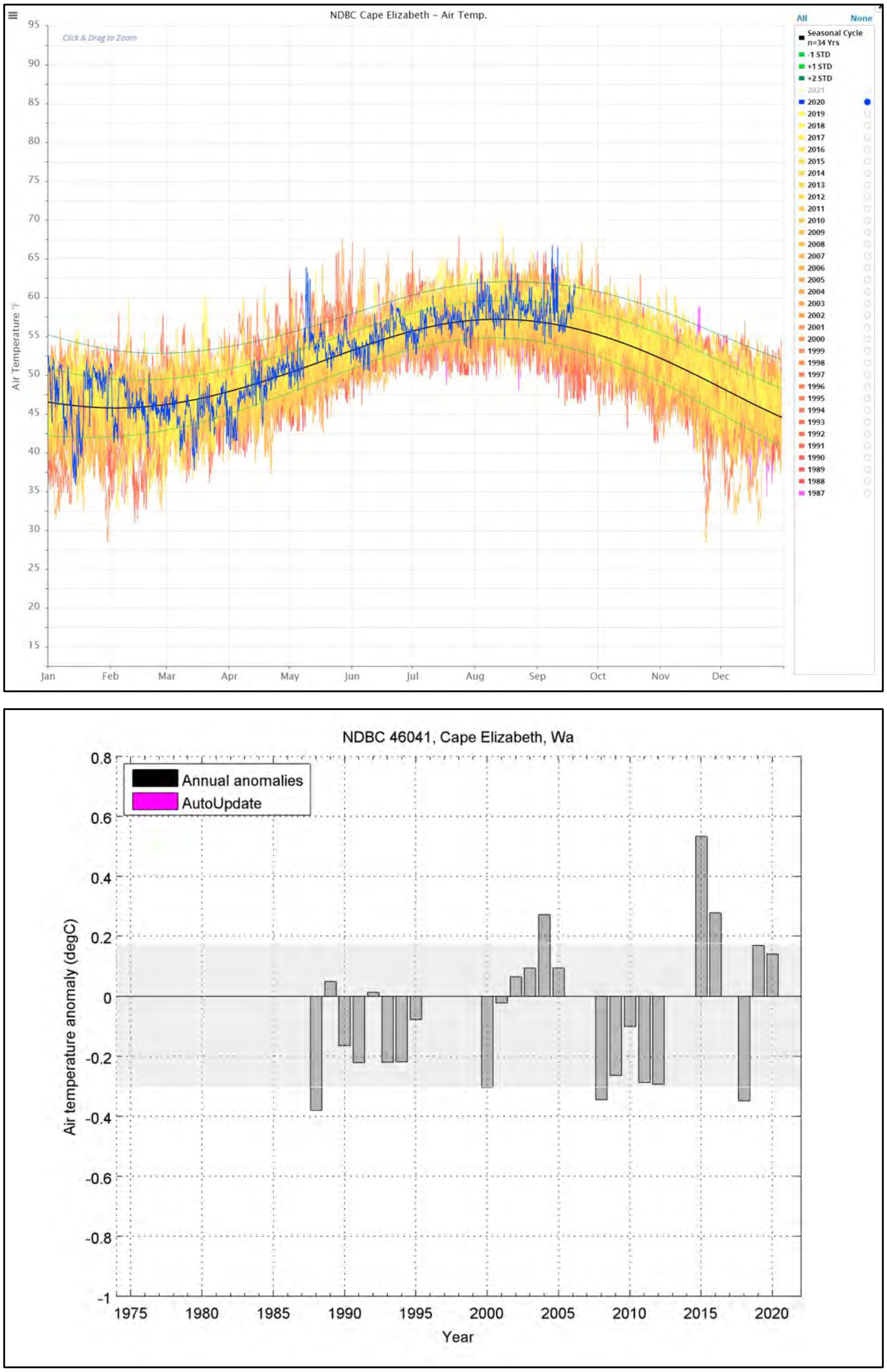


Figure App.S.WQ.8.5. Cape Elizabeth (NDBC 46041) air temperature seasonal variability (left) and annual anomalies (right) in OCNMS, 1987–2020. In the left panel, data from 2020 are shown in red for comparison to previous data, with more recent years shown in blue transitioning to green for earlier years. The black line denotes mean daily value over the complete time series, blue lines depict one standard deviation, and the pink line represents +2 standard deviations. Source: NDBC; Image: NANOOS, 2020

Appendix E:
Additional Living Resources Figures

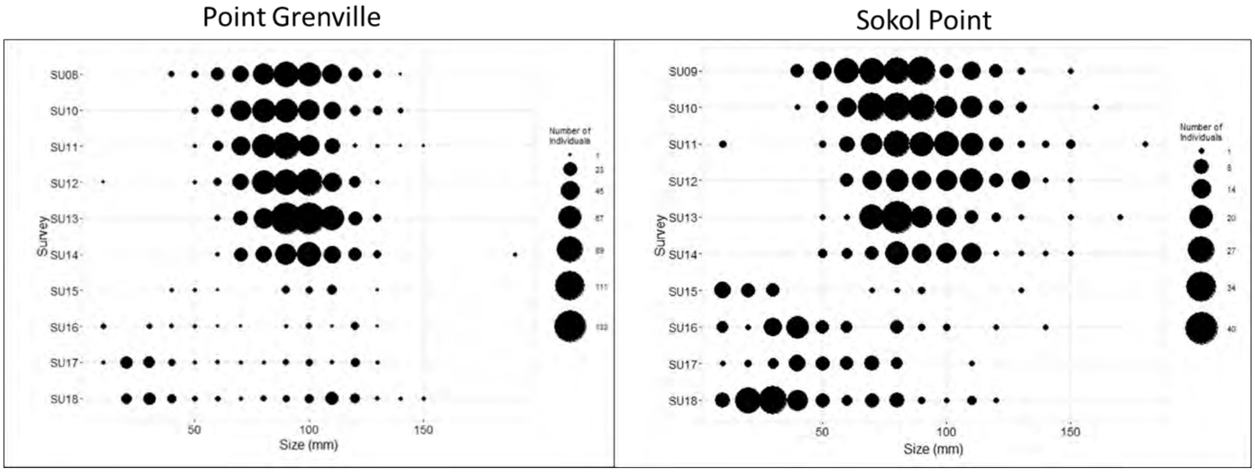


Figure App.S.LR.12.1. Size structure (radius from center of star to tip of arm in mm) of *Pisaster ochraceus* populations in rocky shore habitats at Point Grenville from 2008–2018 and Sokol Point from 2009–2018. Note that values for graduated circles differ between panels. Size structure data are also available for Point of Arches, Kydikabbit, Taylor Point, and Starfish Point. Source: MARINe, 2019; Image: M. Miner/University of California, Santa Cruz

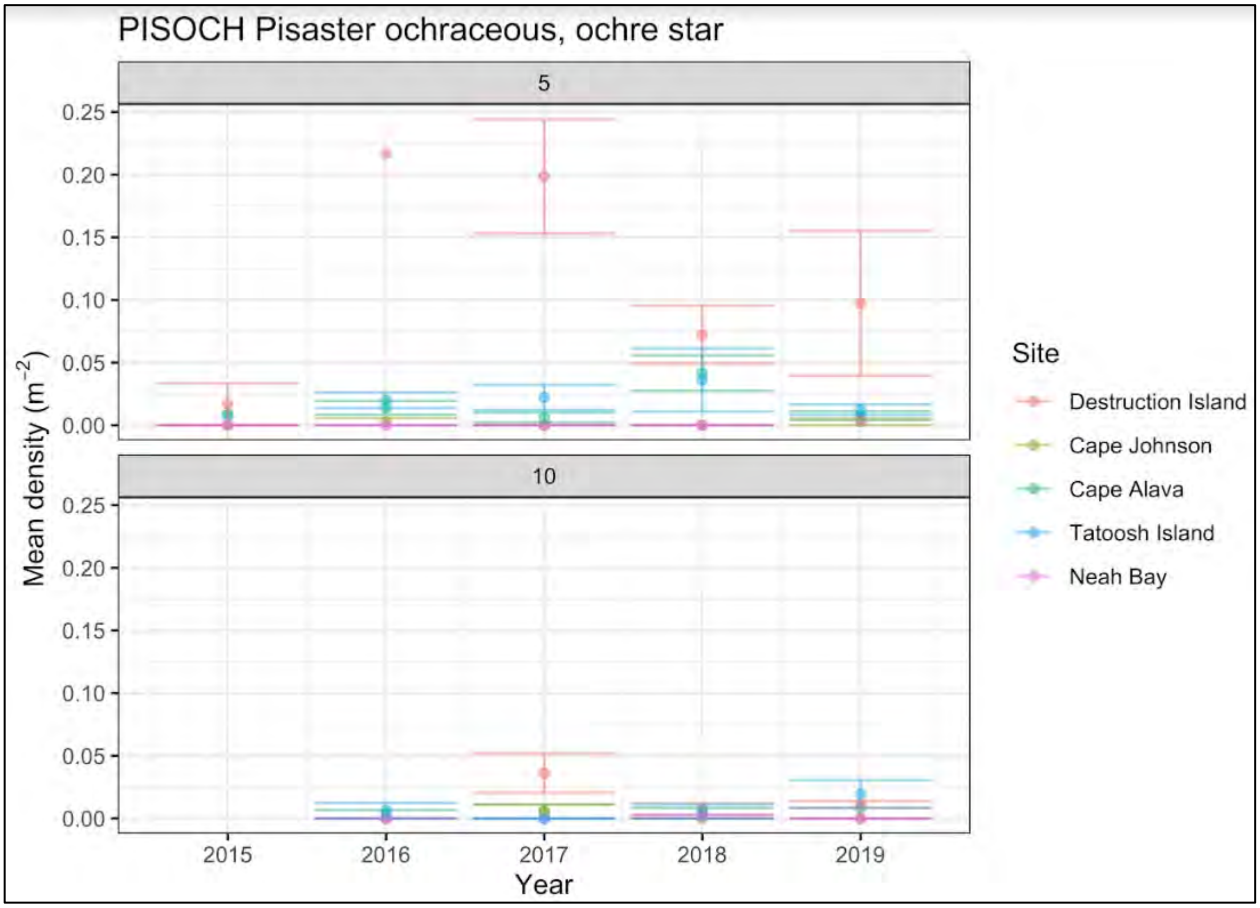


Figure App.S.LR.12.2. Average density of *Pisaster ochraceus* in kelp forest habitats from 2015–2019 at 5 m (top) and 10 m (bottom) depths from Destruction Island to Neah Bay, Washington. Mean density at 5m sites was higher at Destruction Island than at other 5m sites surveyed between 2015 and 2019; mean density among 10m sites was highest at Destruction Island in 2017. Source: NOAA; Image: G. Williams/NOAA

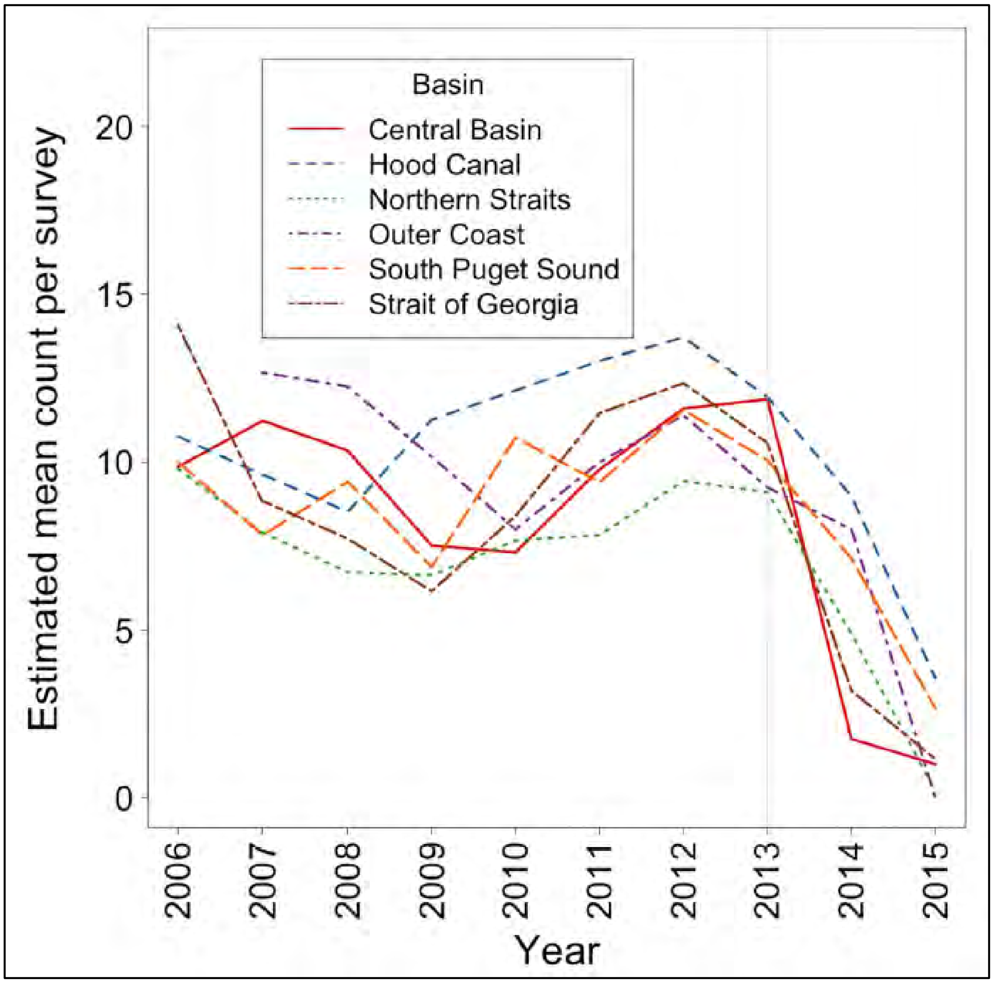


Figure App.S.LR.12.3a. Average counts of *Pycnopodia helianthoides* in rocky, shallow (5–30 m) habitats from 2006–2015 for Washington state. The dashed purple line denotes mean counts for the Washington outer coast from Cape Flattery to the Columbia River. Source: Reef Environmental Education Foundation, 2020; Image: Montecino-Latorre et al., 2016

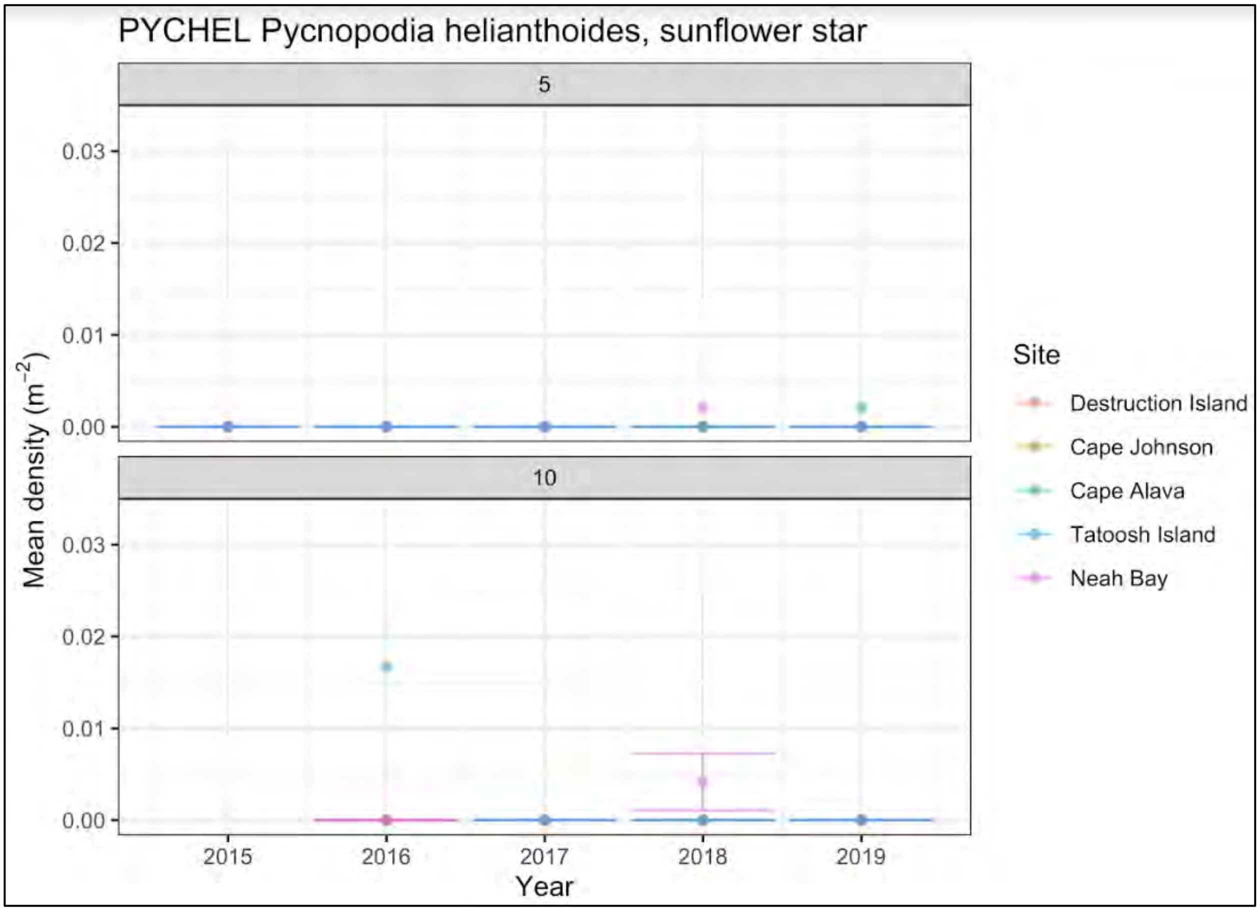


Figure App.S.LR.12.3b. Average density of *Pycnopodia helianthoides* in kelp forest habitats from 2015–2019 at 5 m (top) and 10 m (bottom) depths from Destruction Island to Neah Bay, Washington. Mean density among 5m sites was higher at Neah Bay in 2018 and at Cape Alava in 2019. Mean density among 10m sites was higher at Tatoosh Island in 2016 and at Neah Bay in 2018. Source: NOAA; Image: G. Williams/NOAA

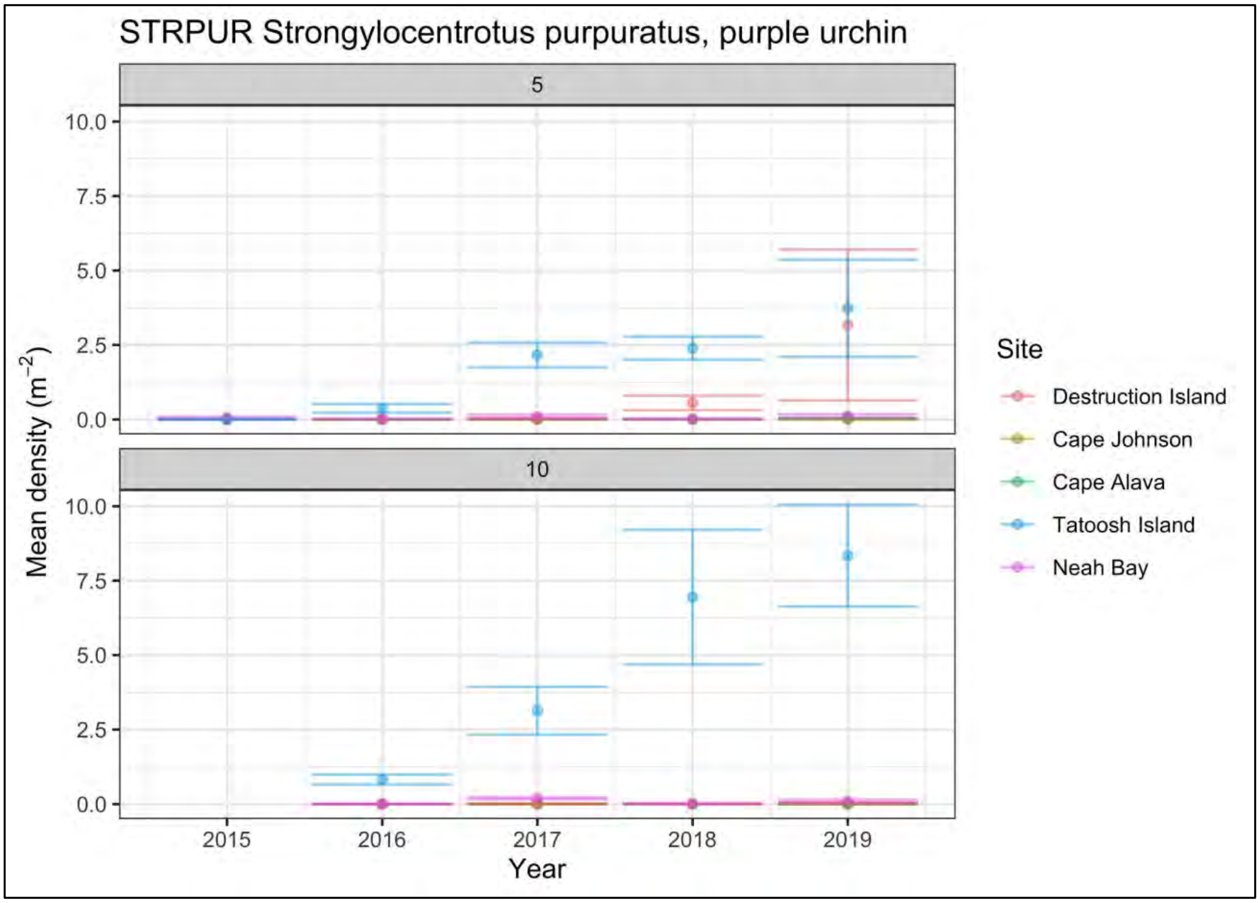


Figure App.S.LR.12.4. Average density of purple sea urchins from 2015–2019 at 5 m (top) and 10 m (bottom) depths from Destruction Island to Neah Bay, Washington. Mean density was higher at Tatoosh Island at both 5 m and 10 m depths from 2016-2019 compared to other sites. In 2019, the mean density of purple urchins at 5m sites at Tatoosh Island was similar to the mean density of urchins at 5m sites near Destruction Island in 2019. Source: NOAA; Image: G. Williams/NOAA

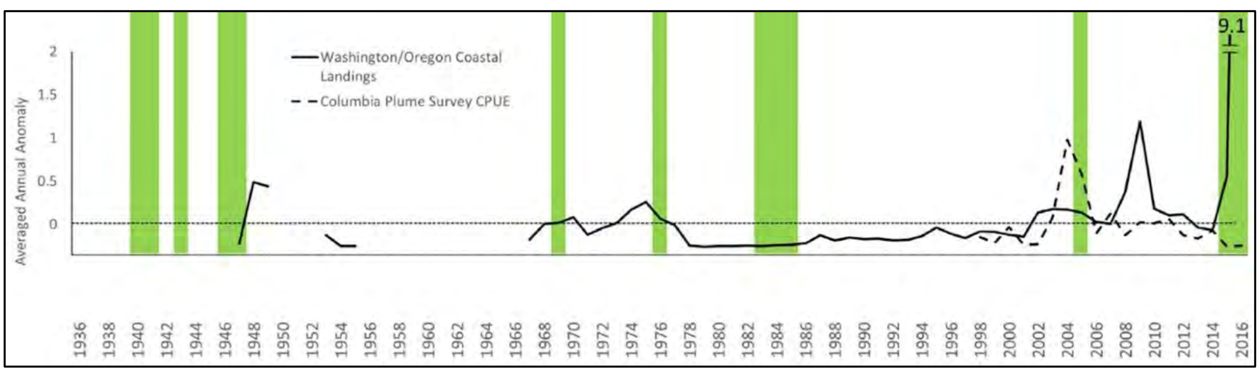


Figure App.S.LR.12.5. Abundance anomalies for northern anchovy *Engraulis mordax* off Washington and Oregon from 1936 to 2016. Green bars indicate more than two datasets show a positive anomaly. Image: Duguid et al., 2019

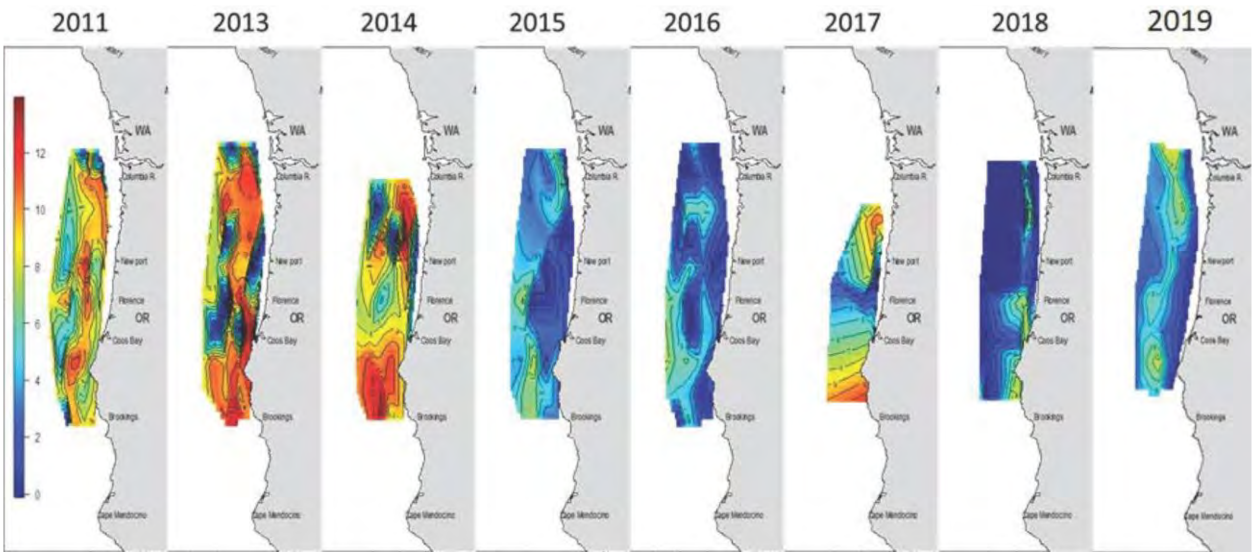


Figure App.S.LR.12.6. Distributions of northern Pacific krill *Euphausia pacifica* off Oregon and southern Washington from May/June 2011–2019. Colors represent catch per unit effort per standardized tow. Source: R. Brodeur/NOAA; Image: Harvey et al., 2020

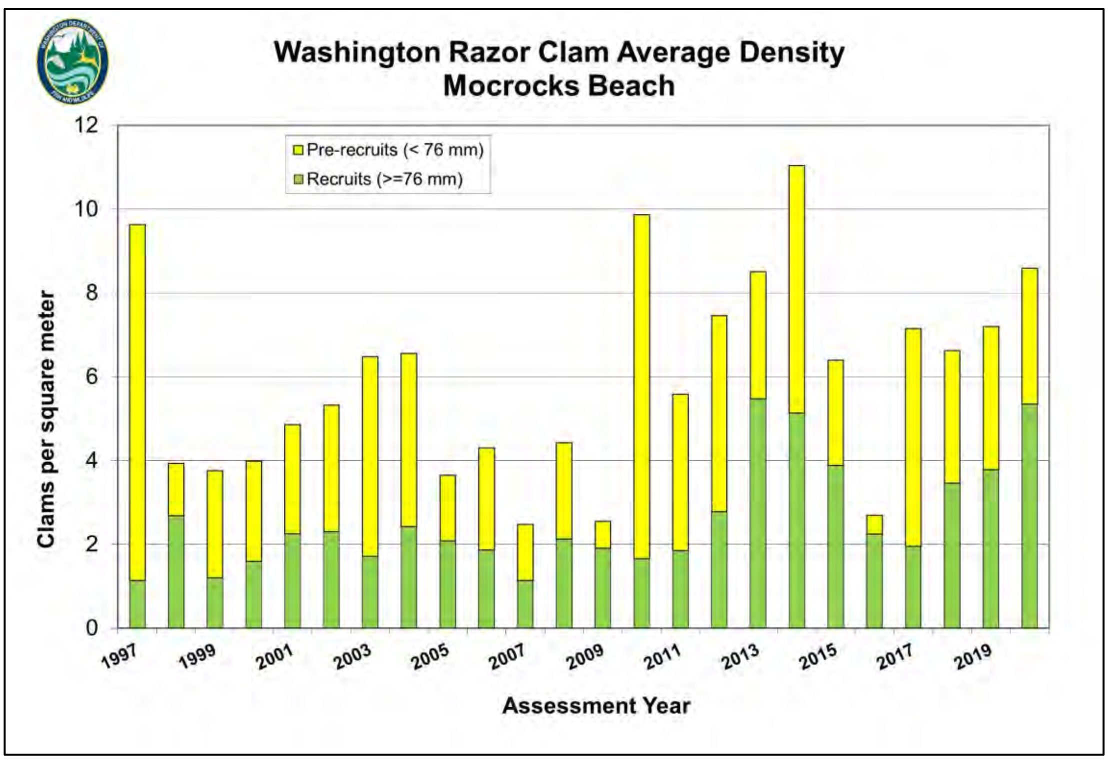


Figure App.S.LR.13.1. Average density of razor clam recruits and pre-recruits at Mocrocks Beach from 1997–2020. The Mocrocks razor clam management beach lies between the Copalis River and the southern boundary of the Quinault Indian Reservation, just south of the Moclips River. Pre-recruits are below the preferable catch size and recruits are above the preferable catch size. Source: WDFW, 2020; Quinault Tribe, 2020; Image: D. Ayres/WDFW

Figure App.S.LR.13.2. Purple olive snail (*Olivella biplicata*) densities (count/m^2) at northern Hobuck Beach, Makah Bay from 2014–2017. Source: Makah Tribe; Image: Akmajian et al., 2017

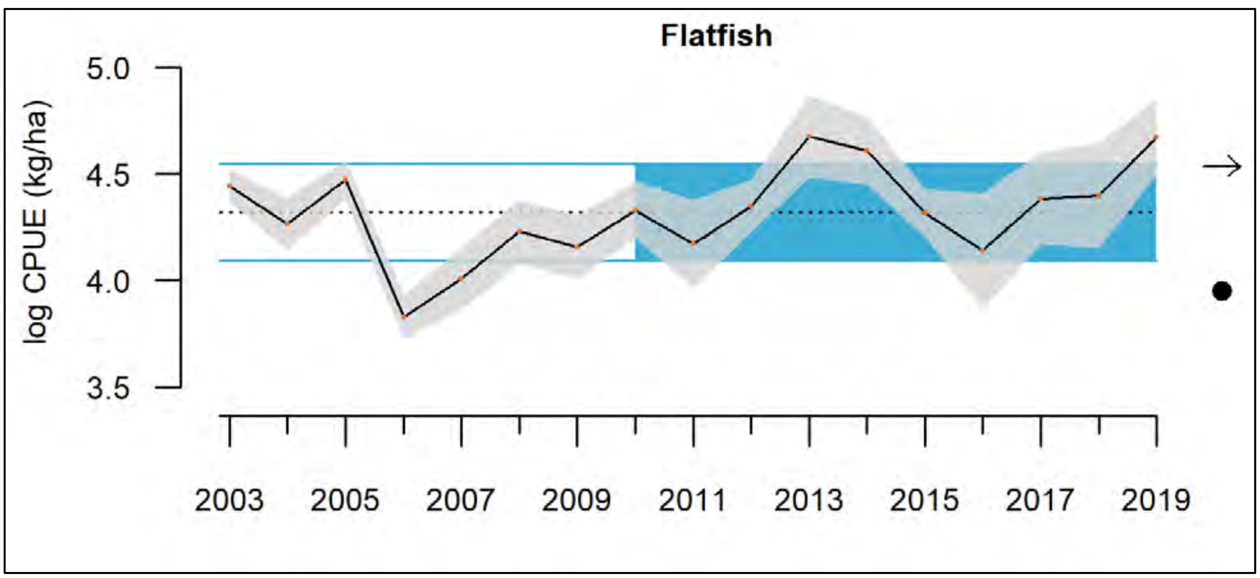


Figure App.S.LR.13.3. Log catch per unit effort from scientific bottom trawling for flatfish from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation compared to the long-term mean.The horizontal arrow (→) indicates no change in the 10-year trend. Source: CCIEA, 2021; Image: G. Williams/NOAA

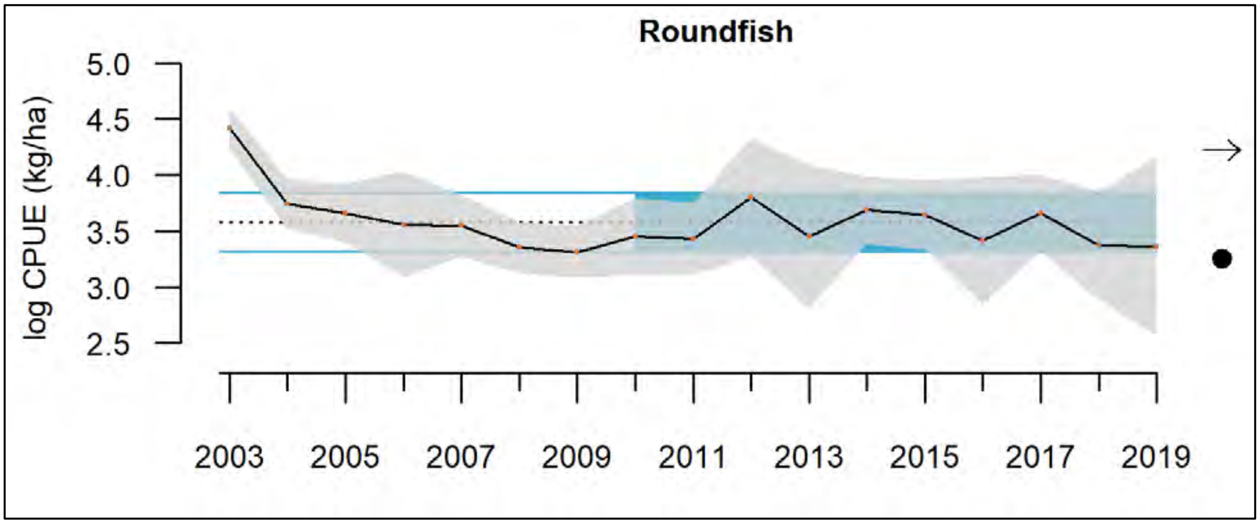


Figure App.S.LR.13.4. Log catch per unit effort from scientific bottom trawling for roundfish from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean.The horizontal arrow (→) indicates no change in the 10-year trend. Source: CCIEA, 2021; Image: G. Williams/NOAA

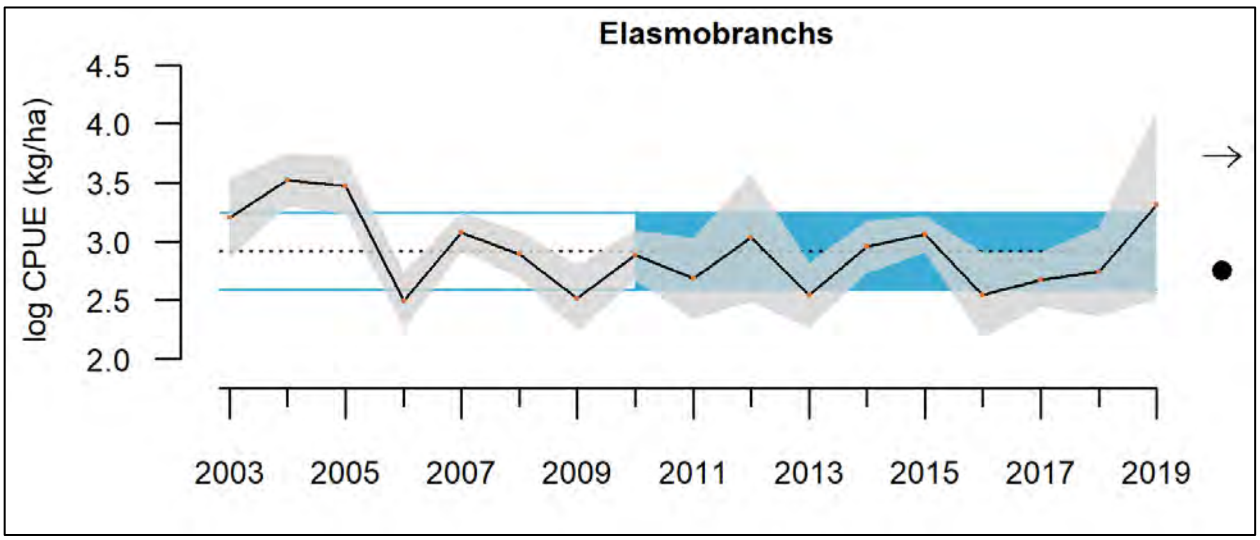


Figure App.S.LR.13.5. Log catch per unit effort from scientific bottom trawling for sharks and skates (elasmobranchs) from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean.The horizontal arrow (→) indicates no change in the 10-year trend. Source: CCIEA, 2021; Image: G. Williams/NOAA

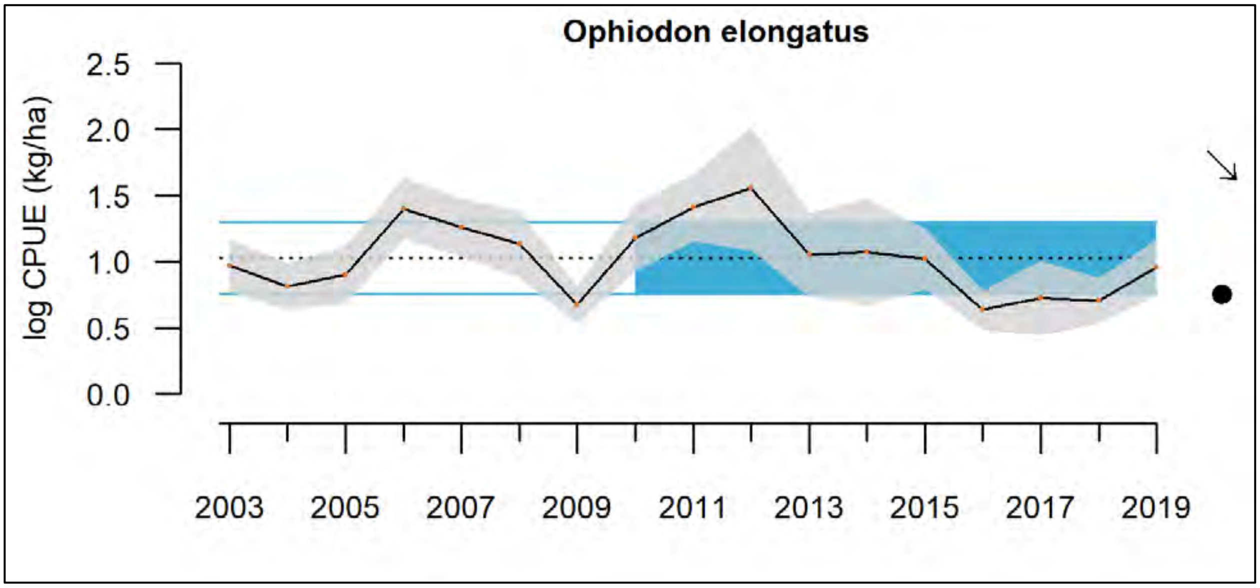


Figure App.S.LR.13.6. Log catch per unit effort from scientific bottom trawling for lingcod (*Ophiodon elongatus*) from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean.The declining arrow (↘) indicates a decreasing 10-year trend. Source: CCIEA, 2021; Image: G. Williams/NOAA

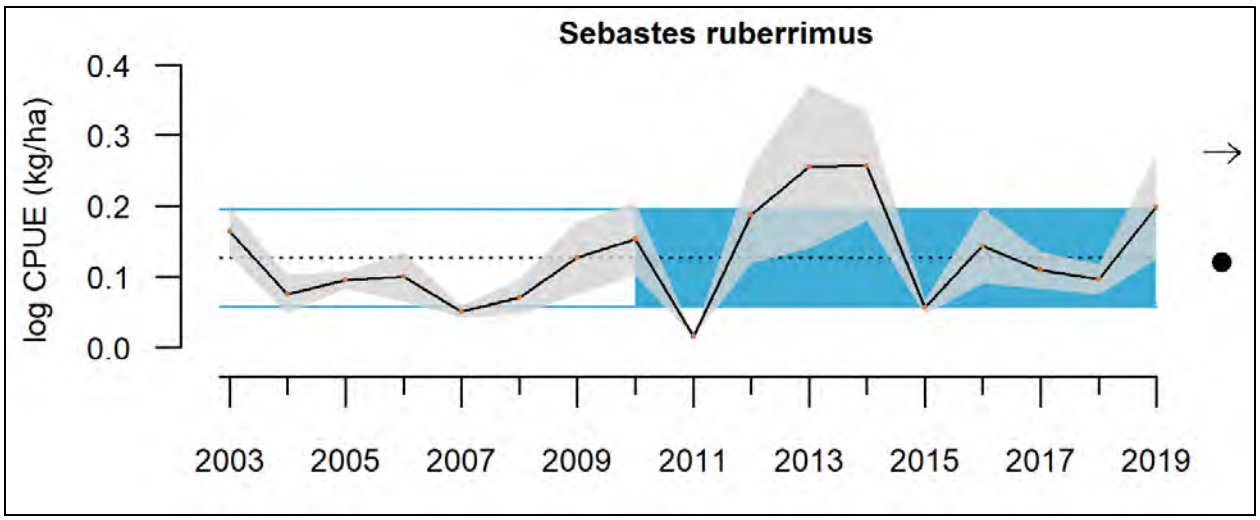


Figure App.S.LR.13.7. Log catch per unit effort from scientific bottom trawling for yelloweye rockfish (Sebastes ruberrimus) from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean.The horizontal arrow (→) indicates no change in the 10-year trend. Source: CCIEA, 2021; Image: G. Williams/NOAA

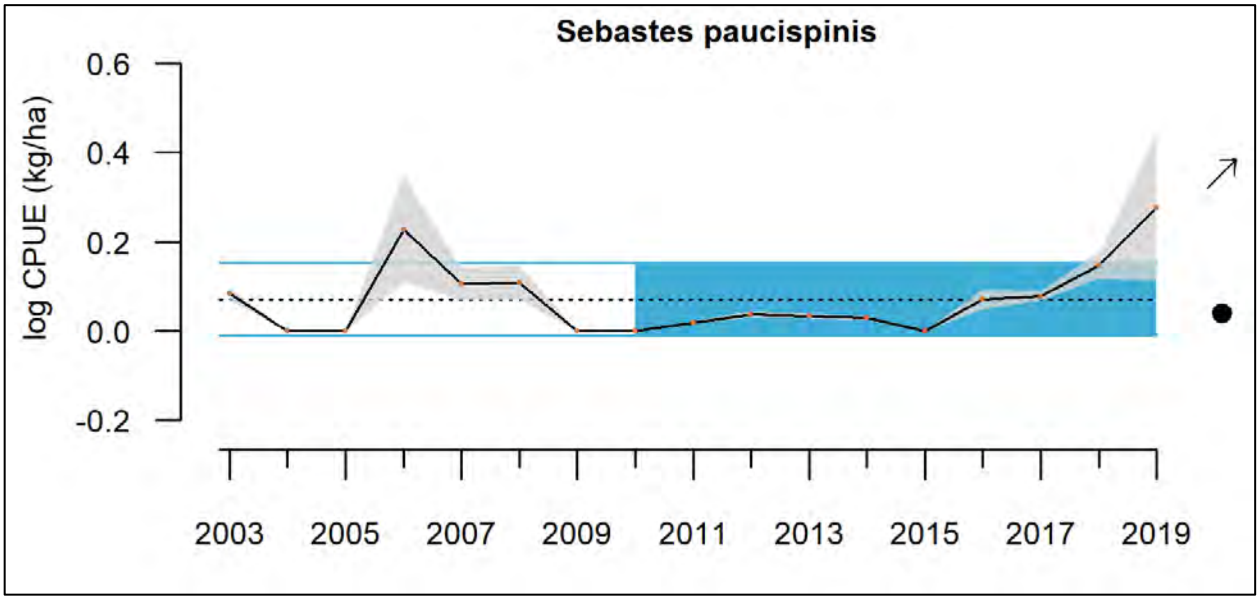


Figure App.S.LR.13.8. Log catch per unit effort from scientific bottom trawling for bocaccio (*Sebastes paucispinis*) from 2003–2019 in OCNMS. Data are from coastwide bottom trawl surveys conducted by NWFSC for groundfish stock assessments. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean. The upward arrow (↗) indicates an increasing 10-year trend. Source: CCIEA, 2021; Image: G. Williams/NOAA

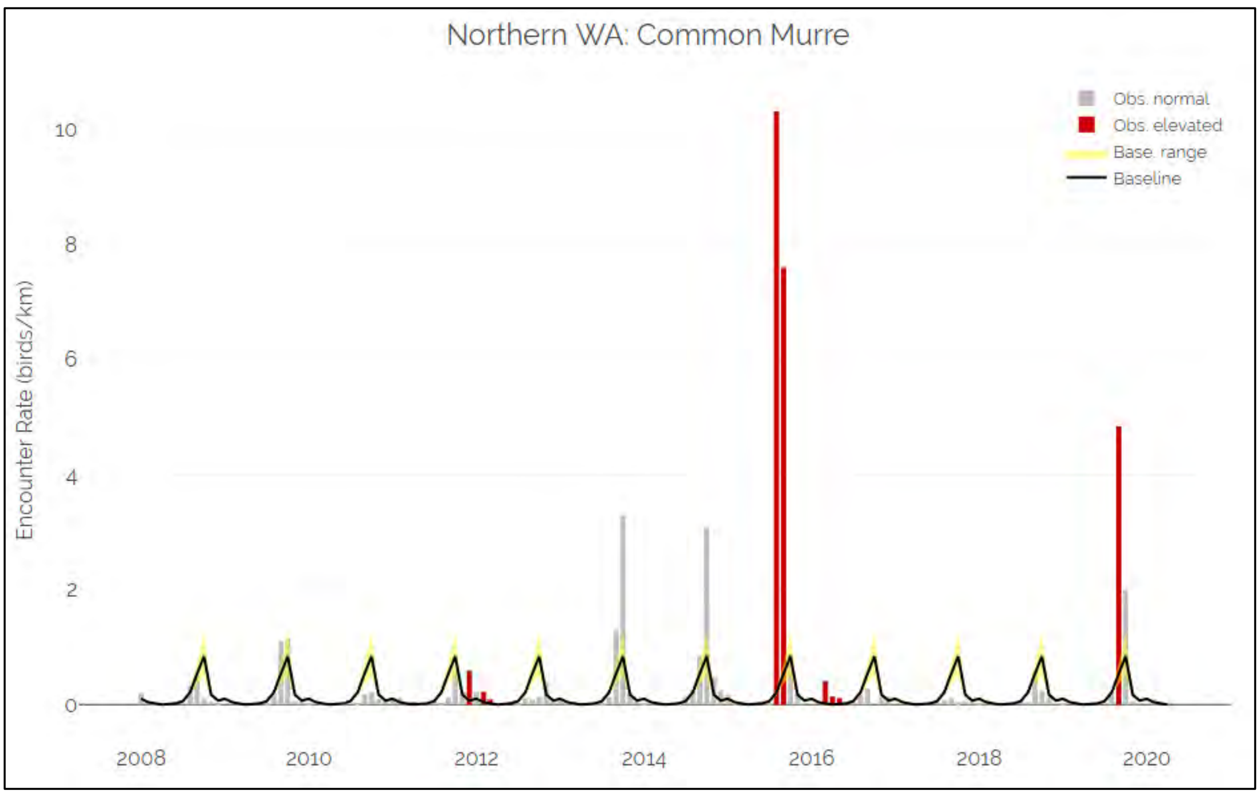


Figure App.S.LR.13.9. Encounter rates for dead common murres (*Uria aalge*) from 2008–2020 for northern Washington. Image: COASST, 2020

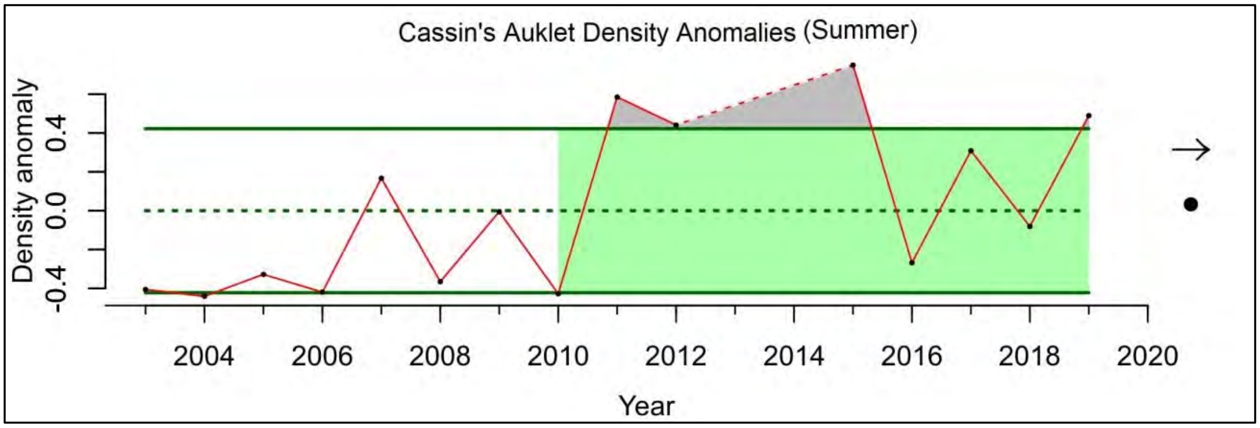


Figure App.S.LR.13.10. Density anomalies (number of birds per km^2) for Cassin's auklet (*Ptychoramphus aleuticus*) from Newport, Oregon to Cape Flattery, Washington during the summer from 2003–2019. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean.The horizontal arrow (→) indicates no change in the 10-year trend. Source: NOAA; J. Zamon/NOAA; Image: CCIEA, 2019

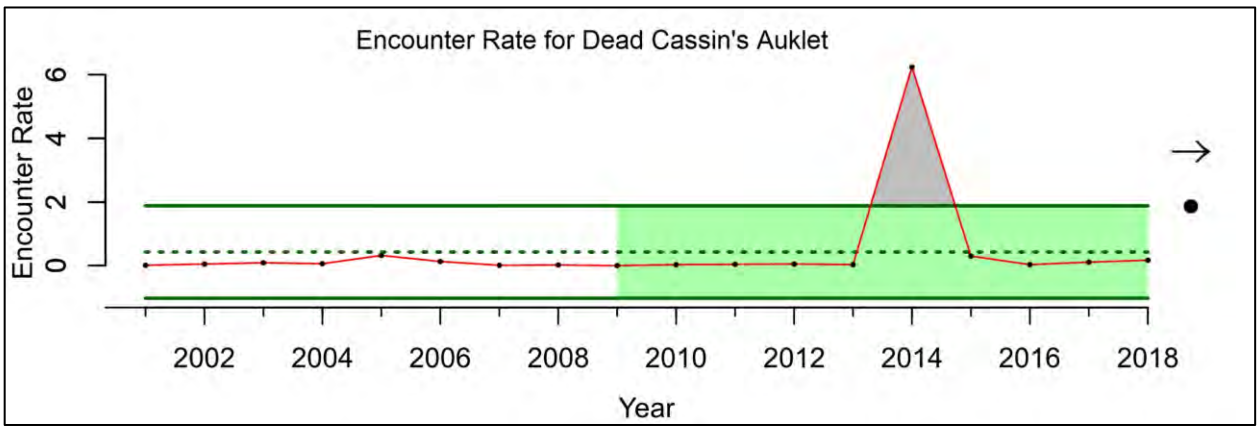


Figure App.S.LR.13.11. Encounter rates for dead Cassin's auklets (*Ptychoramphus aleuticus*) from 2001–2018 from the California-Oregon border to Cape Flattery, Washington. The black dot (●) indicates that the 10-year mean (2010–2019, shaded in blue) is within one standard deviation of the long-term mean.The horizontal arrow (→) indicates no change in the 10-year trend. Source: COASST, 2020; Image: CCIEA, 2019

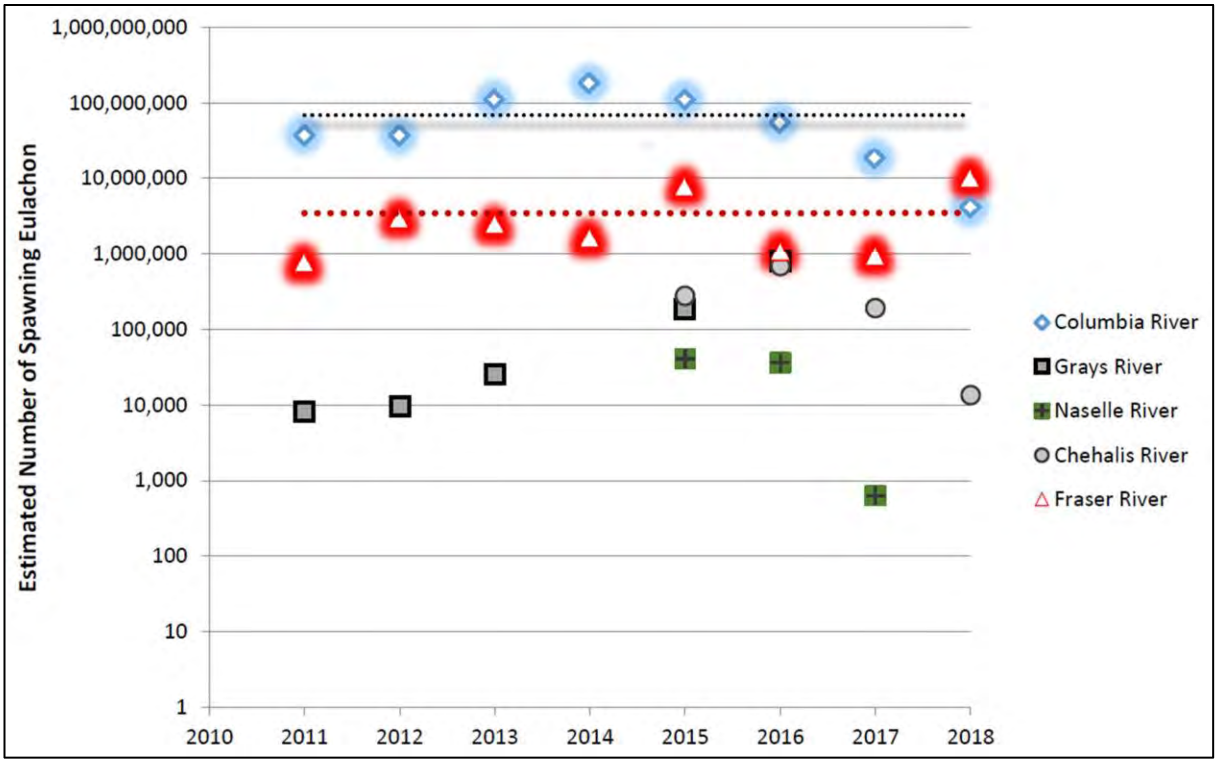


Figure App.S.LR.13.12. Comparison of estimated number of eulachon (*Thaleichthys pacificus*) spawning in Columbia, Fraser, Chehalis, Naselle, and Grays rivers from 2011–2018. Image: Langness et al., 2018

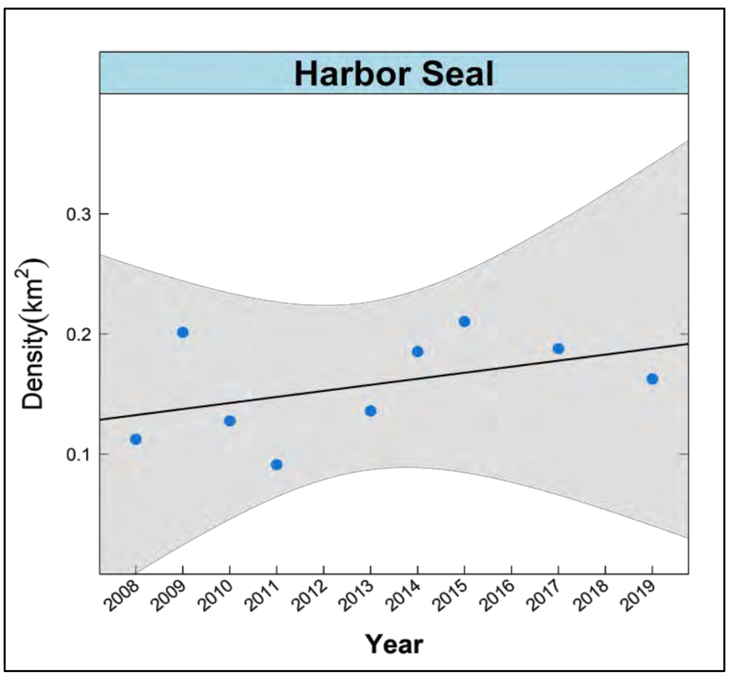


Figure App.S.LR.13.13. Estimated density of Pacific harbor seals (*Phoca vitulina*) from at-sea surveys on the outer Washington coast from (May–July) 2008–2019. Each dot represents the estimated annual density (number of seals per km^2) along the Washington coast. The black line is the estimated linear trend across the time series. Gray band is the 95% confidence interval of the trend. Image: S. Pearson/WDFW

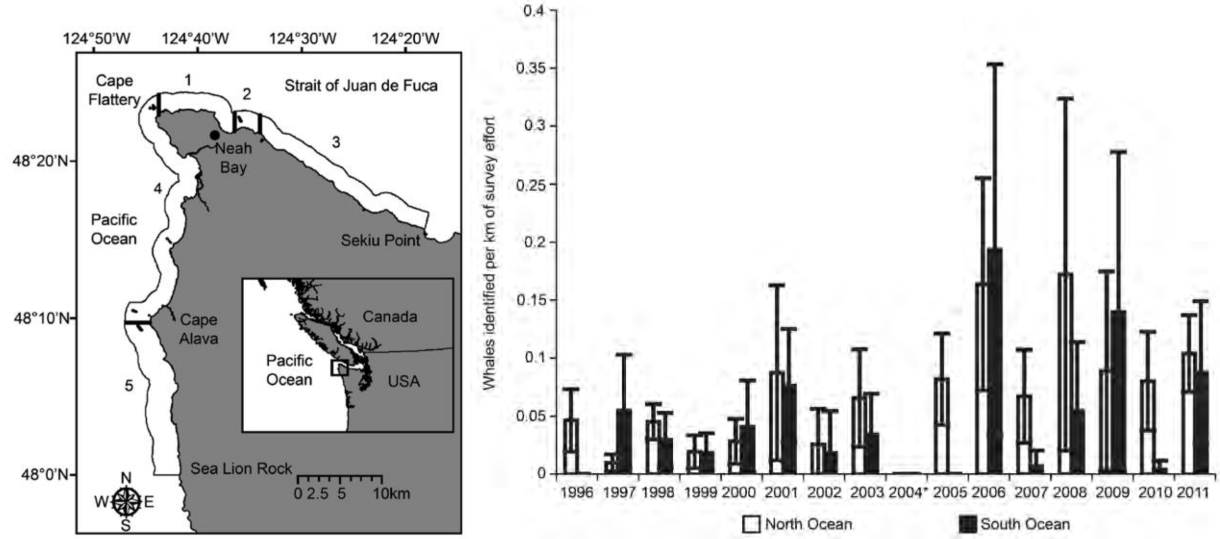


Figure App.S.LR.13.14. Map of gray whale (*Eschrichtius robustus*) survey region, including region 4 (North Ocean) and region 5 (South Ocean) (left). Average observation rates by year for gray whales (per km2) in North and South Ocean regions from June to November, 1996–2011 (right). Error bars represent two times standard error. *No surveys were conducted in 2004. Image: Scordino et al., 2017

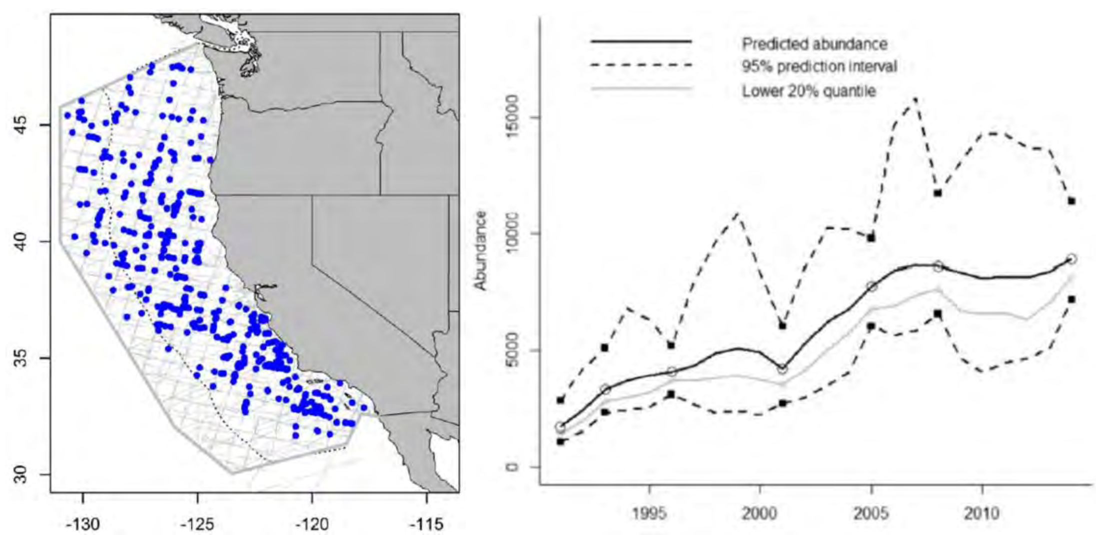


Figure App.S.LR.13.15. Fin whale (*Balaenoptera physalus*) sightings from shipboard surveys on the U.S. West Coast, 1991–2014 (left). Fin whale abundance estimates on the U.S. West Coast, 1991–2014 (right). Image: (left) Carretta et al., 2020; (right) Nadeem et al., 2016

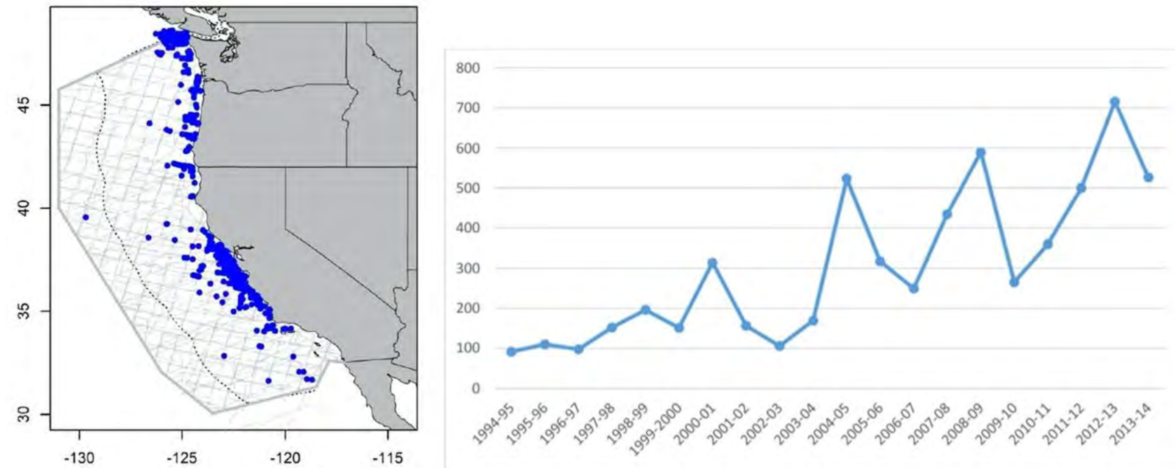


Figure App.S.LR.13.16. Humpback whale (*Megaptera novaeangliae*) sightings from shipboard surveys on the U.S. West Coast, 1991–2014 (left). Humpback whale abundance estimates off Washington and southern British Columbia (right). Image: (left) Carretta et al., 2020; (right) Calambokidis et al., 2017

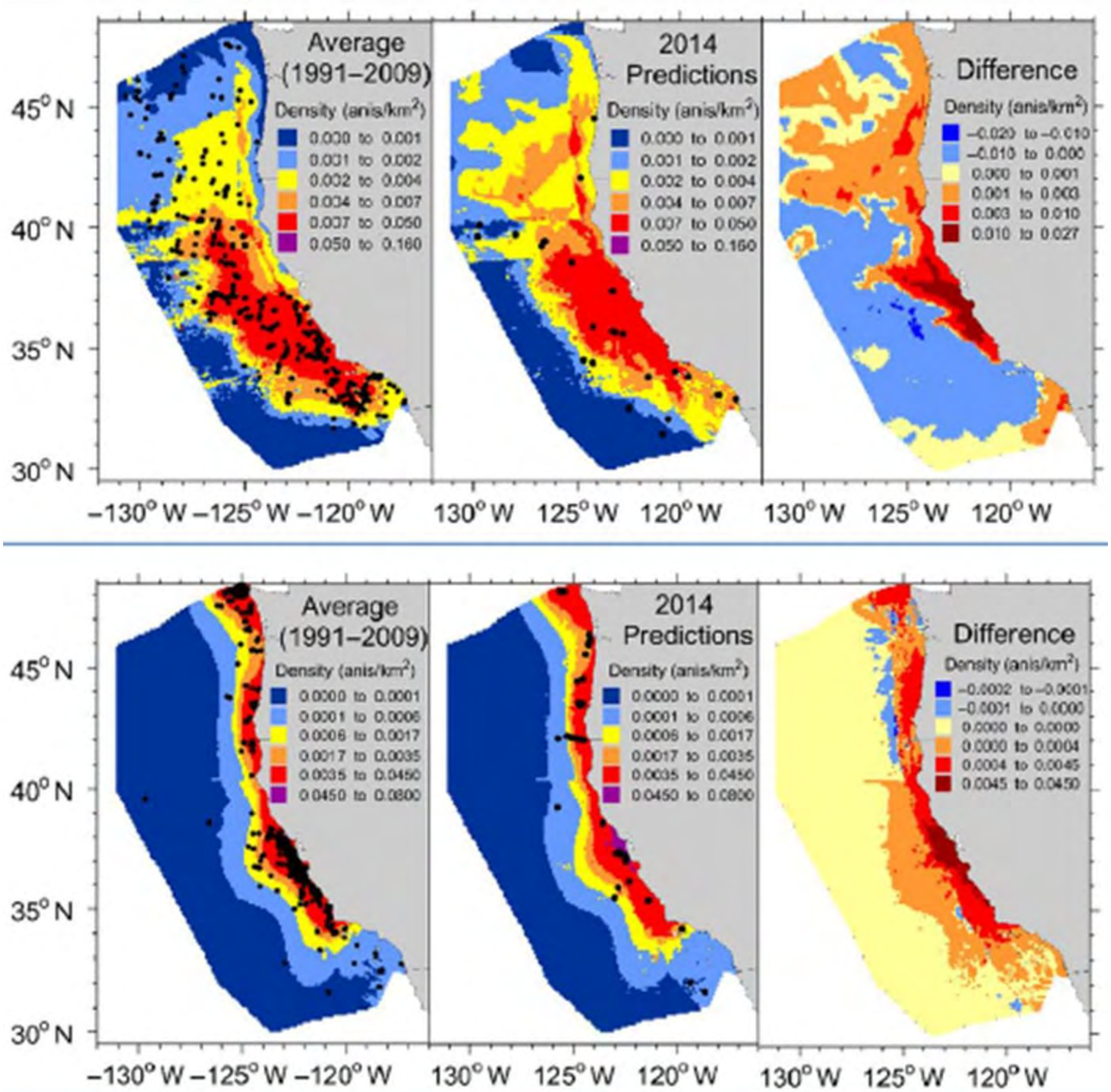


Figure App.S.LR.13.17. Predicted mean densities from 1991–2009 habitat-based density models compared to novel 2014 summer/fall density predictions for fin whales (*Balaenoptera physalus*) (top) and humpback whales (*Megaptera novaeangliae*) (bottom). Left panels show the average prediction for 1991–2009, middle panels show predictions for 2014, and right panels show the difference between the two predictions. Image: Becker et al., 2019

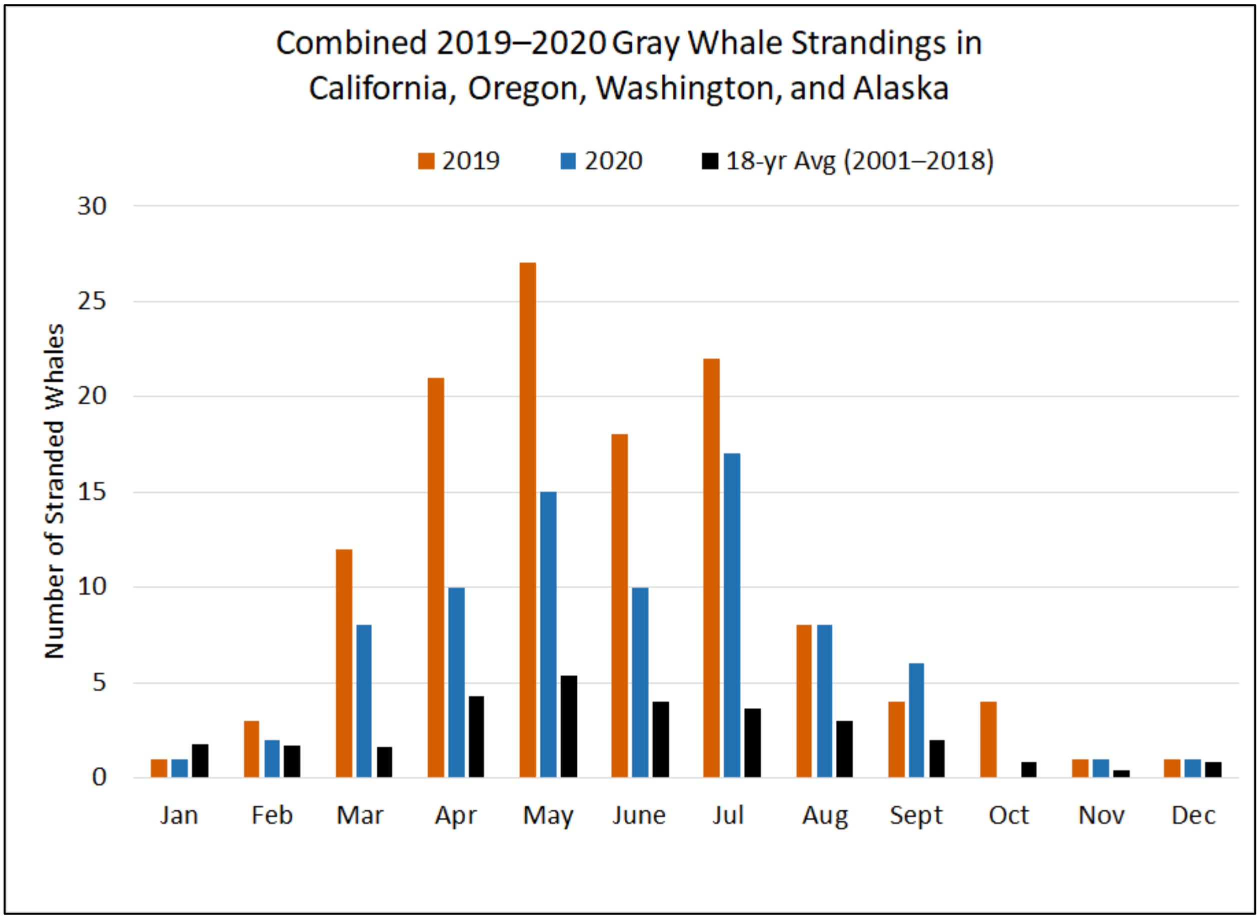


Figure App.S.LR.13.18. Combined 2019–2020 gray whale (*Eschrichtius robustus*) strandings by month in California, Oregon, Washington, and Alaska. Image: D. Fauquier/NOAA

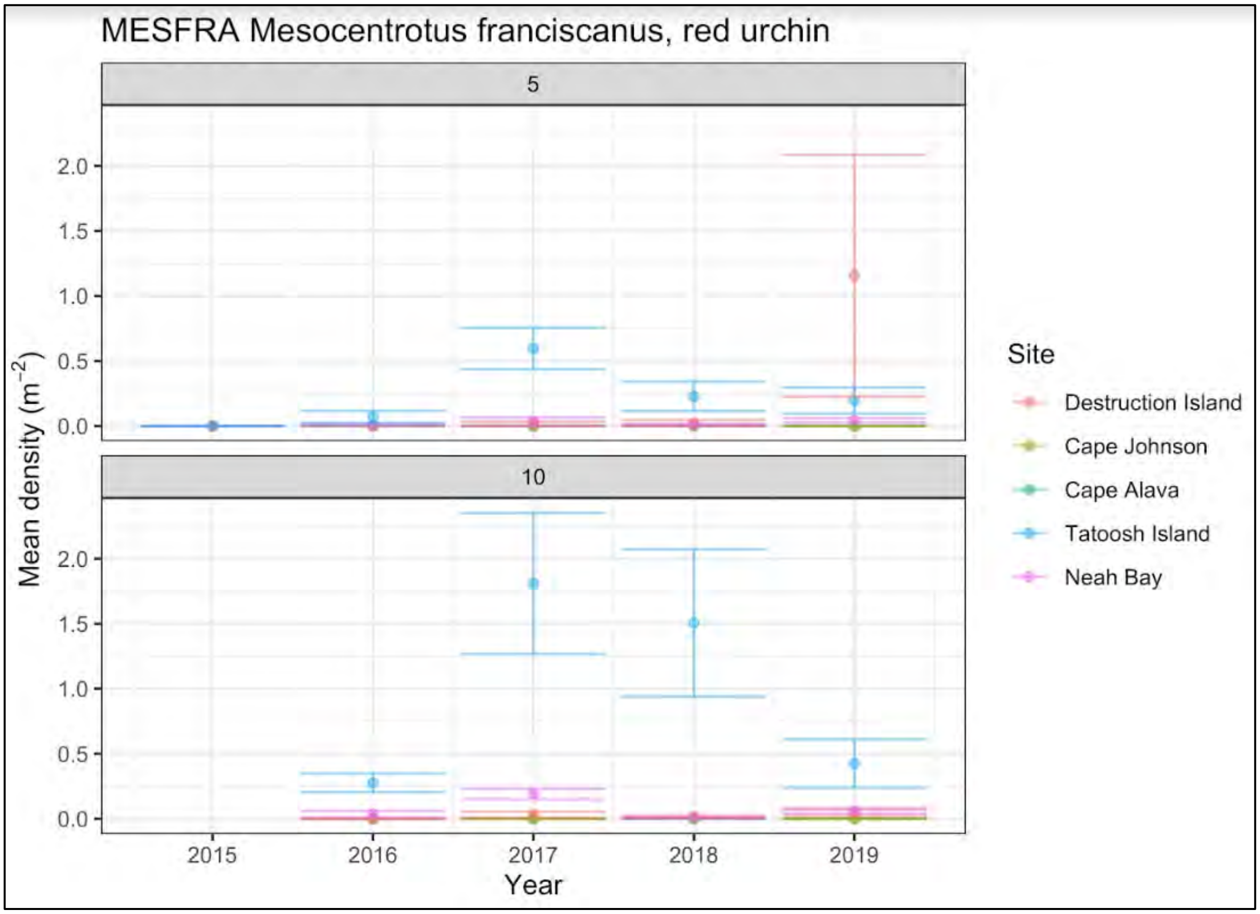


Figure App.S.LR.13.19. Average density of red sea urchins (*Mesocentrotus franciscanus*) (per m2) from 2015–2019 at 5 m (top) and 10 m (bottom) depths for Destruction Island to Neah Bay, Washington. Mean density of red sea urchins at 10 m sites was consistently higher at Tatoosh Island compared to other sites. Source: NWFSC; Image: G. Williams/NOAA

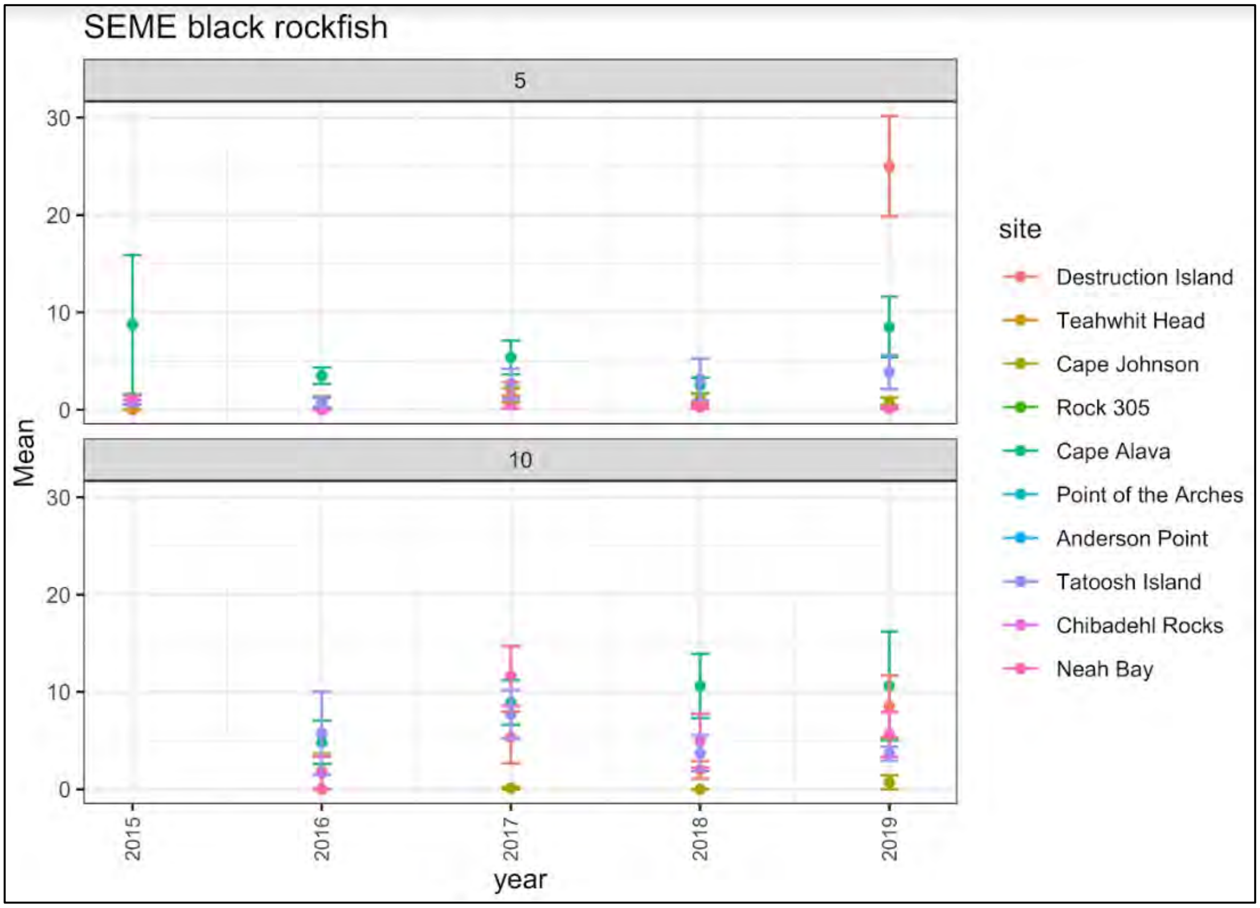


Figure App.S.LR.13.20. Average abundance of black rockfish (*Sebastes melanops*) from 2015–2019 at 5 m (top) and 10 m (bottom) depths for Destruction Island to Neah Bay, Washington. Rockfish average abundance at all sampling sites is variable at both depths over time. Source: NWFSC; Image: G. Williams/NOAA

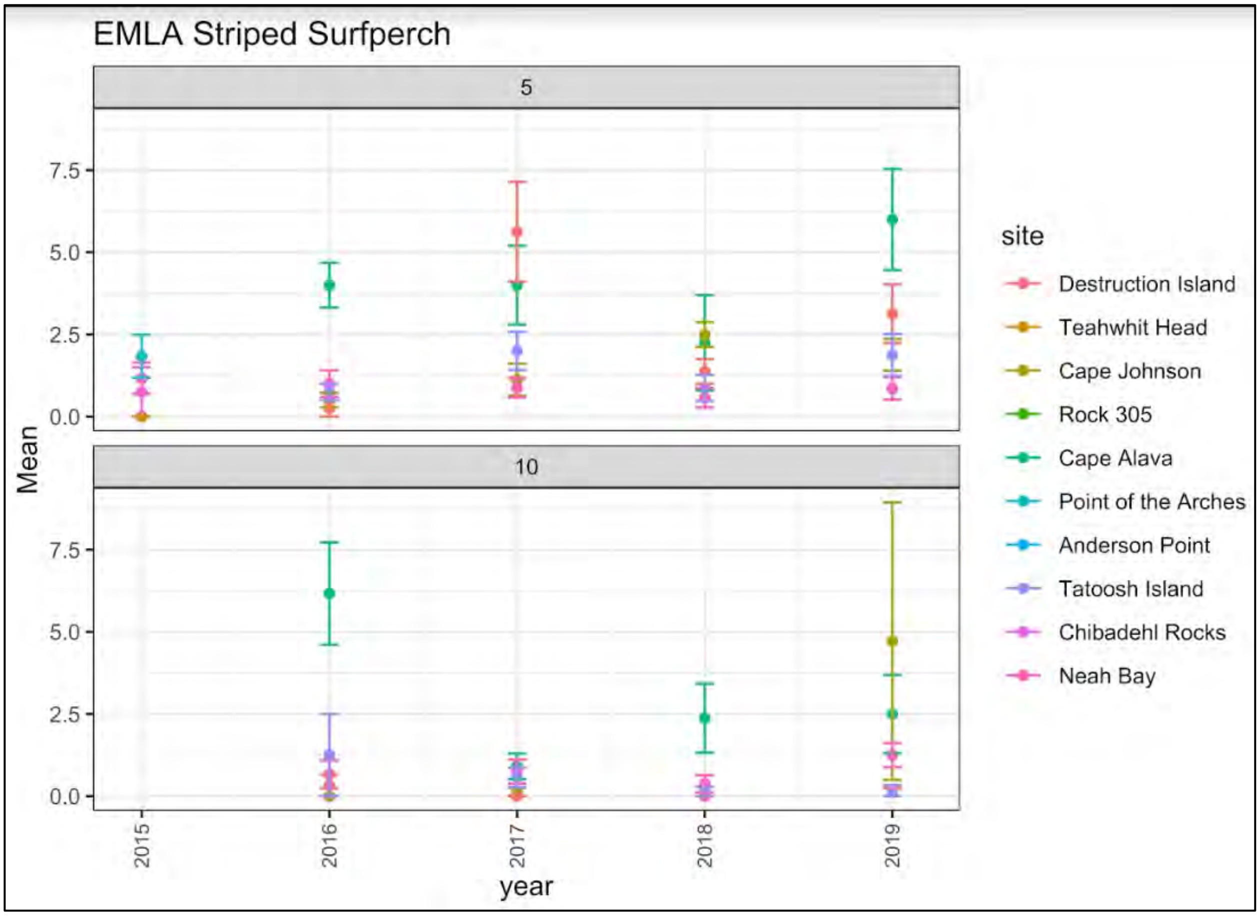


Figure App.S.LR.13.21. Average abundance of striped surfperch (*Embiotoca lateralis*) from 2015–2019 at 5 m (top) and 10 m (bottom) depths for Destruction Island to Neah Bay, Washington. Striped surfperch average abundance at all sampling sites is variable at both depths over time. Source: NWFSC; Image: G. Williams/NOAA

Appendix F:
Additional Ecosystem Services Figures

Additional Consumptive Recreation Tables and Figures

Table App.ES.CR.1. Economic contributions from charter fishing boats, 1998–2019. Multipliers for Washington were provided by J. Leonard/NOAA, personal communication, June 16, 2020.

Year	Employment	Income	Output
1998	204.0	$8,416,153	$19,314,325
1999	229.2	$9,455,749	$21,700,106
2000	233.8	$9,644,518	$22,133,316
2001	319.3	$13,170,237	$30,224,527
2002	321.5	$13,262,349	$30,435,917
2003	332.5	$13,713,517	$31,471,308
2004	299.3	$12,345,771	$28,332,452
2005	294.7	$12,156,529	$27,898,158
2006	267.3	$11,023,775	$25,298,589
2007	258.6	$10,666,958	$24,479,725
2008	209.6	$8,644,337	$19,837,987
2009	256.0	$10,560,757	$24,236,002
2010	251.7	$10,382,065	$23,825,920
2011	219.1	$9,038,698	$20,743,013
2012	258.4	$10,658,996	$24,461,451
2013	252.3	$10,407,562	$23,884,434
2014	301.7	$12,446,083	$28,562,658
2015	301.4	$12,431,390	$28,528,940
2016	213.5	$8,805,088	$20,206,897
2017	219.0	$9,034,453	$20,733,271
2018	233.3	$9,623,660	$22,085,447
2019	233.9	$9,646,082	$22,136,904

Table App.ES.CR.2. Economic contributions from private fishing boats, 1998–2019. Multipliers for Washington were provided by J. Leonard/NOAA personal communication, June 16, 2020.

Year	Employment	Income	Output
1998	48.7	$3,255,658	$8,733,674
1999	52.9	$3,538,377	$9,492,100
2000	54.3	$3,633,946	$9,748,477
2001	85.7	$5,732,292	$15,377,529
2002	70.9	$4,740,581	$12,717,150
2003	86.6	$5,788,955	$15,529,535
2004	88.6	$5,928,719	$15,904,466
2005	80.0	$5,350,184	$14,352,482
2006	61.5	$4,115,277	$11,039,701
2007	63.9	$4,272,720	$11,462,060
2008	51.0	$3,413,559	$9,157,263
2009	83.7	$5,596,189	$15,012,417
2010	81.1	$5,425,740	$14,555,169
2011	81.5	$5,452,188	$14,626,120
2012	91.3	$6,105,564	$16,378,873
2013	96.9	$6,483,293	$17,392,175
2014	116.2	$7,769,840	$20,843,484
2015	105.2	$7,033,373	$18,867,827
2016	73.7	$4,928,309	$13,220,754
2017	84.1	$5,624,999	$15,089,704
2018	77.7	$5,199,279	$13,947,660
2019	87.9	$5,882,117	$15,779,452

Table App.ES.CR.3. Charter fishing boat landings by species in OCNMS, 1998–2019. Source: E. Crust/WDFW, personal communication, December 18, 2020

Species	Charter Quantity Kept	Percent of Total Fish Kept
Black rockfish	2,948,521	72.3%
Yellowtail rockfish	379,643	9.3%
Lingcod	309,495	7.6%
Tuna	205,163	5.0%
Halibut	70,296	1.7%
Miscellaneous	32,208	0.8%
Canary rockfish	28,764	0.7%
Flatfish	28,576	0.7%
Blue rockfish	15,044	0.4%
Quillback rockfish	14,517	0.4%
Other	44,922	1.1%
Total	4,077,149	100.0%

Table App.ES.CR.4. Private fishing boat landings by species in OCNMS, 1998–2019. Source: E. Crust/WDFW, personal communication, December 18, 2020

Species	Quantity Kept	Percent of Total Fish Kept
Black rockfish	1,661,691	63.3%
Lingcod	287,114	10.9%
Tuna	150,542	5.7%
Halibut	108,928	4.1%
Kelp greenling	79,765	3.0%
Yellowtail rockfish	60,806	2.3%
China rockfish	50,305	1.9%
Cabezon	46,836	1.8%
Blue rockfish	32,873	1.3%
Quillback rockfish	27,563	1.0%
Other	119,359	4.5%
Total	2,625,782	100.0%

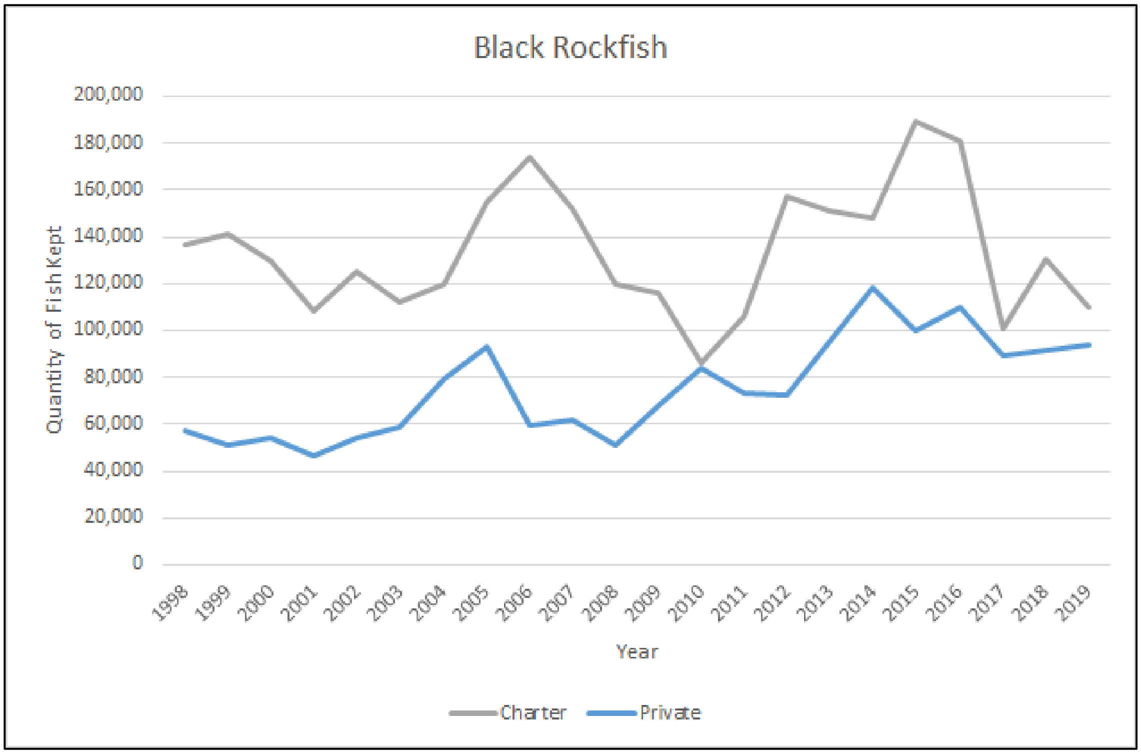


Figure App.ES.CR.1. Quantity of black rockfish kept for charter and private boats in statistical areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

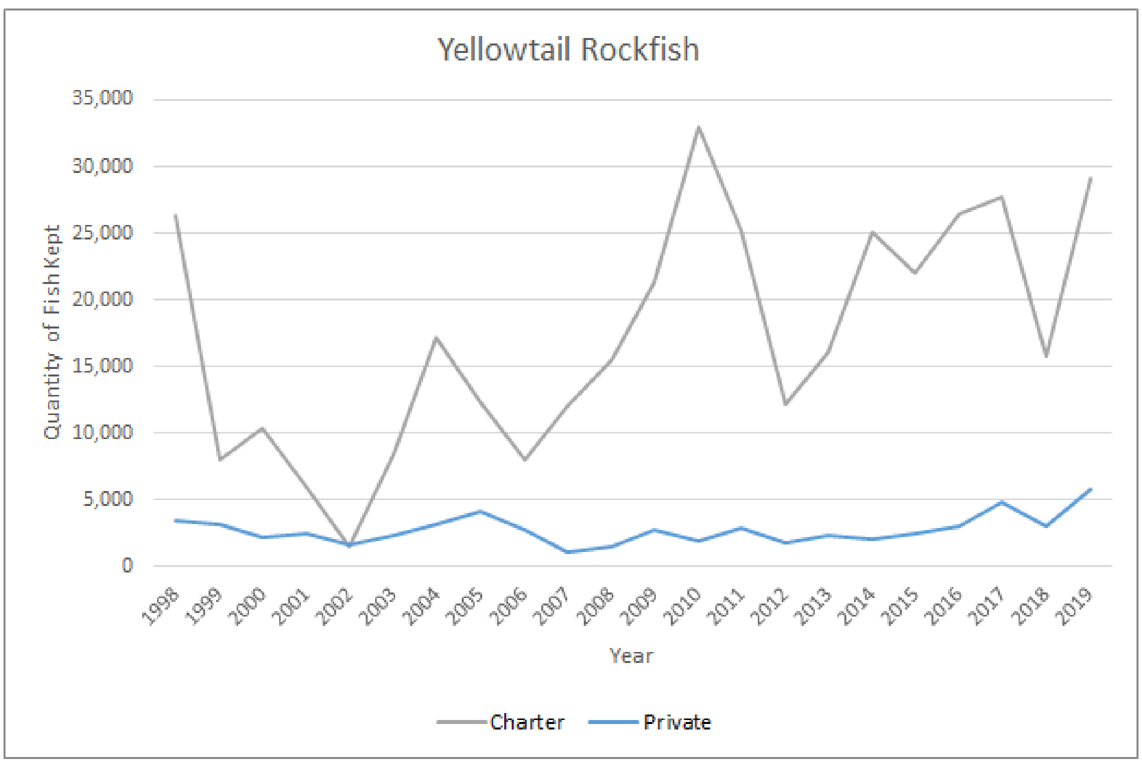


Figure App.ES.CR.2. Quantity of yellowtail rockfish kept for charter and private boats in statistical areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

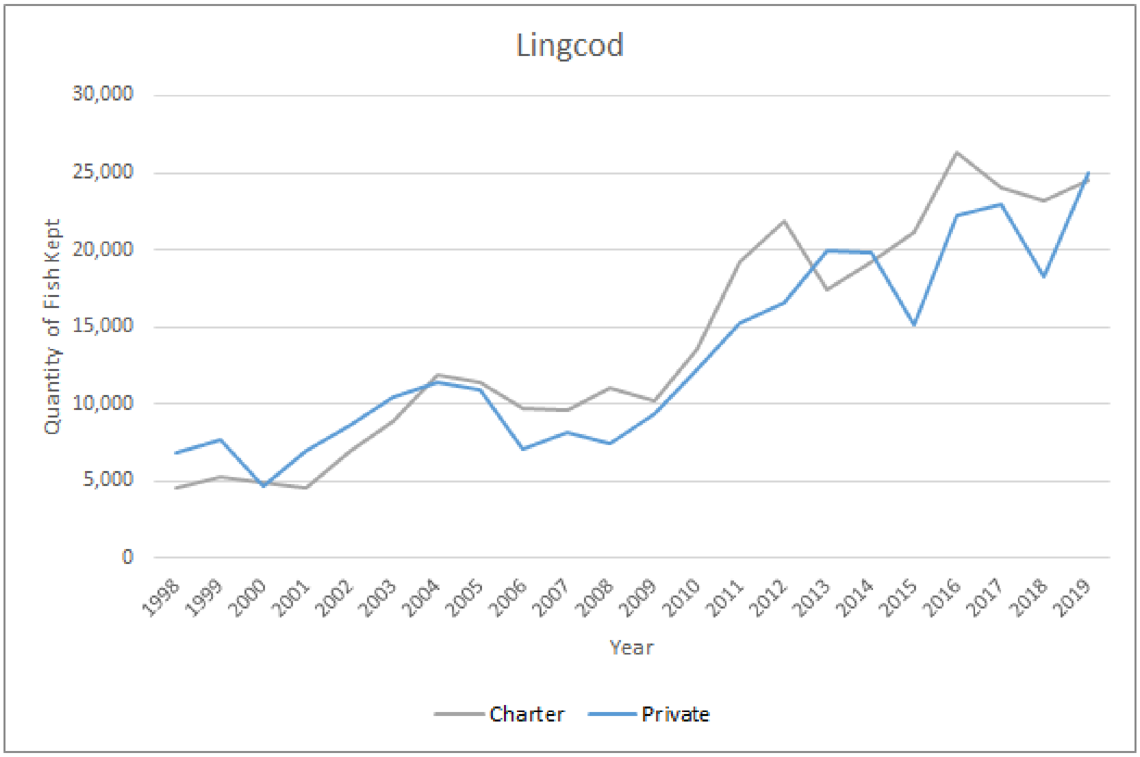


Figure App.ES.CR.3. Quantity of lingcod kept for charter and private boats in statistical areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

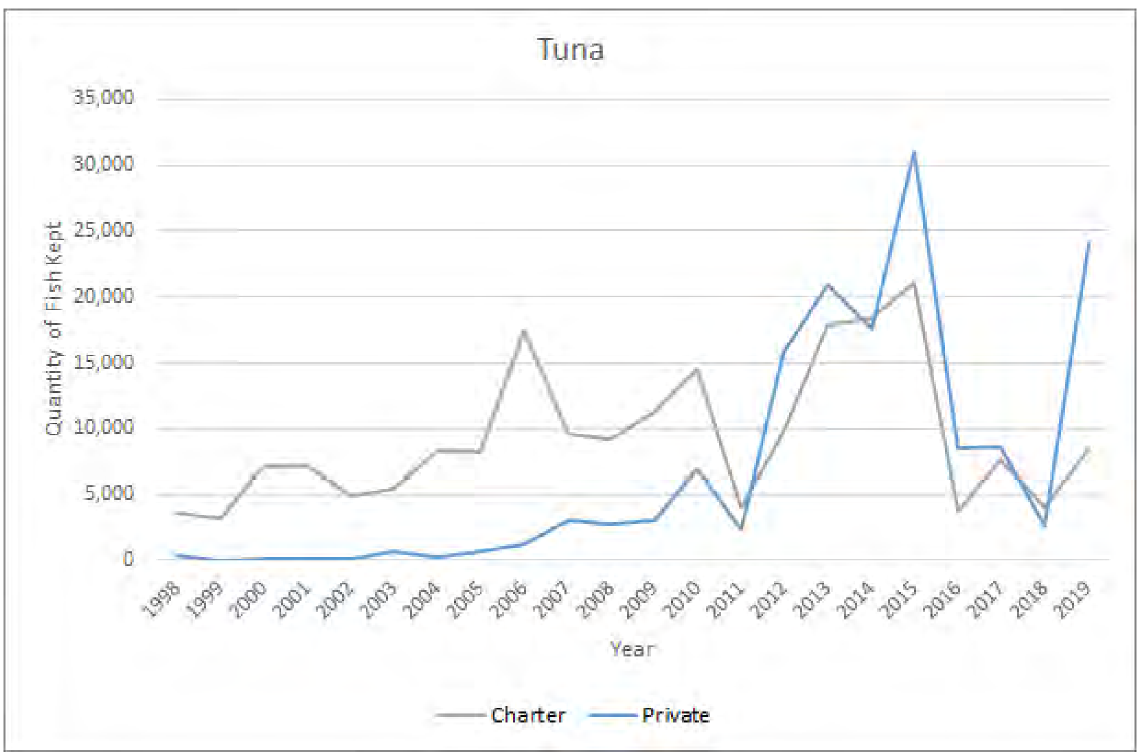


Figure App.ES.CR.4. Quantity of tuna kept for charter and private boats in statistical areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

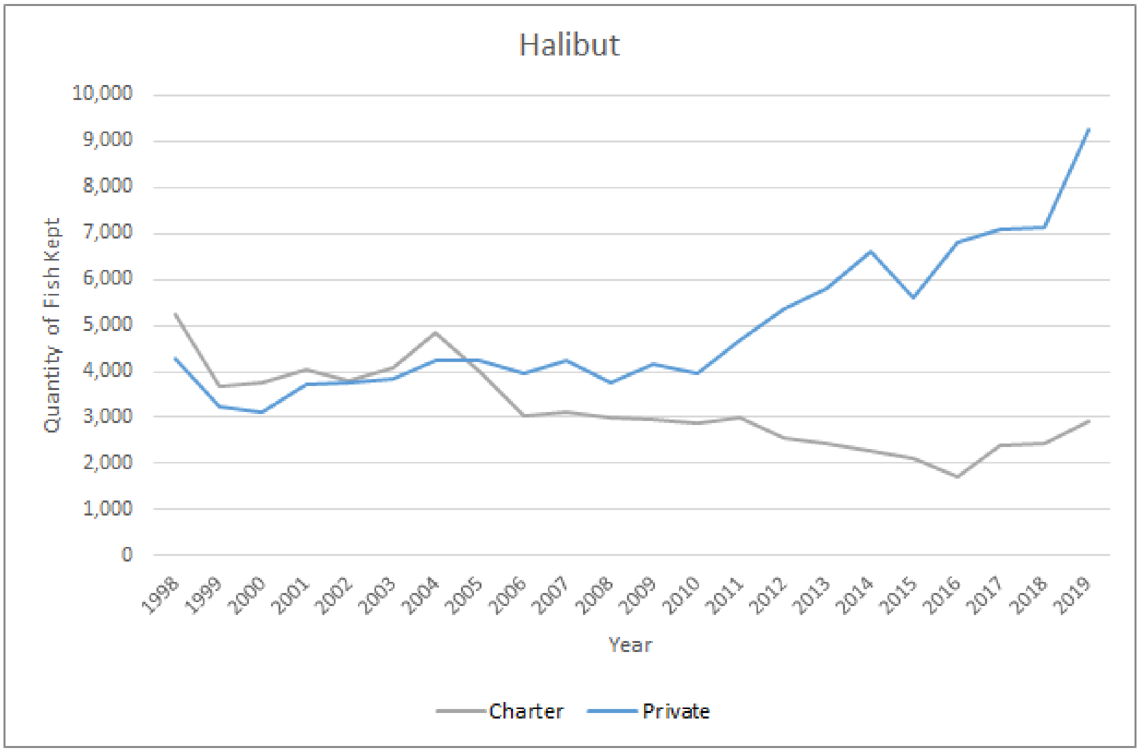


Figure App.ES.CR.5. Quantity of halibut kept for charter and private boats in statistical areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

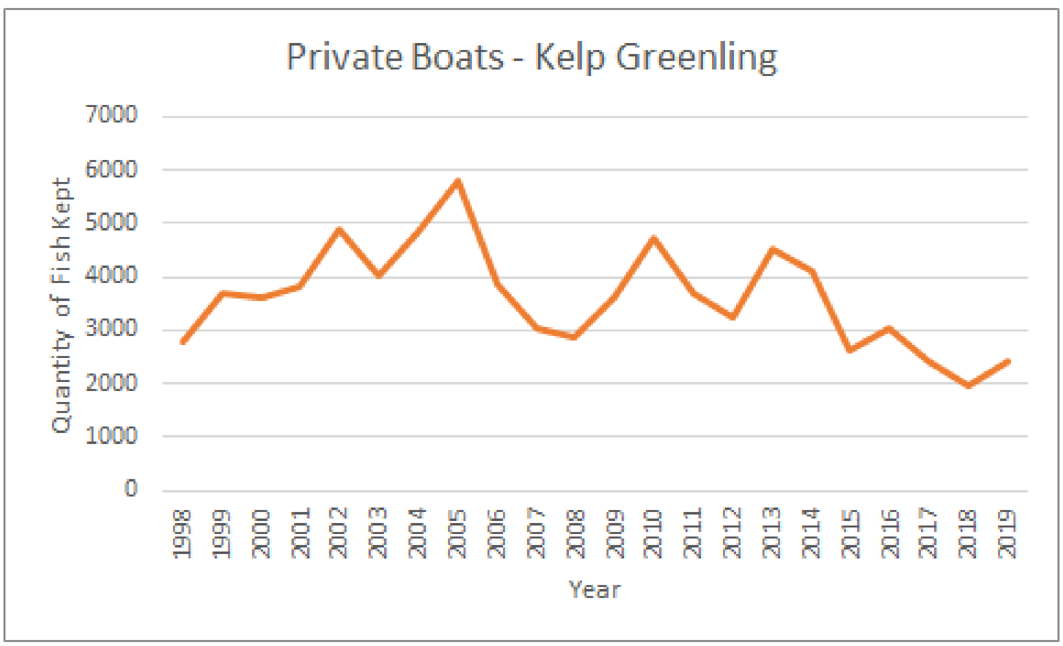


Figure App.ES.CR.6. Trend in the quantity of kelp greenling kept for private boats in Statistical Areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

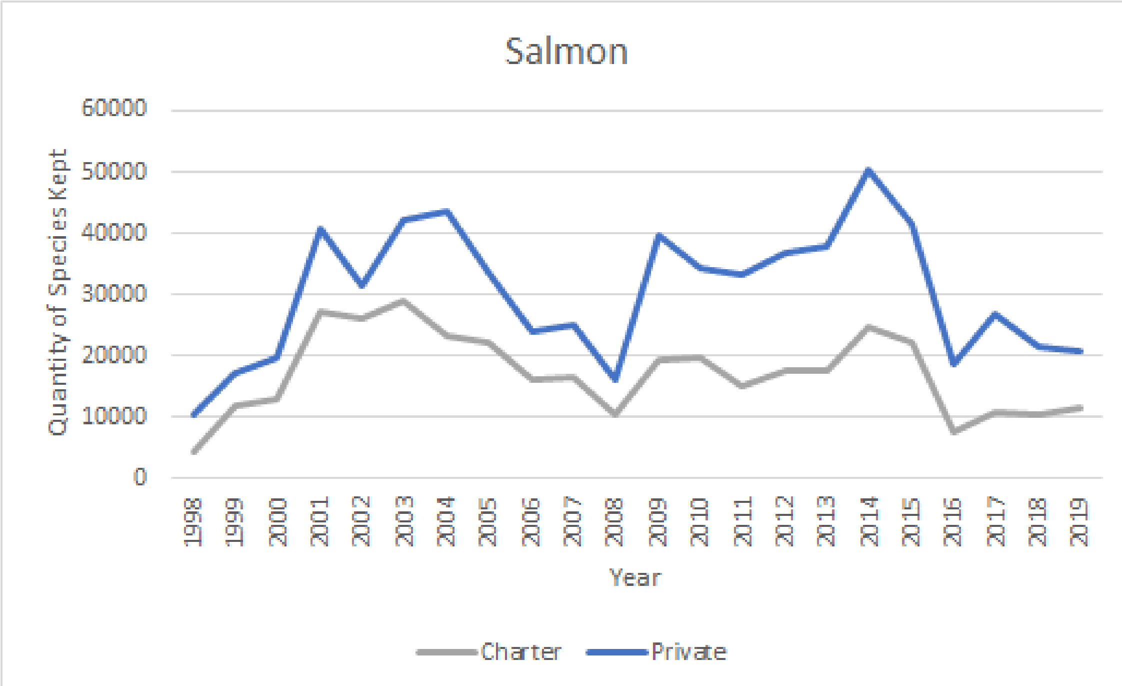


Figure App.ES.CR.7. Trend in the quantity of salmon kept by private and charter boats in statistical areas 2, 3, 4, and 4B (1998–2016) (see Figure App.ES.CR.8 for map of statistical areas). Source: E. Crust/WDFW, personal communication, December 18, 2020

Additional Science Table

Table App.ES.S.1. Research programs conducted in OCNMS.

Researcher	Institution	Location	Topic	Time Period*
Bob Paine	University of Washington	Tatoosh Island	Intertidal research; “keystone species” concept	1967–2005
Cathy Pfister, Tim Wooton	University of Chicago	Tatoosh Island; Strait of Juan de Fuca, Olympic Coast	Intertidal and kelp research; ocean acidification	1980–present
OCNMS staff, Jenny Waddell	OCNMS	Olympic Coast	OCNMS moorings; oceanographic data	2000–present
Simone Alin	NOAA Pacific Marine Environmental Laboratory	Olympic Coast	Analysis of OCNMS oceanographic data	2015–present

Researcher	Institution	Location	Topic	Time Period*
Jan Newton	NANOOS, University of Washington Applied Physics Laboratory, NOAA Pacific Marine Environmental Laboratory	Olympic Coast	Ćháʔba· and NEMO moorings; oceanographic data	2010–present
Simone Alin, Adrienne Sutton	NOAA Pacific Marine Environmental Laboratory, NDBC	Cape Elizabeth, Olympic Coast	Carbon chemistry sensors (air and water) added to NDBC buoy 46041	2006–present
Dick Feely, Simone Alin	NOAA Pacific Marine Environmental Laboratory	West Coast	Ocean acidification cruises	2007–2016 (not annual)
Parker MacCready, Samantha Siedlecki	University of Washington, NANOOS, University of Connecticut	Pacific Northwest	LiveOcean model forecasts near-term ocean acidification conditions in Pacific Northwest and J-SCOPE model provides seasonal forecasts; both use OCNMS data	2015–present with major upgrades in 2019
Vera Trainer, Olympic Region Harmful Algal Blooms Partnership	NWFSC, Coastal Treaty Tribes, etc.	Pacific Northwest	Olympic region HABs	1994–present
Stephanie Moore, John Mickett	University of Washington, NWFSC	OCNMS	Environmental Sample Processor mooring (real-time HAB monitoring)	Seasonal deployments, 2016–present
Ed Bowlby, Jenny Waddell, Liz Clarke	OCNMS, NOAA Fisheries	OCNMS	Deep-sea coral research cruises using ROVs, etc.	2006, 2008, 2010, 2011, 2017, 2018, 2019
Melissa Miner	MARINe	OCNMS	Intertidal monitoring (2 sites)	1996–present
Julia Parrish	COASST	West Coast	Beached seabird monitoring	1999–present
Lisa Ballance, Jeffrey Moore	NOAA Fisheries, SWFSC	West Coast	Cetacean abundance and the pelagic ecosystem	1991–2005

Researcher	Institution	Location	Topic	Time Period*
Steve Fradkin	Olympic National Park	Olympic National Park	Intertidal monitoring (4 sites)	2004 (sandy), and 2008 (rocky) to present
Steve Fradkin	Olympic National Park	Olympic National Park	Ocean acidification monitoring (2 sites)	2010–present
Helen Berry; Tom Mumford; Ecoscan	Washington State Department of Natural Resources	Washington state	Extent of Washington kelp forest habitat from plane-based surveys	1989–present
Ole Shelton, Greg Williams, Jameal Samhouri; Steve Lonhart; Jenny Waddell	NWFSC, Monterey Bay National Marine Sanctuary, OCNMS	OCNMS (Partnership for Interdisciplinary Studies of Coastal Oceans protocols); 5 core sites	Kelp forests; dive surveys of benthic habitats, kelp, fishes, and invertebrates	2015–present
Steve Jefferies, Deanna Lynch, Jenny Waddell	WDFW, USFWS	Olympic Coast	Sea otter and pinniped surveys	1985–present
Christy Pattengill-Semmens	Reef Environmental Education Foundation	West Coast	Distribution and abundance of common fish and invertebrates	1997–present
NOAA Mussel Watch Program	NOAA National Centers for Coastal Ocean Science; WDFW	National (two sites in OCNMS)	Contamination in mussels	1996–present
Chris Harvey, Greg Williams, Kelly Andrews, Toby Garfield	NOAA Fisheries, NWFSC, SWFSC	California Current	CCIEA Program	2012–present
U.S. West Coast Groundfish Bottom Trawl Survey	NOAA Fisheries, NWFSC	U.S. West Coast trawlable shelf and slope habitats (>50 m)	Groundfish data collection, used to generate stock assessments for fisheries management	2003–present
Brian Burke, Cheryl Morgan	NOAA Fisheries, NWFSC	Newport, Oregon to Cape Flattery, Washington	Juvenile salmon and ocean ecosystem survey; surface trawls targeting juvenile salmon in nearshore ocean waters	1998–present

Researcher	Institution	Location	Topic	Time Period*
Kevin Stierhoff, David Demer, Juan Zwolinski	NOAA Fisheries, SWFSC	U.S. West Coast, Vancouver Island to San Diego, California to 35 nm offshore	West Coast coastal pelagic species survey; acoustic trawl targeting northern anchovy, Pacific herring, Pacific sardine, Pacific mackerel, jack mackerel	2008, 2012–2019
Joint U.S.-Canada Integrated Ecosystem and Pacific Hake Acoustic Trawl Survey	NOAA Fisheries, Fisheries and Oceans Canada	Point Conception, California to northern British Columbia	Transect-based acoustic and trawl surveys of Pacific hake	1977–2001 (triennially), biennial since then
Sue Thomas	USFWS	Washington Maritime NWR Complex	Nesting seabird colony surveys (aerial photographs) of offshore islands	1996–present
Melissa Poe, Melissa Watkinson, Coastal Treaty Tribe liaisons	Washington Sea Grant	Olympic Coast	Tribally important species, community health and well-being, vulnerability to ocean change, resilience, marine-based cultural practices	2017–present
Jennifer Sepez	University of Washington Department of Anthropology, NOAA Fisheries	Neah Bay, Makah Tribe	Political and social ecology of contemporary Makah subsistence hunting, fishing, and shellfish collecting practices	1998–2002
Janine Ledford, Rebekah Monette, Richard Daugherty, Gary Wessen, Ruth Kirk, Ann Renker	Makah Cultural and Research Center	Ozette, Olympic Coast	Ozette archeological research	1970s–present
Jay V. Powell; members of the Quileute Tribe and Hoh Tribe		Quileute and Hoh tribal reservations	Quileute language, place names, resource use, basketry	1970s–present

Researcher	Institution	Location	Topic	Time Period*
Jeff E. Moore, Robyn Angliss, Erin Oleson	NOAA Fisheries	Offshore (Washington/ Oregon/ California)	Pacific Marine Assessment Program for Protected Species (PacMAPPS) marine mammal density surveys**	2017–2018
Brad Hanson	NOAA Fisheries	Offshore	Passive acoustic and visual monitoring of Southern Resident killer whale seasonal movements**	2014–2017
Amanda Debich, Simone Baumann-Pickering, Ana Sirovic	Scripps Institution of Oceanography, NOAA Fisheries	Offshore	Passive acoustic monitoring for marine mammals and soundscapes; seasonal movements and baseline data**	2012–2014
Brad Hanson	NOAA Fisheries	Offshore	Southern Resident killer whale satellite tagging and seasonal movements**	2012–2016
Brad Hanson, Robin Baird	NOAA Fisheries, Cascadia Research	Offshore, inland	Southern Resident killer whale prey study**	2015
John Calambokidis	Cascadia Research	Offshore	Marine mammal tagging and movement**	2011–present
Mariko Langness, Phillip Dionne, Erin Dilworth, Dayv Lowry	WDFW	Nearshore sand and gravel beaches	Evaluation of use of Washington coastal beaches by beach-spawning forage fish (smelt, sand lance)	2012–2014
Bruce Mate, Daniel Palacios	Oregon State University/HDR, Inc.	Offshore Washington/ Oregon	Fin whale tagging and distribution**	2013–2015
Bruce Mate, Daniel Palacios	Oregon State University	Offshore Washington/ Oregon	Gray whale tagging and distribution**	2012
Bruce Mate, Daniel Palacios	Oregon State University	Offshore Washington/ Oregon	Humpback whale tagging and distribution**	2017–2019
Laura Heironimus	WDFW	Offshore Washington	Green sturgeon tagging and distribution **	2020–2022

Researcher	Institution	Location	Topic	Time Period*
Joseph Smith, David Huff	NOAA Fisheries	Offshore Washington and Gulf of Alaska	Ocean distribution and survivorship of salmon, steelhead, bull trout **	2018–2022
Scott Pearson, M. Lance	WDFW	Offshore	At-sea densities of marbled murrelet **	2017, 2019

* Many monitoring efforts were delayed or canceled in 2020 due to COVID-19.
** Supported by the U.S. Navy; results available at https://www.navymarinespeciesmonitoring.us/

Additional Sense of Place Tables and Figures

Table App.ES.SP.1. Willingness to pay for resource condition improvement in OCNMS. Source: Leeworthy et al., 2017

Variable	Change in Resource Condition		
	Low to Medium	Medium to High	Low to High
Marine mammals	$102	$37	$139
Seabirds	$47	-$29	$18
Large predators	$73	$20	$93
Number tidal pool organisms	$0	$0	$0
Tidal pool access	-$53	-$53	-$106
Water quality	$97	$66	$163
Shoreline quality—marine debris	$59	$40	$99
Shoreline quality—number of beaches open	$45	$66	$111
Obstructed views from development	$102	$50	$152

Table App.ES.SP.2. Population and per capita income for the U.S., Washington, and the OCNMS study area.

	Population			Per Capita Income		
Year	U.S.	Washington	Study Area	U.S.	Washington	Study Area
2010	309,326,085	6,742,902	174,243	$47,538	$50,035	$33,743
2011	311,580,009	6,821,655	173,958	$48,571	$50,815	$35,054
2012	313,874,218	6,892,876	173,330	$49,662	$53,191	$36,586
2013	316,057,727	6,962,906	173,098	$49,221	$53,011	$36,597
2014	318,386,421	7,052,439	173,399	$50,819	$55,636	$38,905

	Population			Per Capita Income		
Year	**U.S.**	**Washington**	**Study Area**	**U.S.**	**Washington**	**Study Area**
2015	320,742,673	7,163,543	174,580	$52,830	$58,074	$40,075
2016	323,071,342	7,294,680	176,748	$53,122	$59,528	$41,276
2017	325,147,121	7,425,432	179,456	$54,115	$61,067	$43,032
2018	327,167,434	7,535,591	182,367	$55,433	$63,150	$44,938

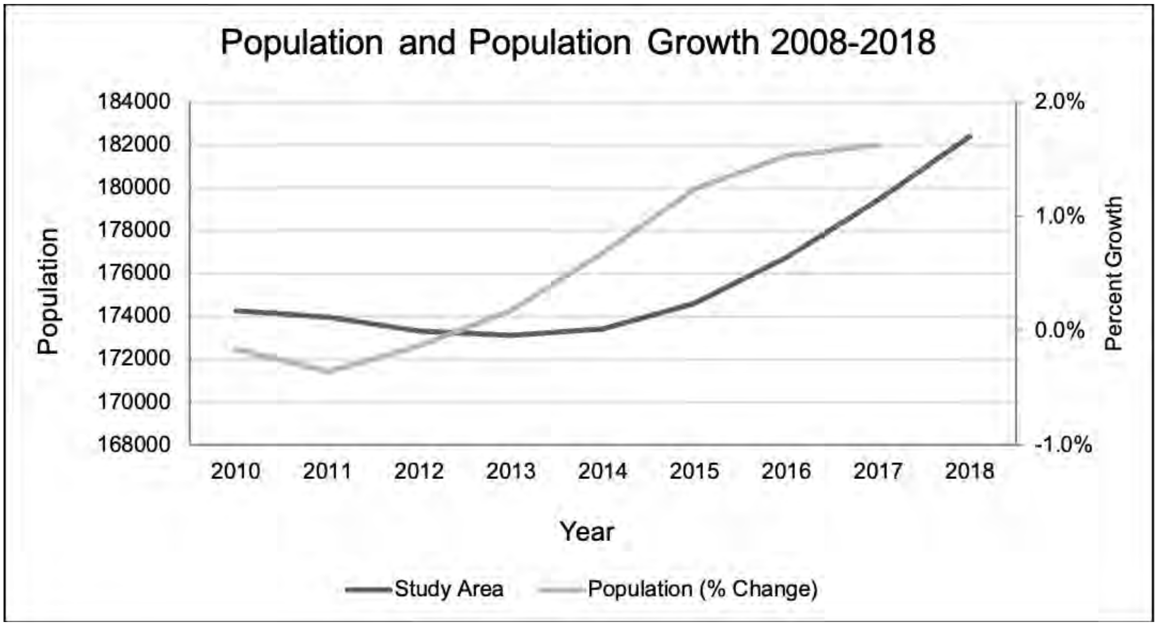


Figure App.ES.SP.1. Population growth in the OCNMS study area, 2008–2018. Source: BEA, 2020

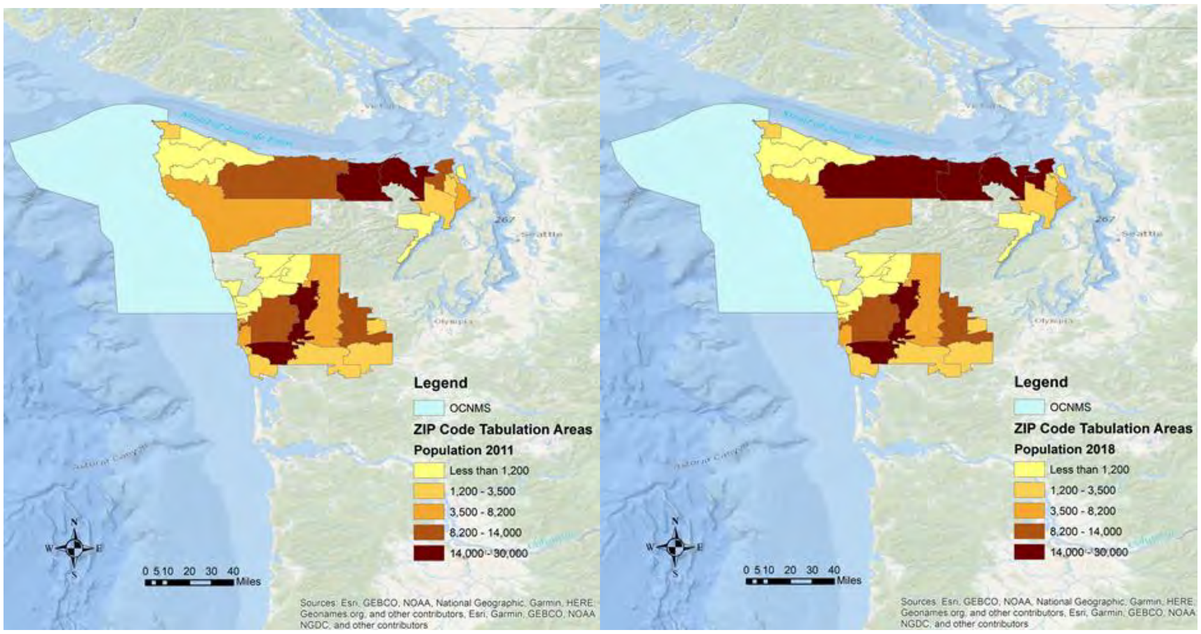


Figure App.ES.SP.2. Population by ZIP code in 2011 (left) and 2018 (right). Source: BEA, 2020

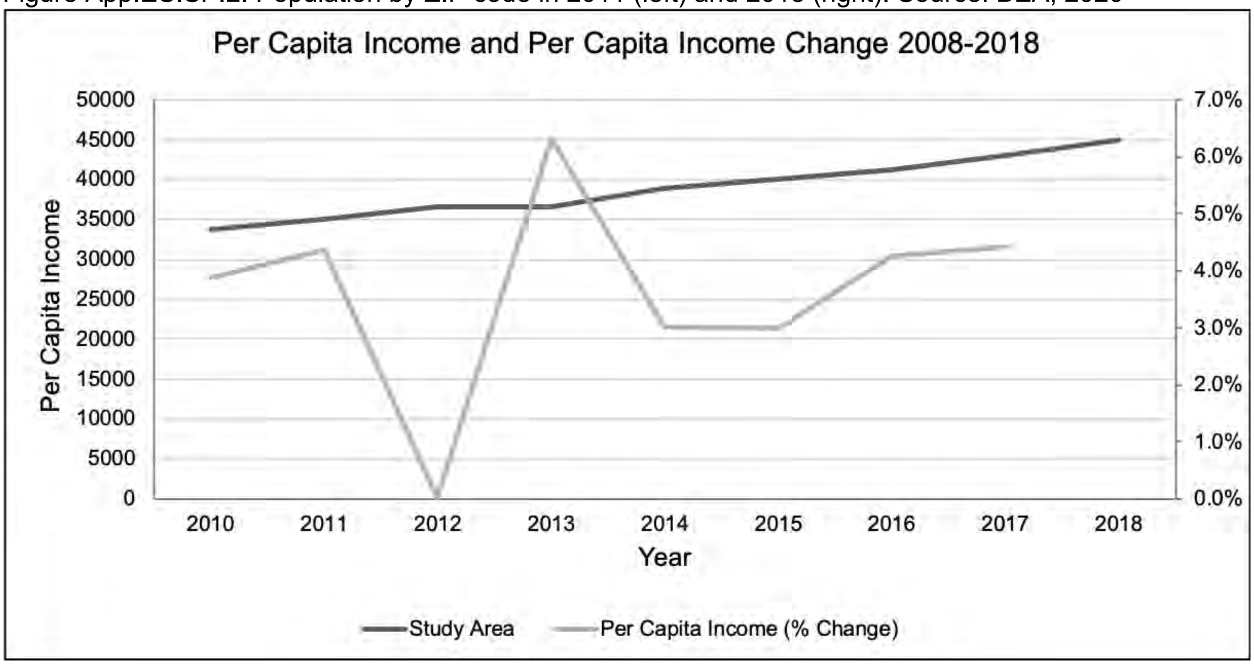


Figure App.ES.SP.3. Per capita income in the OCNMS study area, 2008–2018 Source: BEA, 2020

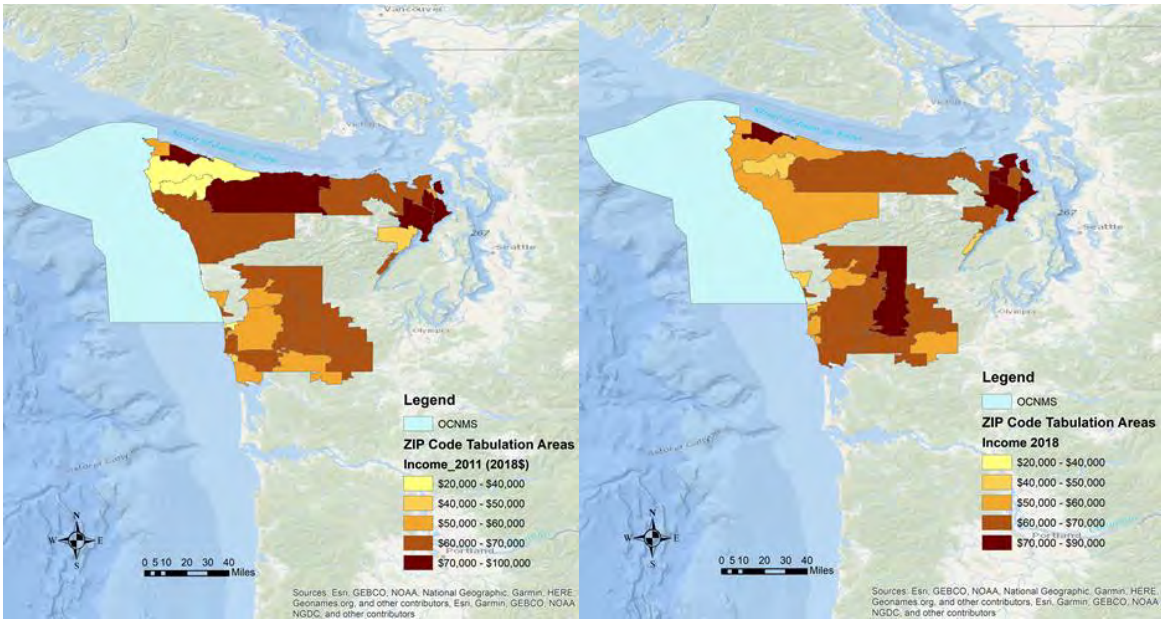


Figure App.ES.SP.4. Per capita income by ZIP code in 2011 (left) and 2018 (right). Source: BEA, 2020

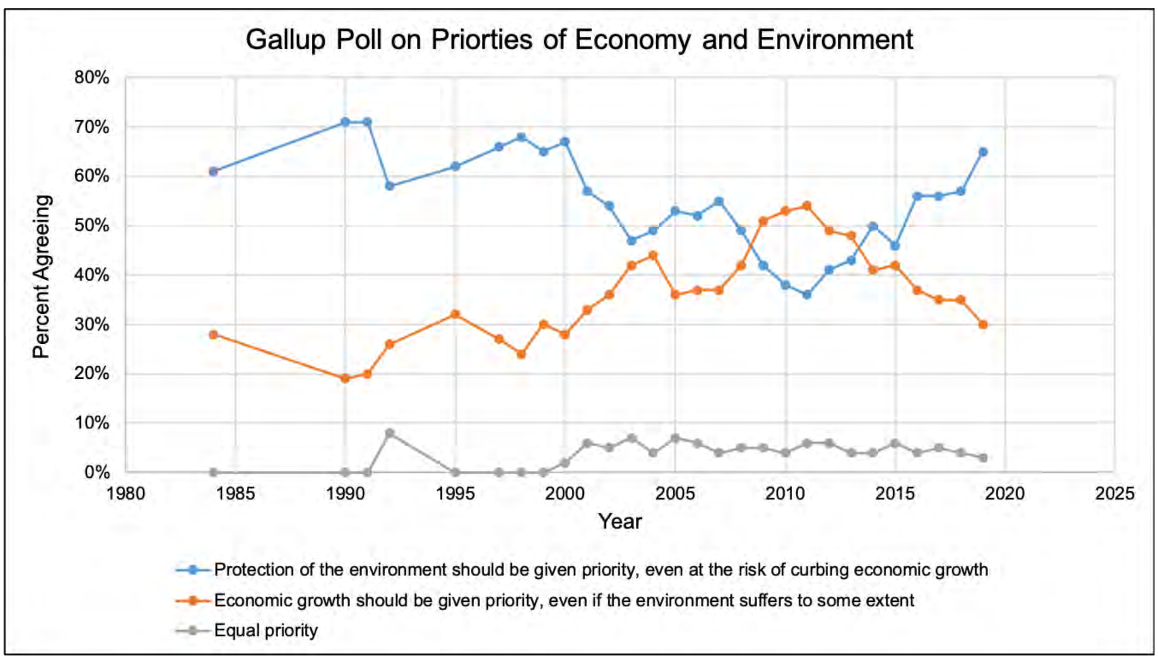


Figure App.ES.SP.5. Responses to the question: “With which one of these statements about the environment and the economy do you most agree—‘Protection of the environment should be given priority, even at the risk of curbing economic growth,’ or ‘Economic growth should be given priority, even if the environment suffers to some extent?’” Source: Gallup, 2020

Additional Commercial Harvest Tables and Figures

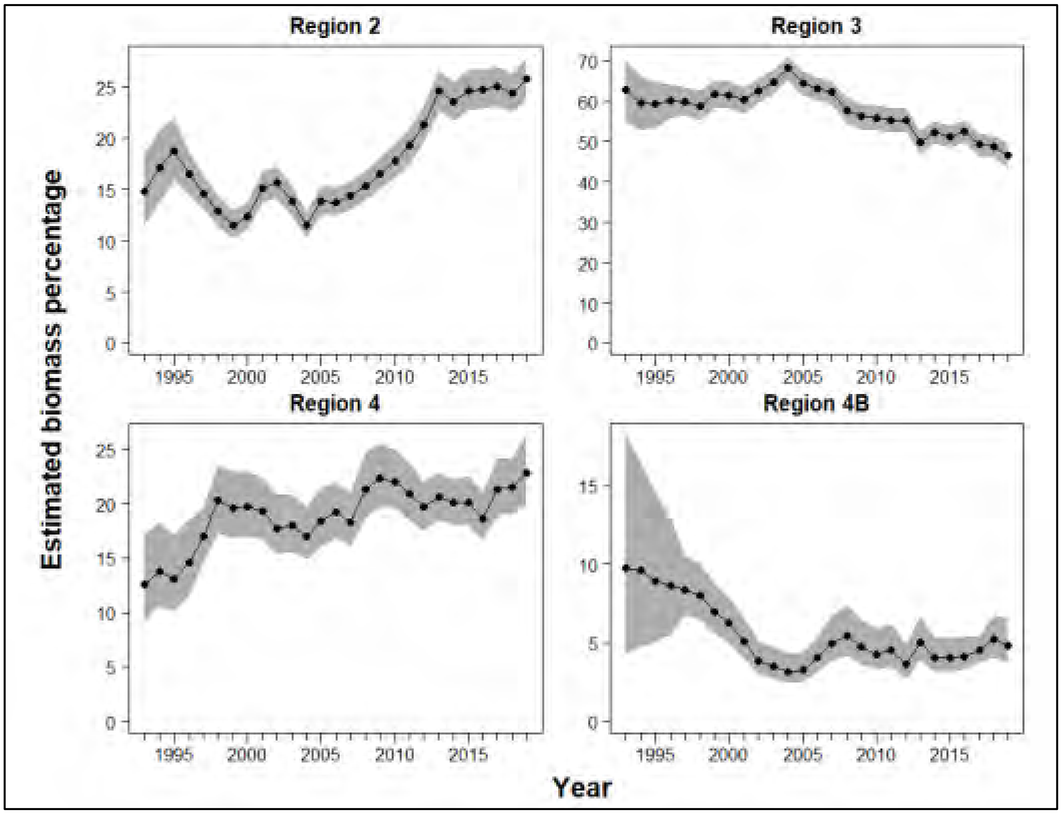


Figure App.ES.CH.1. Biomass trends for Pacific halibut by management area. Image: IPHC, 2020

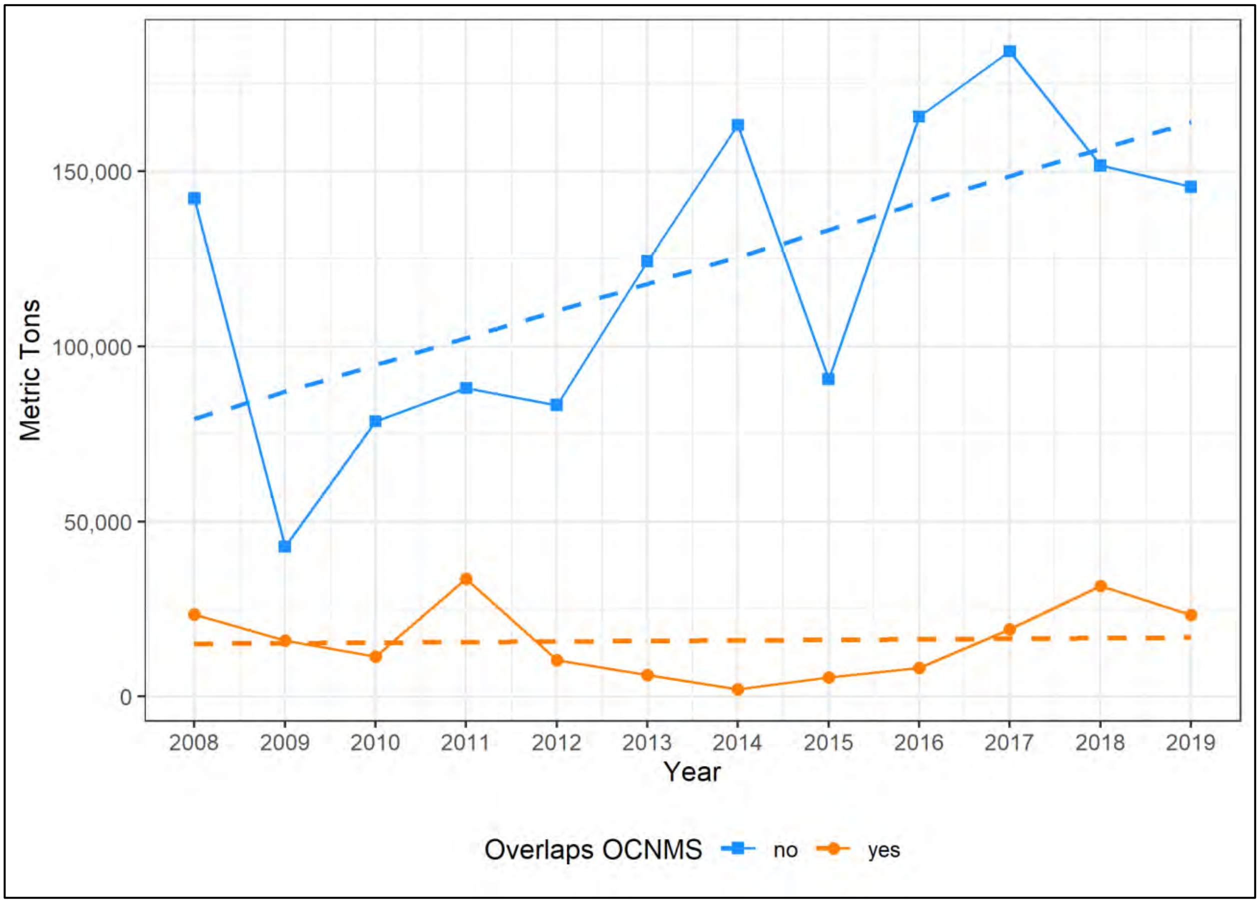


Figure App.ES.CH.2. Annual catch of Pacific whiting, 2008–2019, for hauls conducted inside (orange, circles) or outside OCNMS waters (blue, squares). Dashed lines show the 2008–2019 trend for each category. Catch in OCNMS did not change during the study period, whereas catch outside OCNMS increased. Haul data were provided in GIS as straight lines using start and end coordinates. A haul was considered to have occurred in OCNMS waters if the line intersected with the OCNMS GIS boundary layer. Source: NWFSC, 2021

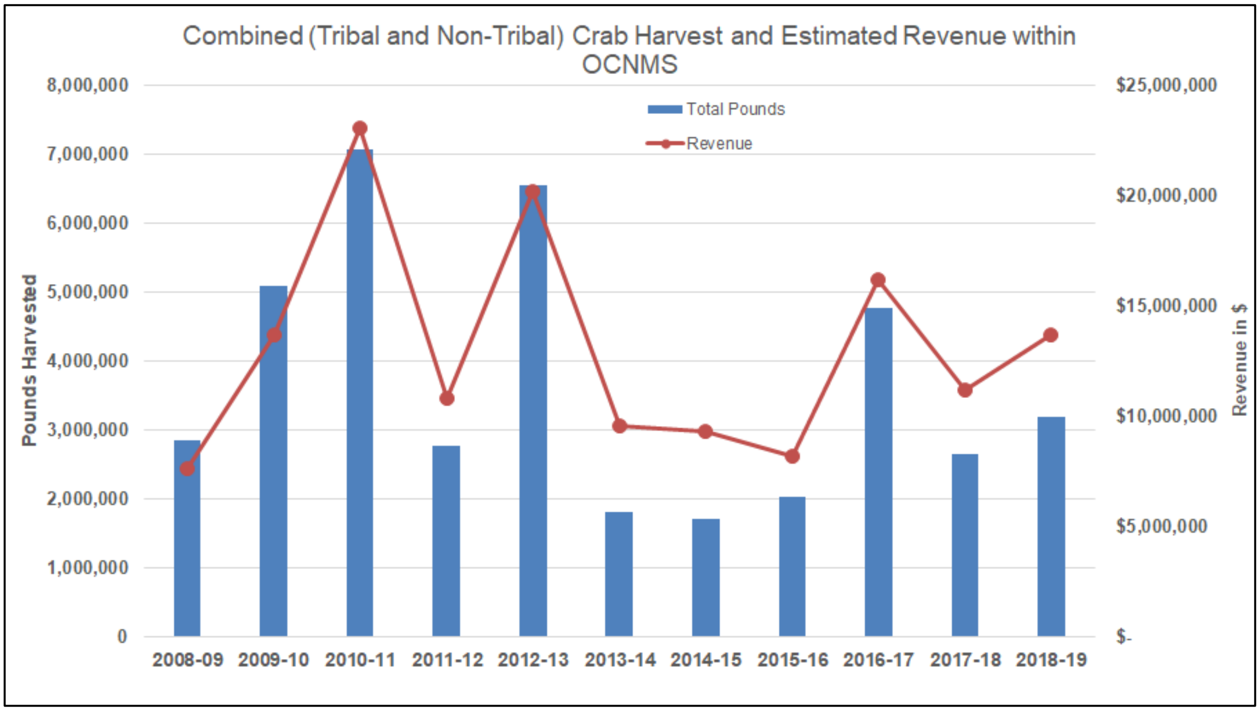


Figure App.ES.CH.3. Estimated catch and revenue for Dungeness crab harvested within OCNMS. Source: WDFW, 2020

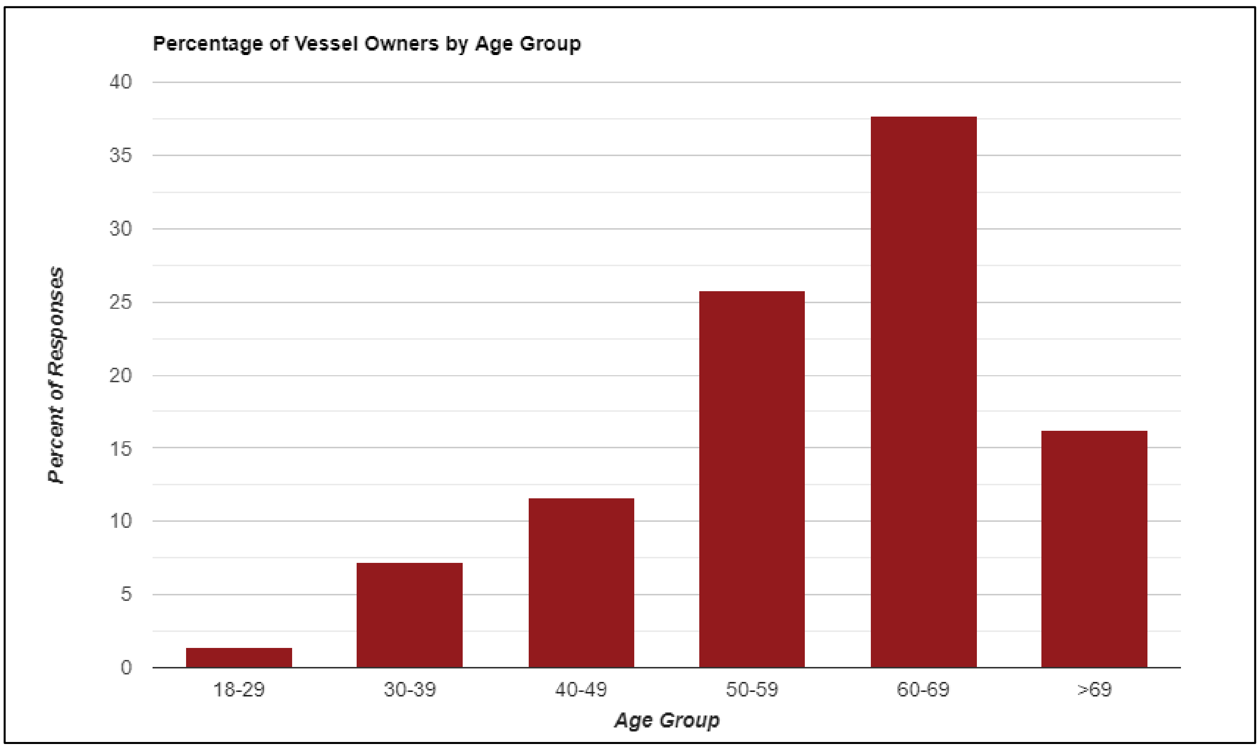


Figure App.ES.CH.4. Age demographics of vessel owners from Washington state commercial fisher participation survey responses in 2017. Source: NOAA Fisheries, 2017

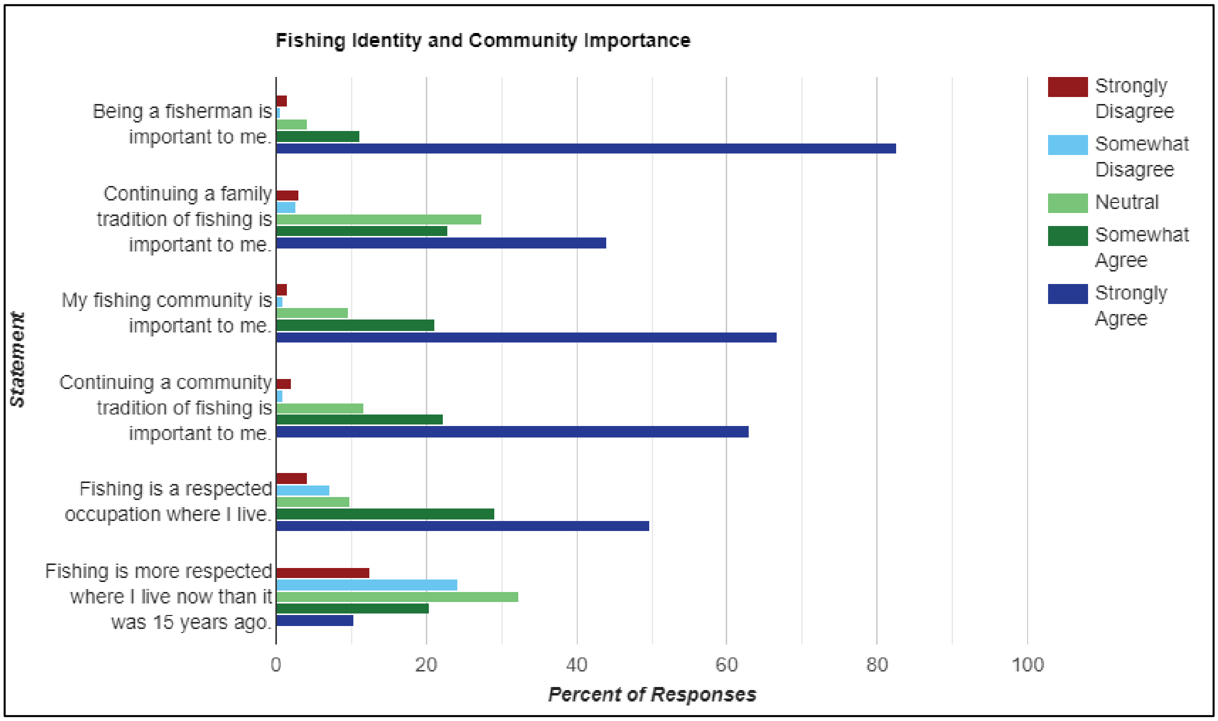


Figure App.ES.CH.5. Commercial fishers rated their agreement with a series of statements pertaining to fishing identity and community importance. Image: NOAA Fisheries, 2017

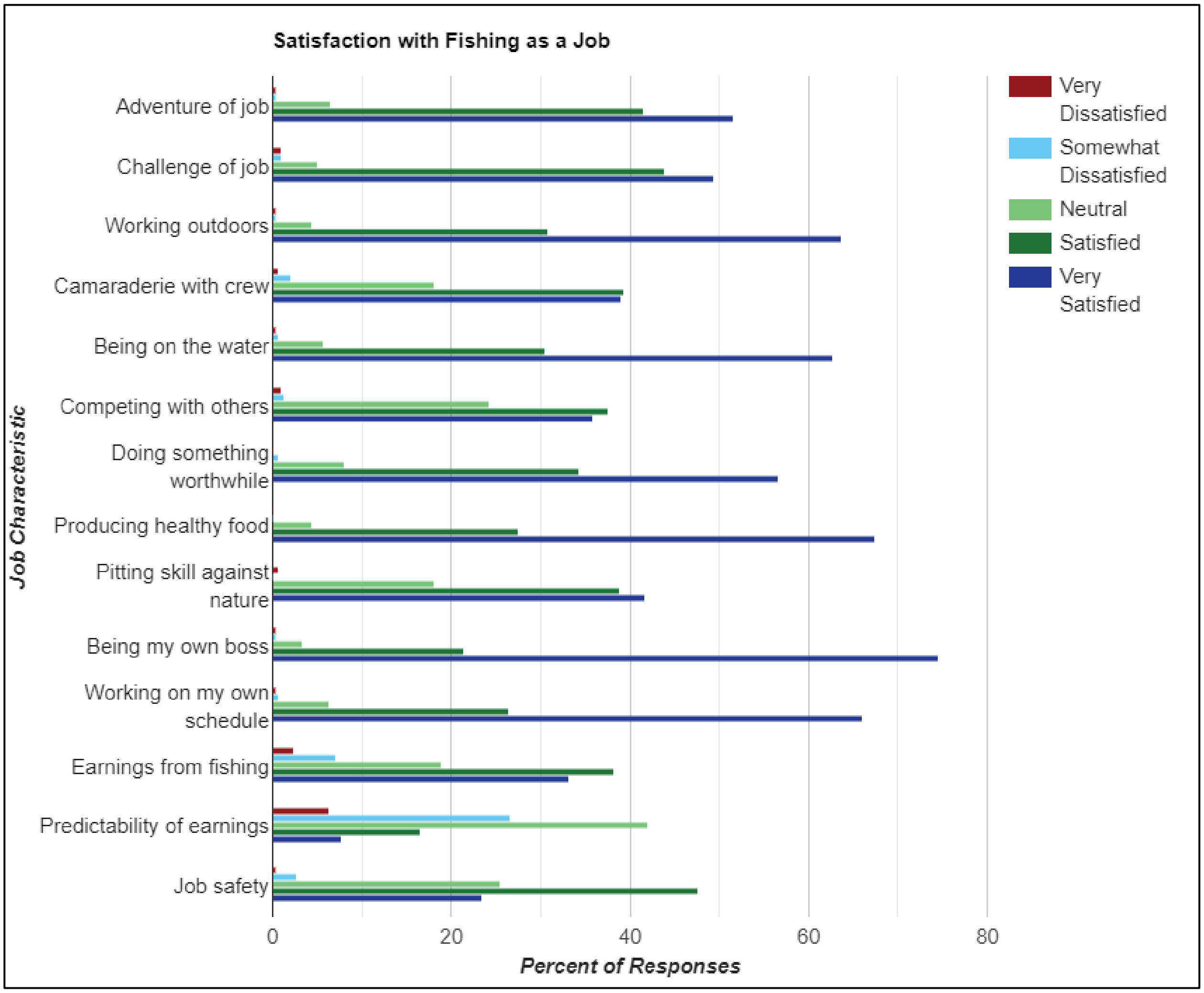


Figure App.ES.CH.6. Commercial fishers rated their satisfaction with various job characteristics. Being their own boss, setting their own schedule, producing healthy food, being on the water, and working outdoors generated the greatest satisfaction. Image: NOAA Fisheries, 2017

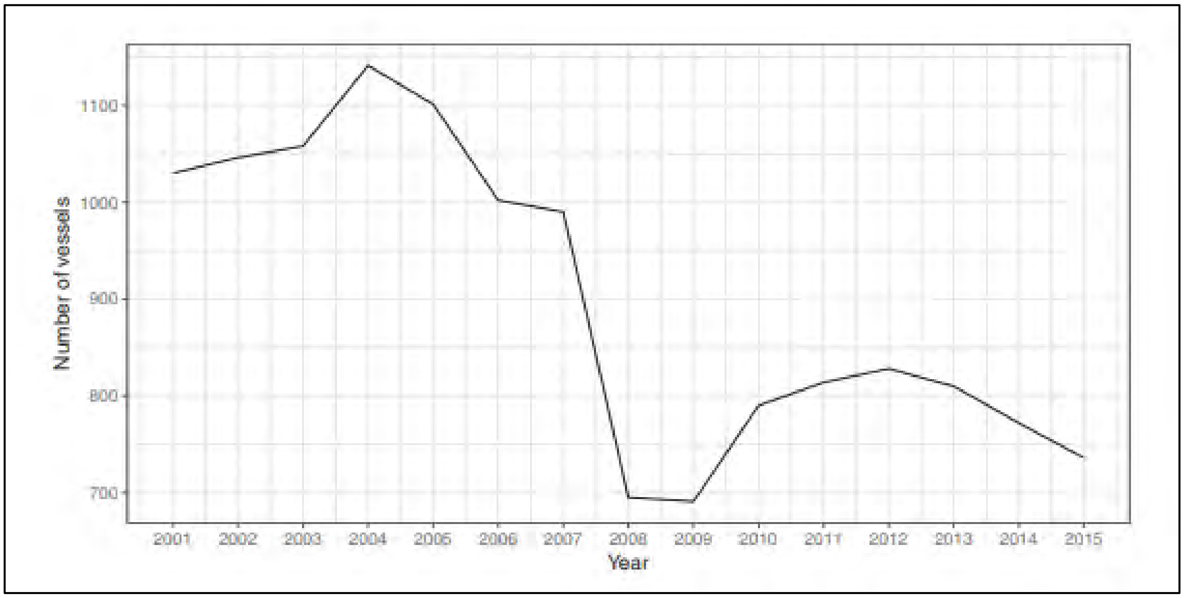


Figure App.ES.CH.7. Number of vessels in the salmon troll fleet that participated in fishing, 2001–2015. For criteria used to identify vessels in the salmon troll fleet, see Richerson and Holland (2017). Image: Richerson & Holland, 2017

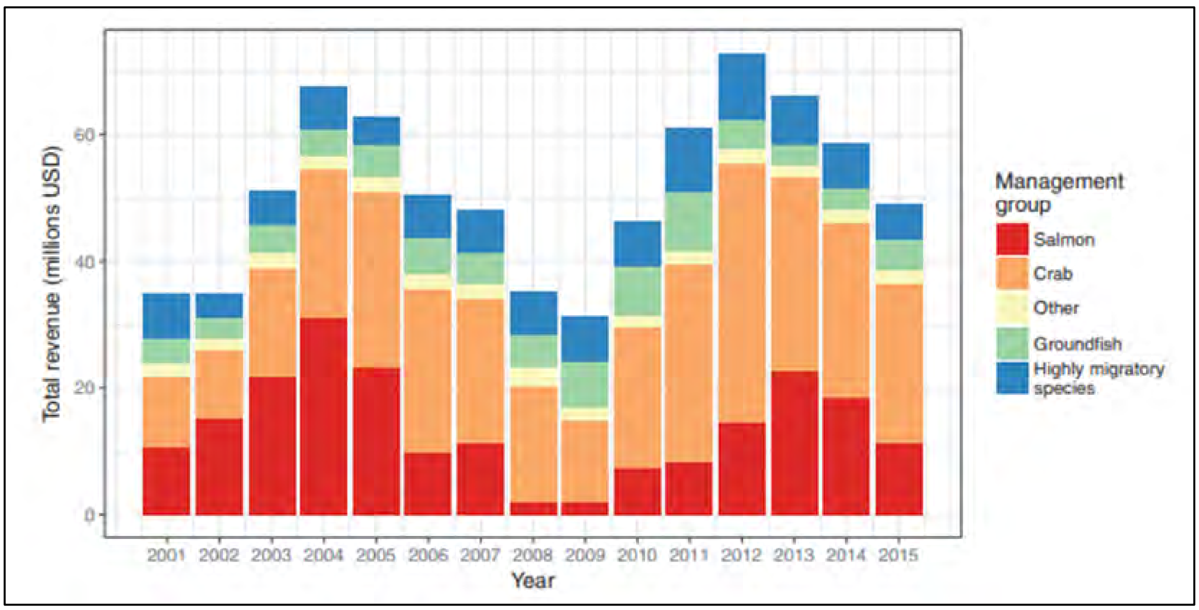


Figure App.ES.CH.8. Total annual revenue from each species (management) group harvested by vessels in the salmon troll fleet. For criteria used to identify vessels in the salmon troll fleet, see Richerson and Holland (2017). Image: Richerson & Holland, 2017

Appendix G: Glossary of Acronyms

AIS – automatic identification system
ASP – amnesic shellfish poisoning
ATBA – Area to be Avoided
BEA – Bureau of Economic Analysis
B-WET – Bay Watershed Education and Training
CCIEA – California Current Integrated Ecosystem Assessment
CMECS – Coastal and Marine Ecological Classification Standard
CO_2 – carbon dioxide
COASST – Coastal Observation and Seabird Survey Team
DDT – dichoro-diphenyl-trichloroethene
DPSER – Drivers-Pressure-State-Ecosystem Services-Response
DSP – diarrhetic shellfish poisoning
EEZ – exclusive economic zone
EIA – United States Energy Information Administration
ENSO – El Niño Southern Oscillation
EPA – U.S. Environmental Protection Agency
ESA – Endangered Species Act
GDP – gross domestic product
HAB – harmful algal bloom
IEA – Integrated Ecosystem Assessment
IMO – International Maritime Organization
IOOS – Integrated Ocean Observing System
IPC – Intergovernmental Policy Council
IPCC – Intergovernmental Panel on Climate Change
IPHC – International Pacific Halibut Commission
LUSI – Length of Upwelling Season Index
MARINe – Multi-Agency Rocky Intertidal Network
MDMAP – Marine Debris Monitoring and Assessment Program
MWEE – Meaningful Watershed Educational Experience
NADP – National Atmospheric Deposition Program
NANOOS – Northwest Association of Networked Ocean Observing Systems
NCA – National Coastal Assessment
NCCOS – National Centers for Coastal Ocean Science
NDBC – National Data Buoy Center
NEMO – Northwest Enhanced Moored Observatory
NMMA – National Marine Manufacturers Association
NMSA – National Marine Sanctuaries Act
NOAA – National Oceanic and Atmospheric Administration
NPGO – North Pacific Gyre Oscillation
NWFSC – Northwest Fisheries Science Center
NWR – National Wildlife Refuge

NWTT – Northwest Testing and Training
OASeS – Ocean Acidification Sentinel Site
OCNMS – Olympic Coast National Marine Sanctuary
OECD – Organisation for Economic Co-operation and Development
OMB – White House Office of Management and Budget
ONI – Oceanic Niño Index
ONMS – Office of National Marine Sanctuaries
PBDE – polybrominated diphenyl ether
PC-1 – Pacific Crossing-1
PCB – polychlorinated biphenyl
$p\text{CO}_2$ – partial pressure of carbon dioxide
PDO – Pacific Decadal Oscillation
PSP – paralytic shellfish poisoning
RHIB – rigid hull inflatable boat
ROV – remotely operated vehicle
SPARROW – spatially referenced regression on watershed attributes
SST – sea surface temperatures
STEAM – Science, Technology, Engineering, Arts, and Mathematics
STI – Spring Transition Index
SWFSC – Southwest Fisheries Science Center
TK – Traditional Knowledge
TUMI – Total Upwelling Magnitude Index
U&A – usual and accustomed
UAV – uncrewed aerial vehicle
UNESCO – United Nations Educational, Scientific and Cultural Organization
USCG – United States Coast Guard
USFWS – United States Fish and Wildlife Service
USGCRP – United States Global Change Research Program
USGS – United States Geological Survey
WDFW – Washington Department of Fish and Wildlife
Ω_{arag} – aragonite saturation state

Appendix H: Comparing the 2008 Olympic Coast National Marine Sanctuary condition report to the 2008–2019 Olympic Coast National Marine Sanctuary condition report

2008 OCNMS condition report findings (left) and 2008–2019 OCNMS condition report findings (right).

2008 Condition Report Questions	2008 Rating	2008–2019 Condition Report Questions	2008–2019 Condition Report Rating
N/A	N/A	1. Influential Drivers	Not rated
4.Human activities and water quality	—	2. Human activities and water quality	Good/Fair —
8. Human activities and habitat	▲	3. Human activities and habitat	Fair ?
14. Human activities and living resources	▲	4. Human activities and living resources	Good/Fair ▲
17. Human activities and maritime archaeological resources	?	5. Human activities and maritime heritage resources	Fair ?
2. Eutrophic condition	—	6. Eutrophic condition	Good —
3. Human health risks	—	7. Human health risks	Fair —
1. Multiple stressors (including climate)	?	8. Climate drivers	Fair/Poor ▼
		9. Other stressors	Good/Fair ▼
5. Habitat abundance/distribution	—	10. Integrity of major habitats	Fair ▼
6. Condition of biologically structured habitat	?		
7. Contaminants	—	11. Contaminants	Good ?
12. Status of key species	?	12. Keystone & foundation species	Fair ▲▼
13. Condition/health of key species	?	13. Other focal species	Fair ▲▼

11. Non-indigenous species	▼	14. Non-indigenous species	Good/Fair ▼
9. Biodiversity	?	15. Biodiversity	Good/Fair ▼
15. Maritime archaeological resource integrity	?	16. Maritime heritage resource integrity	Good/Fair ?

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