



GREATER FARALLONES & CORDELL BANK NATIONAL MARINE SANCTUARIES  
JOINT ADVISORY COUNCIL MEETING  
9:00am – 4:30pm PT  
On-Site Meeting  
Martin Griffin Preserve Volunteer Canyon  
**MEETING HIGHLIGHTS**

Note: The following notes are an account of discussions at the Sanctuary Advisory Council meeting and do not necessarily reflect the opinion or position of the Cordell Bank National Marine Sanctuary (CBNMS), Greater Farallones National Marine Sanctuary (GFNMS), or the National Oceanic and Atmospheric Administration (NOAA).

To view slides from any presentation referenced in this document, please email [tishma.patel@noaa.gov](mailto:tishma.patel@noaa.gov).

**CBNMS Advisory Council Business**

CBNMS Advisory Council (CBNMS AC) Chair Jeff Dorman welcomed all to the meeting and called roll for the council. See Appendix I for CBNMS AC attendance record for this meeting.

The council then welcomed new member Grace Milstein who will serve as one of the two Community-at-Large members, Bibit Traut who will serve as one of the two Education members, and Adrienne Correa who will serve as one of the two Education members.

The council then approved the draft meeting highlights from the February 2024 council meeting. Research member Jaime Jahncke motioned to approve the highlights, and Maritime Activities member Kai Martin seconded the motion.

CBNMS AC MOTION: Approve February Meeting Highlights

Vote: 9 yes, 0 no, 1 abstained

A copy of the meeting highlights is available upon request to [tishma.patel@noaa.gov](mailto:tishma.patel@noaa.gov), and will be posted online at <https://cordellbank.noaa.gov/council/documents.html>.

**CBNMS Advisory Council Member and Alternate Reports**

Council members and alternates shared reports from their constituencies.

Community-at-Large Sonoma member Frank Cappurro mentioned an overturned vessel in Tomales Bay and is unsure about its status. He mentioned that there are some restrictions being made regarding whale watching in the area and he is educating the public on said restrictions.

Conservation member Scott Artis said that on May 15 the California Fish and Game Commission meeting will convene and discuss closing the salmon fishing season. He is also working with

Tribes and other organizations in Sacramento on water flow and how it affects fisheries and species.

Education member Bibit Traut stated that Virtual Field is lacking representation for certain habitats and at their June meeting they will be discussing potential sanctuary habitats to add. She is also continuing to bring both GFNMS and CBNMS's education programs to her students and the Biology Club.

Maritime Activities member Kai Martin stated that the voluntary vessel speed reduction season has started. On offshore winds, the permitting and citing processes are being made easier to complete and will give updates regarding this process at future meetings.

Research member Jaime Jahncke brought up that the MBNMS ACCESS cruise is wrapping up their surveys this week and GFNMS and CBNMS will start their ACCESS cruise on May 15. A report was submitted to the Ocean Protection Council at the end of March and other agencies where it was outlined which areas offshore winds can be good for energy while having the least impact on wildlife.

Research member Jeff Dorman mentioned that the California Cooperative Oceanic Fisheries Investigations (CalCOFI) is completing surveys along the coast to gather data from sanctuaries and that the presidential budget came out and there is a reduction to the Integrated Ocean Observing System (IOOS) budget.

Community-at-Large Marin member Grace Milsten mentioned that she has been working on a program called the Cleaner California Coast Initiative and is working on digital outreach and education products for the initiative.

Education member Adrienne Correa is starting a new movement to coalesce marine expertise at UC Berkeley and stated that this is a good opportunity to incorporate CBNMS by adding corals to ocean curriculum along with incorporating CBNMS data to the course material. She is also looking for funding to start a marine disease education program.

#### **GFNMS Advisory Council Arrive and Roll Call**

GFNMS Advisory Council (GFNMS AC) Chair Jaime Jahncke welcomed all to the meeting and called roll for the council.

See Appendix II for GFNMS AC attendance record for this meeting.

#### **Morgan Patton, Aide to Supervisor Rodoni Welcoming Remarks**

Morgan updated both councils on the Marin County Tomales Bay Working Group. They will be at an on-site meeting to discuss safety hazards, permitting for large-scale events, trash and litter, sea level rise, overnight parking, advertising and public outreach and other visitor impacts of Tomales Bay. After this initial meeting, there will be a public meeting discussing any issues regarding Tomales Bay.

### **GFNMS and CBNMS Superintendent's Report**

Maria Brown, Superintendent of GFNMS and CBNMS, provided updates on GFNMS and CBNMS Operations, Research, Education/Outreach, and Resource Protection program activities since the last council meeting in February.

Highlights included 1) GFNMS and CBNMS received their budget appropriations; 2) Superintendent Brown attended the 2nd Cross-Pacific Indigenous Exchange; 3) Published the Blue Carbon Education Toolkit to increase communication and education about the value of preserving and restoring blue carbon habitats and processes; 4) Published an addendum to the Climate Change Vulnerability Assessment for the North-central California Coast and Ocean which provides the latest climate vulnerability information for key species, habitats, ecosystem services, and maritime heritage resources.

### **Emergency Response and Enforcement Updates**

Max Delaney, Resource Protection and Emily Henderson, NOAA Office of Law Enforcement, provided a brief report on recent events that have occurred within the sanctuaries.

Max Delany, spoke about the fishing vessel Aleutian Storm has an insurance policy for the vessel and they have been cooperative. The salvage company has helped remove three quarters of the vessel and salvage is to resume in June during the next favorable low tide series pending snowy plover activity.

### **Monterey Bay National Marine Sanctuary Superintendent's Report**

Lisa Wooninck, Superintendent of Monterey Bay National Marine Sanctuary (MBNMS), Superintendent Brown provided a brief report on behalf of Superintendent Woonick on recent and upcoming events at the sanctuary.

Highlights included: 1) Coastal Discovery Center team delivered 46 education programs so far with the 2023-2024 school year, 43 of which were partnered with One Cool Earth and California State Parks, San Luis Obispo Coast District; 2) Staff attend the Climate Informed Ecosystem Restoration MPAs symposium; 3) MBNMS will issue an Interpretive Rule to clarify that eFoils fall within the current definition of Motorized Personal Watercraft to reduce wildlife disturbances.

### **Joint GFNMS and CBNMS Advisory Council Business**

Informational Item: Advocating for Continued Support: The Crucial Role of Farallon Island Data in Sanctuary Management; Jaime Jahncke, GFNMS AC Chair, provided a presentation on the role of data obtained from the Farallon Islands in GFNMS management.

Following the presentation, the councils engaged in a discussion.

GFNMS Conservation member Francesca Koe asked if there are Inflation Reduction Act (IRA) funds to assist with the Point Blue Conservation Science projects on the Farallon Islands? GFNMS and CBNMS Research member Jaime Jahncke stated that he is not sure that the funds are available or will be prioritized.

CBNMS Education member Adrienne Correa wanted to emphasize how critical it is to have baseline data from the sanctuaries and how the data can be critical to managing responses to events.

### **Public Comment**

Tom Gaman, Tomales Bay Foundation: Inform the Advisory Committee about the Tomales Bay Foundation's 20-year water quality testing on Tomales Bay and tributaries.

Dan Howard, Cordell Marine Sanctuary Foundation: Cordell Marine Sanctuary Foundation (CMSF), Bodega Marine Laboratory, GFNMS and CBNMS are currently advertising a one year position for a graduate student to analyze 10 years of hypoxia data collected from CBNMS and CMSF is donating \$26,500 for the analysis. CMSF has also approved \$17,500 for Jenny Stock and Justin Holl to purchase 10 virtual reality headsets and train interns to develop an outreach program using virtual reality headsets and integrating the 3D video capture from CBNMS. This is a pilot program that will provide information for developing an outreach tool and program for use at the GFNMS Crissy Field education center and at other outreach opportunities. CMSF approved \$2,000 funding for a graduate student to conduct ocean acidification sampling and help GFNMS and CBNMS on an upcoming ACCESS cruise. CMSF Board Member Gavin Chilcott presented at the annual (29th year) Peter Leveque Natural History Lecture at the Santa Rosa Junior College Campus. The presentation was on the deep diving exploration & aspects of the physical and biological oceanography of CBNMS and featured the 3D footage that the Bay Area Underwater Explorers filmed with a 3D camera while diving at CBNMS two years ago. The auditorium was full and reports are that Gavin's presentation was entertaining and exposed a good crowd to CBNMS for the first time.

Leila Monroe, Clear Resource Law for Natural Resources Defense Council (NRDC): Support on your round data collection on Farallon Islands. Also, requesting for water quality assessment in the condition report. There is a concern about lack of wet weather monitoring and known runoff and outflows from the Bay and septic systems from coastal villages.

Jeff Loomans: On behalf of the Bolinas Lagoon Advisory Council we would like to recommend consideration of ongoing and enhanced management of invasive flora and fauna in sanctuary waters especially in its embayments and lagoon environments. Greater Farallones Association is strongly in support of getting funding for the Farallon Islands and are advocating for the revenue stream to the Farallon Islands.

CBNMS Advisory Council adjourned and GFNMS Advisory Council continued to meet on agenda items that are specific to GFNMS.

### **Presentation on Audubon Canyon Ranch's Tomales Bay Program**

Nils Warnock, Director of Conservation Science, provided a presentation on changes in waterbird number at Tomales Bay.

Following the presentation, the council engaged in discussion.

Community-at-Large Marin Alternate member Richard James inquired about any studies going on about shellfish impacts in Tomales Bay? Director of Conservation Science, Nils Warnock stated that there are impacts but is not sure of the exact studies.

### **Tomales Bay Vessel Management Plan**

Karen Reyna, Resource Protection Coordinator, and Brad Damitz, Independent Coastal Management Consultant for GFNMS, provided a presentation on the status of the plan and mooring program along with accomplishments.

Following the update, the council engaged in discussion with sanctuary staff.

Community-at-Large Marin Alternate member Richard James mentioned that the pump out station is no longer working properly so it is not being used. Tomales Bay Specialist Brad Damitz mentioned that he will look into that.

California Natural Resources Agency Alternate member Abby Mohan asked if the number of moorings is sufficient for this program? Brad stated that there is a limited amount of moorings on Tomales Bay which is a maximum of 135. Currently there are about 65 and the remoteness of Tomales Bay has contributed to less mooring demand.

### **Action item: Tomales Bay**

GFNMS/CBNMS staff provided a comprehensive presentation on Tomales Bay work that has taken place since the last management plan review in 2014. The presentations included information on resource protection, conservation science, and education activities as well as staff recommendations for activities for the next management plan.

Following the presentations, the councils engaged in a discussion with sanctuary staff.

Education member Mary Miller asked if there were any ideas on why aragonite saturation would change. Research Ecologist Dani Lipski stated that stratification and water temperature changes could have an effect but is unsure because there are multiple factors.

Community-at-Large San Francisco-San Mateo member Bart Selby asked if boats are allowed to anchor in eelgrass? Resource Protection Coordinator Karen Reyna stated that there are currently regulations in designated zones. Eelgrass beds have expanded in the bay and now extend beyond the no anchor zones.

Following discussion, the councils made edits and additions to staff recommendations. GFNMS Advisory Council motioned to support the staff recommendations with Sanctuary Advisory Council edits. Community-at-Large Marin member Geroge Clyde motioned to support the staff recommendations with Advisory Council edits and Community-at-Large San Francisco-San Mateo member Bart Selby seconded the motion.

### **GFNMS AC MOTION: To support recommendations for Tomales Bay**

Vote: 12 yes, 0 no, 0 abstention. The recommendations will be forwarded to the sanctuary.

To view the recommendations within the topic briefing, please visit [https://farallones.noaa.gov/manage/sac\\_actions.html](https://farallones.noaa.gov/manage/sac_actions.html).

### **GFNMS Advisory Council Business**

The council approved the draft meeting highlights from the February 2024 council meeting. National Park Service member Craig Kenkel motioned to approve the highlights and Community-at-Large San Francisco-San Mateo Bart Selby seconded.

### **GFNMS AC MOTION: Approve February 2024 Meeting Highlights**

Votes: 10 yes, 0 no, 2 abstention.

### **GFNMS AC Member and Alternate Reports**

Council members and alternates shared reports from their constituencies.

National Parks Service member Craig Kenkel stated that the fishing vessel The Westerly is being cleaned up by the National Parks Service (NPS) near Chimney Rock and are hoping that it will be removed before nesting season starts.

Conservation member Francesca Koe attended the 19th annual California Oceans Day where people advocated for issues including water quality, climate change, kelp, etc. Greater Farallones Association has a new executive director, Monika Krach. Deb Self will now be the Senior Director of Restoration and Partnerships.

Education member Mary Miller is joining the Snapshot Cal Coast using iNaturalist to document species found in tide pools. She is attending a webinar on BioBlitz with the Ocean Protection Council to crowdsource data on environmental changes. She is participating with the Exploratorium to switch out their carbon buoy. She attended the Ocean Observing in California meeting in San Diego celebrating the Central & Northern California Ocean Observing System (CeNCOOS).

Research member Jaime Jahncke was invited to do an oral presentation on ACCESS and mentioned that there are new regulations on crab seasons closing for a certain amount of time depending on the injured animal. For humpback whales, if there are three confirmed entanglements during a calendar year, the fishing season will close and will not reopen until January 1 of the following year. For blue whales, if there is one confirmed entanglement the season will close statewide, and for the next two calendar years the fishing seas will close on April 1 statewide. For Pacific leatherback sea turtles, if there is one confirmed entanglement it will close the fishing season the Fishing Zones 3 and 4 for the next nine years there is an automatic season curtailment in those two zones (January 1-June 1).

Research Alternate member Ellen Hines is celebrating four students defending their theses. She attended the International Whaling Commission Scientific Committee meeting where she presented work on the effects of different management alternatives to ship strikes of whales.

Conservation member Kathi George mentioned that there have been increased levels of domoic acid causing strandings of seals and sea lions. High numbers of pelicans were reported dying due to starvation. Also, a gray whale was killed by a ship strike within the Golden Gate Strait. She recently attended a passive acoustic monitoring conference looking at lessons learned on the east coast, what is being done on the west coast, and what opportunities are needed to be effective on the west coast related to wind farm development and operations. Also, the San Francisco Harbor Safety committee voted to adopt marine mammal guidelines as part of their regulations and next week she is participating on a panel on whales and vessels in Washington DC on behalf of Puget Sound Partnership.

Community-At-Large San Francisco-San Mateo member Barton Selby mentioned April was harbor seal pupping month in Pillar Point Harbor and that the harbor is quiet because of decreased fishing. He also mentioned that pelicans are moving to Pillar Point Harbor looking for food.

U.S. Fish and Wildlife Service (USFWS) Alternate member Gerry McChesney will be spending the next year with Point Blue Conservation Science to determine how to prioritize restoration projects and surveys conducted on the Farallon Islands. USFWS is trying to figure out what facilities can continue to be kept operational and how to transport people onto the island safely. Currently, seabird nesting season is underway on the islands and there have been some humpback and gray whale sightings and it seems that more whales are staying in the area during the winter.

Community-At-Large Marin Alternate member Richard James presented to the members abandoned oyster bags from Tomales Bay along with smaller pieces from broken bags and that the California Coastal Commission is working with the bag producer to improve the design of the bags.

Community-At-Large Marin member George Clyde mentioned Cypress Grove in Marshall and Martinelli Park in Inverness living shoreline projects are not moving forward with their plans.

California Department of Natural Resources Alternate member Abby Mohan is presenting to the Ocean Protection Council for the 30x30 framework on what will be included and how it will be evaluated. She also mentioned that the state was awarded 1 million dollars towards tribal priority projects.

*Meeting highlights prepared by Tishma Patel, Advisory Council Coordinator.*

**Appendix I. CBNMS AC Attendance for the May 2024 GFNMS/CBNMS Advisory Council Meeting. The blue rows are voting members and the purple rows are non-voting members.**

Name	Seat	Attendance
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Vacant	Community-at-Large Marin	--
Grace Milstein	Community-at-Large Marin	Y
Frank Capurro	Community-at-Large Sonoma	Y
Steve Tubbs	Community-at-Large Sonoma	N
Scott Artis	Conservation	Y
Vacant	Conservation	--
Bibit Traut	Education	Y
Adrienne Correa	Education	Y
Chris Ohanian	Fishing	N
Richard Ogg	Fishing	N
Kai Martin	Maritime Activities	Y
Daisy Ruvalcaba	Maritime Activities	Y



Jeff Dorman (Chair)	Research	Y
Jaime Jahncke	Research	Y
Lisa Wooninck	Monterey Bay National Marine Sanctuary (Non-voting member)	N
Dawn Hayes	Monterey Bay National Marine Sanctuary (Non-voting alternate)	N
LT Kynan Barrios	National Marine Fisheries Service (Non-voting member)	N
Vacant	National Marine Fisheries Service (Non-voting alternate)	--
LTJG Nazere Jones	United States Coast Guard (Non-voting member)	N
Vacant	United States Coast Guard (Non-voting alternate)	--

**Appendix II. GFNMS AC Attendance for the May 2024 GFNMS/CBNMS Advisory Council Meeting. The blue rows are voting members and the purple rows are non-voting members.**

Name	Seat	Attendance
Sarah Bates	Commercial Fishing (Primary)	N

Richard Ogg	Commercial Fishing (Alternate)	N
George Clyde	Community-at-Large Marin (Primary)	Y
Richard James	Community-at-Large Marin (Alternate)	Y
Steve Tubbs	Community-at-Large Mendocino-Sonoma (Primary)	N
Vacant	Community-at-Large Mendocino-Sonoma (Alternate)	--
Bart Selby	Community-at-Large San Francisco-San Mateo (Primary)	Y
Vacant	Community-at-Large San Francisco-San Mateo (Alternate)	--
Francesca Koe	Conservation (Primary)	Y
Kathi George	Conservation (Primary)	Y
Scott Artis	Conservation (Alternate)	Y
Vacant	Conservation (Alternate)	--
Mary Miller	Education (Primary)	Y
Vacant	Education (Alternate)	

Jacqueline Moore	Maritime Commercial Activities (Primary)	N
Kai Martin	Maritime Commercial Activities (Alternate)	Y
Mark Bartolini	Maritime Recreational Activities (Primary)	Y
Peter Molnar	Maritime Recreational Activities (Alternate)	N
Jaime Jahncke (Chair)	Research (Primary)	Y
Ellen Hines	Research (Alternate)	Y
Amelia King	Youth (Primary)	N
Vacant	Youth (Alternate)	--
Jenn Eckerle	California Department of Natural Resources (Primary)	N
Abby Mohan	California Department of Natural Resources (Alternate)	Y
Craig Kenkel	National Park Service (Primary)	Y
Ben Becker	National Park Service (Alternate)	N

LTJG Nazere Jones	U.S. Coast Guard (Primary)	N
Vacant	U.S. Coast Guard (Alternate)	--
Matthew Brown	U.S. Fish and Wildlife Service (Primary)	N
Gerry McChesney	U.S. Fish and Wildlife Service (Alternate)	Y
Jennifer Boyce	National Marine Fisheries Service (Primary)	N
Vacant	National Marine Fisheries Service (Alternate)	--
Chris Mobley	Channel Islands National Marine Sanctuary (Primary)	N
Mike Murray	Channel Islands National Marine Sanctuary (Alternate)	N
Lisa Wooninck	Monterey Bay National Marine Sanctuary (Primary)	N
Dawn Hayes	Monterey Bay National Marine Sanctuary (Alternate)	N

## COVER LETTER

### Support Funding for Farallon Islands Research and Monitoring Program

August 2, 2024

Maria Brown,  
Sanctuary Superintendent

Dear Superintendent Brown,

By this letter, the Sanctuary Advisory Councils for Greater Farallones and Cordell Bank National Marine Sanctuaries are recommending that the Greater Farallones and Cordell National Marine Sanctuaries (GF-CBNMS) share the attached resolution with the West Coast Regional Office and the National Office of the National Marine Sanctuaries for consideration.

Sincerely,

---

Sarah Bates, Vice-Chair  
GFNMS Advisory Council

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Jeff Dorman, Chair  
CBNMS Advisory Council

*The councils are an advisory body to the sanctuary superintendent. The opinions and findings of this letter/publication do not necessarily reflect the position of the sanctuaries and the National Oceanic and Atmospheric Administration*

## **PROPOSED RESOLUTION**

### **Support Funding for Farallon Islands Research and Monitoring Program**

Whereas, protecting endangered species and sanctuary resources is a priority issue for the National Oceanic and Atmospheric Administration (NOAA), the Office of National Marine Sanctuaries (ONMS), and the U.S. Fish and Wildlife Service (USFWS).

Whereas, the Farallon Islands, managed by the USFWS as the Farallon Islands National Wildlife Refuge, provide critical habitat for the largest seabird breeding colony in the contiguous United States, as well as five breeding pinniped species. The islands also play a significant role in the broader ecosystem of NOAA's Greater Farallones and Cordell Bank National Marine Sanctuaries (GFNMS).

Whereas, Point Blue Conservation Science has maintained a continuous research and monitoring presence on the Farallon Islands for 56 years, providing invaluable data that supports the management and conservation of both the refuge and the adjacent marine sanctuaries.

Whereas, citing budgetary constraints at the regional and federal level, the USFWS has notified Point Blue that it will no longer be able to provide funding for its research and monitoring program on the Farallon Islands starting in 2025. This funding cut threatens the continuity of vital ecological data and potentially impacts wider marine ecosystem management.

Whereas, the loss of continuous year-round data from the Farallon Islands will significantly impact the ability of the GFNMS to manage and protect marine resources effectively. The data collected by Point Blue is crucial for understanding predator-prey dynamics, seasonal migrations, and the health of marine populations, including whales, seabirds, and pinnipeds.

Whereas, the Point Blue research program has contributed to significant environmental policy reforms, including the prohibition of gill-netting to protect seabirds and the creation of Marine Protected Areas around the Farallon Islands. The long-term datasets provided by Point Blue are critical for ongoing conservation efforts and policy development.

Whereas, the discontinuation of year-round monitoring will hinder the ability to report and respond to environmental threats, such as vessel groundings and oil pollution events, which are integral to minimizing environmental damage and ensuring the health of the marine ecosystem.

Whereas, the absence of Point Blue's research team during the fall and winter months will reduce the sanctuary's ability to enforce regulations designed to protect sensitive environments and wildlife, leading to increased human disturbance and potential wildlife mortality.

Therefore be it resolved, that the Sanctuary Advisory Councils for Greater Farallones and Cordell Bank National Marine Sanctuaries hereby jointly recommend that:

1. GFNMS should communicate with the USFWS to explore alternative mechanisms to maintain a year-round presence on the Farallon Islands, ensuring the continued collection of critical ecological data.
2. GFNMS should communicate at all policy levels the importance of Farallon Islands data in supporting sanctuary management goals and highlight the potential impacts of data loss on marine conservation efforts.
3. GFNMS should engage the public and private sectors, as well as conservation organizations, to provide support and resources to sustain the long-term ecological monitoring and research activities on the Farallon Islands.
4. GFNMS will explore requesting and allocating funds from NOAA to support activities that directly benefit sanctuary management and contribute those funds to Point Blue's research and monitoring program on the Farallon Islands.

By taking these steps, we can ensure the protection of the Farallon Islands' unique ecosystem and support the ongoing conservation efforts critical to the health and resilience of the Greater Farallones and Cordell Bank National Marine Sanctuaries.

*The councils are an advisory body to the sanctuary superintendent. The opinions and findings of this letter/publication do not necessarily reflect the position of the sanctuaries and the National Oceanic and Atmospheric Administration*

## Summary of Ratings: GFNMS Condition Report 2010-2022

Full report and summary documents can be found at: <https://sanctuaries.noaa.gov/science/condition/gfnms/>

### GFNMS Condition Report 2010-2022 Ratings: COASTAL AND OFFSHORE

#	Resource Question	Question	Status	Confidence	Trend	Confidence
1	Human Dimension	Drivers	No rating assigned			
2		Water/Human Activities	Fair	Medium	↑↓	High
3		Habitat/Human Activities	Fair	Low	?	Medium
4		Living Resources/Human Activities	Fair	High	↑↓	High
5		Heritage Resources/Human Activities	Good/Fair	Medium	↑	Medium
6	Water Quality	Eutrophication	Good	High	?	Medium
7		Risk to Human Health	Fair	Medium	↑↓	Medium
8		Climate Change	Fair	High	↓	Medium
9		Other Stressors	Good/Fair	Low	↑↓	Medium
10		Habitat Integrity	Fair	Medium	↑↓	Medium
11	Habitat	Contaminants	Good/Fair	High	↑↓	High
12	Living Resources	Keystone and Foundation Species	Fair/Poor	High	↑↓	High
13		Other Focal Species	Fair	Medium	↑↓	Medium
14		Non-Indigenous Species	Good	Low	?	Medium
15		Biodiversity	Good/Fair	High	↑↓	High
16	Maritime Heritage	Integrity	Good/Fair	Medium	—	Low

### GFNMS Condition Report 2010-2022 Ratings: ESTUARINE AND LAGOON

#	Resource Question	Question	Status	Confidence	Trend	Confidence
1	Human Dimension	Drivers	No rating assigned			
2		Water/Human Activities	Fair	Low	↑↓	Low
3		Habitat/Human Activities	Fair	Medium	?	Medium
4		Living Resources/Human Activities	Good/Fair	Medium	—	Medium
5		Heritage Resources/Human Activities	Good	Medium	↑	Medium
6	Water Quality	Eutrophication	Good/Fair	Medium	?	Medium
7		Risk to Human Health	Fair	High	?	High
8		Climate Change	Fair	Low	?	Medium
9		Other Stressors	Fair	High	?	Low
10		Habitat Integrity	Fair/Poor	Medium	—	High
11	Habitat	Contaminants	Fair	Low	↑↓	Low
12	Living Resources	Keystone and Foundation Species	Fair	Medium	?	Medium
13		Other Focal Species	Fair/Poor	Medium	?	Low
14		Non-Indigenous Species	Fair	Medium	↑↓	High
15		Biodiversity	Undet.	Medium	?	Medium
16	Maritime Heritage	Integrity	Good	Medium	—	Low



**GFNMS Condition Report 2010-2022 Ratings: Ecosystem Services**

#	Ecosystem Service		Status	Confidence	Trend	Confidence
1	Cultural	Science	Good/Fair	High	↑	Low
2		Education	Good/Fair	Very High	↑	Very High
3		Heritage	Good	High	↑	High
4		Sense of Place	Good/Fair	High	↑	High
5		Consumptive Recreation	Fair	High	?	Low
6		Non-consumptive Recreation	Good/Fair	Medium	↑↓	Medium
7	Provisioning	Commercial Harvest	Good/Fair	Medium	↑↓	High
8	Regulating	Coastal Protection	Fair/Poor	Medium	?	Medium

Key	
Status	Trend
Good	improving ↑
Good/Fair	no change —
Fair	worsening ↓
Fair/Poor	
Poor	
Mixed	mixed ↑↓
Undet.	undet. ?
N/A	N/A



# Addendum to “Climate Change Vulnerability Assessment for the North-central California Coast and Ocean”



**February 2024**

U.S. Department of Commerce  
Gina Raimondo, Secretary

National Oceanic and Atmospheric Administration  
Richard W. Spinrad, Ph.D., Under Secretary of Commerce for Oceans and Atmosphere and  
NOAA Administrator

National Ocean Service  
Nicole LeBoeuf, Assistant Administrator

Office of National Marine Sanctuaries  
John Armor, Director



**NATIONAL  
MARINE  
SANCTUARIES**

Suggested citation: Hutto, S.V. 2024. Addendum to “Climate Change Vulnerability Assessment for the North-central California Coast and Ocean.” National Oceanographic and Atmospheric Administration Greater Farallones and Cordell Bank National Marine Sanctuaries. DOI: 10.25923/20fo-b058

Cover photo: (left) Sea Palm; (top): North-central California coastline; (bottom, center): black oystercatcher; (bottom, right): California hydrocoral

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## Glossary of Acronyms

BML: Bodega Marine Lab  
CBNMS: Cordell Bank National Marine Sanctuary  
CDFW: California Department of Fish and Wildlife  
CSUMB: California State University, Monterey Bay  
CVA: Climate Vulnerability Assessment  
GFA: Greater Farallones Association  
GFNMS: Greater Farallones National Marine Sanctuary  
MBNMS: Monterey Bay National Marine Sanctuary  
MHR: Maritime Heritage Resources  
MHW: Marine Heat Wave  
MLML: Moss Landing Marine Labs  
NERR: National Estuarine Research Reserve  
NMFS: National Marine Fisheries Service  
NPS: National Park Service  
NOAA: National Oceanic and Atmospheric Administration  
ONMS: Office of National Marine Sanctuaries  
SCCWRP: Southern California Coastal Water Research Project  
UCB: University of California, Berkeley  
UCD: University of California, Davis  
UCSC: University of California, Santa Cruz  
USFWS: United States Fish and Wildlife Service  
USGS: United States Geological Survey

## Executive Summary

This addendum to the report *Climate Change Vulnerability Assessment for the North-central California Coast and Ocean* (Hutto et al., 2015) provides updated information for 25 of the 40 resources assessed in 2014, and presents first-time assessments for three maritime heritage resource (MHR) categories. This addendum provides the latest climate vulnerability information for key species, habitats, ecosystem services, and MHR of the north-central California coast and ocean (Figure 1), including Greater Farallones and Cordell Bank National Marine Sanctuaries, as well as the northern portion of Monterey Bay National Marine Sanctuary (sanctuaries), and should be referenced alongside the 2015 report. Of the 40 resource assessments conducted in 2014, 35 were reviewed by subject matter experts to determine if a revision was required based on continued changing ecological conditions and improved scientific understanding since the 2015 publication. Of these, 25 were identified by experts as requiring revision, which included modifications to the vulnerability scores and new information for the narrative descriptions based on experts' current understanding of the resource's exposure to climate change, sensitivity to climate change, and/or its capacity to adapt to these changes.

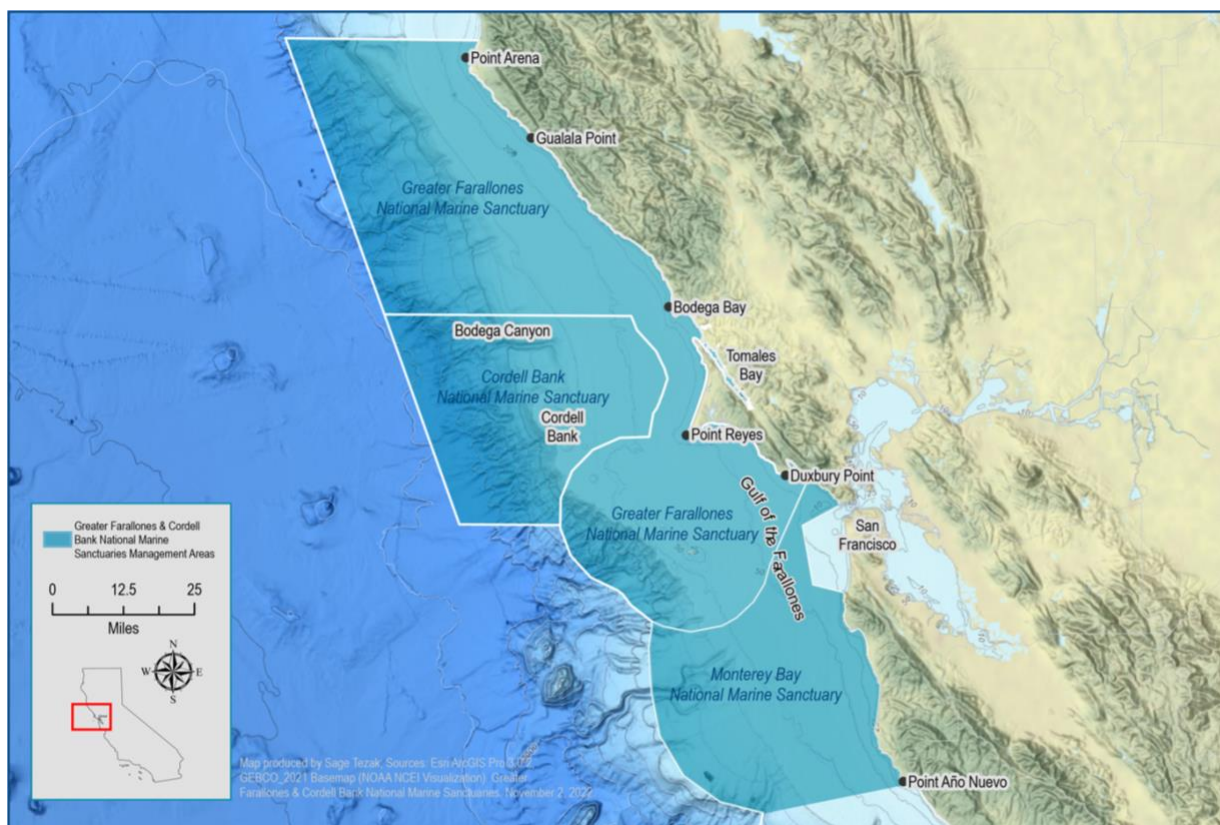


Figure 1. Map of the study region, which includes Greater Farallones and Cordell Bank National Marine Sanctuaries, as well as the northern portion of Monterey Bay National Marine Sanctuary.

These revisions resulted in increased vulnerability scores for 17 species and six habitats, and decreased vulnerability scores for one species group and two ecosystem services. One species assessment was modified and corrected, but no changes were made to its score. The primary

driving factor for increased vulnerability is increased exposure and sensitivity to elevated water temperatures due to the increasing frequency and severity of marine heatwaves (MHW). The sanctuaries experienced profound and severe impacts to species abundance and health, community composition, and ecosystem function from the 2014-2016 MHW and subsequent MHW events (Auth et al., 2018; Elliott et al., 2022; Rogers-Bennett and Catton, 2019; Sanford et al., 2019), and models suggest MHWs will become more frequent and severe in a changing climate (Frölicher et al., 2018). Of these revisions, which on average resulted in a two-point increase to vulnerability, a few resources in particular stand out as having high increases in vulnerability to climate change since the 2015 report, including approximately a three-point increase for rocky intertidal habitat, red abalone, blue whale, pteropod and krill species, and over a four-point increase for kelp forest habitat. Some of these increases in vulnerability are due, in part, to a methodological change that increased the contribution of exposure to the vulnerability score. Though the most vulnerable resources are still largely those in coastal areas, offshore oceanographic processes and drivers of change are now a much greater relative concern. The 2014-2016 MHW had unprecedented impacts on nearly all resources in the sanctuaries; it is clear that sea surface temperature, driven both by discrete events like El Niño and other MHW events, as well as persistent ocean warming, will be an ongoing concern and stressor on sanctuary health and resilience, and impacts to resources from this stressor must be prioritized to ensure ecological function persists across all habitats.



Figure 2. Bull kelp forest received the greatest increase in vulnerability. Photo: NOAA

Three tangible MHR categories—doghole ports, nearshore shipwrecks and offshore shipwrecks—were also assessed. These resources were not included in the 2014 assessment and, as such, a full assessment was conducted and is presented separately from the other resources described in this addendum, on pages 67-85. The potential impact of climate change, which for MHR is defined only as the exposure and sensitivity to climate and non-climate stressors, was rated as high for both nearshore shipwrecks and doghole ports, and low for offshore shipwrecks.



## Methods

From June 2022 to February 2023, Office of National Marine Sanctuary staff initiated an expedited but thorough update of the 2015 report (Hutto et al., 2015). First, a single subject-matter expert (Appendix 1) was identified for 35 of the original 40 resources in the 2015 report and was asked to complete a revision survey. Five of the 40 original assessments were not surveyed and are thus excluded from this addendum, either because the expertise to do so was not available (ecosystem service assessments of food production, water quality and recreation and tourism) or because the resource was outside sanctuaries' management area and authority (gaper clam and American dune grass, included in the 2015 assessment at the request of National Parks Service). For the remaining 35 assessments, subject-matter experts were asked to: 1) review the 2015 assessment, updated climate trends for the region (Appendix 2), information that was compiled for the draft condition reports for GFNMS for the years 2010-2022 and CBNMS for the years 2009-2021, and 2) complete a survey (Appendix 3) indicating whether revisions are needed in light of any new information since the assessments were conducted in 2014. Based on the survey results, it was determined that 10 of the assessments remained accurate and did not need an update: beach/dune habitat, cliff habitat, black oystercatcher, black rail, cavity-nesting birds, copepods, mole crab, surface-nesting birds, tidewater goby, widow rockfish. For the 25 assessments that did require an update, extensive literature review and expert elicitation (via email and phone conversations) were conducted to draft revision summaries, which included proposed changes to the original vulnerability scores<sup>1</sup>, using the below equation, confidence in those scores, and narrative justification.

Vulnerability = (Exposure + Sensitivity) - Adaptive Capacity


Based on the score revisions, new categorical ratings (very low, low, moderate, high, very high) were assigned when the revision resulted in the score falling into a different rating category than in the previous assessment. Each draft revision summary was then distributed to two to three additional experts, termed reviewers (Appendix 1), for review and further modification. Following this review period, a vulnerability revision workshop was held with 24 regional experts to review and confirm the revisions, and incorporate any additional information, for each of the 25 revised assessments.

In addition to the score revisions based on this expert input, a methodological revision was also applied to the 35 surveyed resource assessments to remove the half-weighting previously assigned to the exposure score. In the 2015 report, exposure was weighted 50% less than sensitivity and adaptive capacity because of the uncertainty and variability that was observed at the time in the climate projections for the region. However, in 2023, experts agreed that confidence in climate models increased sufficiently to apply equal weighting to exposure, sensitivity, and adaptive capacity. Comparing the original 2015 scores (exposure half-weighted) to the new 2023 scores (exposure fully weighted) resulted in an across-the-board increase in vulnerability in 2023, which over-inflates the actual increases in vulnerability. Therefore, the

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<sup>1</sup> For information on the vulnerability assessment model and scoring methodology, reference pages 17-26 of the 2015 Climate Vulnerability Assessment Report:

<https://sanctuaries.noaa.gov/science/conservation/vulnerability-assessment-gfnms.html>



2015 scores were adjusted using the 2023 formula (removing the half-weighting for exposure) to allow for a more direct comparison of resources' vulnerabilities in 2015 vs. 2023. This removed large increases in vulnerability that were a result of methodological modifications alone (e.g., pteropod, krill) and retained those that were a result of actual changes in the understanding of resource climate vulnerability (e.g., kelp, red abalone; see Appendix 4 for original and adjusted scores for all 40 original resource assessments).

## Results and Discussion

### *Habitats*



Figure 3. Beaches and dunes in the study region ranked as the most vulnerable habitat. Photo: NOAA.

Of the eight habitats assessed, the ranking of the three most vulnerable habitats (Table 1) have not changed since 2015. Beaches and dunes still have the highest vulnerability score, followed by estuaries, then rocky intertidal. However, kelp forest habitat went from the lowest vulnerability score (eight out of eight) in the 2015 assessment to the fourth most vulnerable in this revision. The significant increase in the climate vulnerability score of bull kelp as the primary canopy-forming species in the sanctuary represents the most significant and unexpected change in our understanding of climate vulnerability since 2015, and exemplifies how much our understanding of a resource's vulnerability can change as novel ecological conditions arise. During the 2014 vulnerability workshop, kelp ecologists and phycologists agreed that kelp is highly resilient and well adapted to oceanographic variability and large swings in its relative abundance. While this assessment was accurate based on the best available scientific information at the time, the severe and unprecedented decline and persistent lack of recruitment since 2014 changed the scientific community's perception of kelp's vulnerability, which is reflected in these results. This exemplifies the difficulty facing marine resource managers under increasingly uncertain and unprecedented climatological conditions. The other major change in habitat vulnerability rankings is that cliffs were ranked as the fourth most vulnerable in 2015 and are now ranked as the least vulnerable in 2023; this is largely due to the vulnerability scores for nearshore, pelagic, and offshore habitats increasing more than that of cliff habitat, due in part to the 2014-2016 MHW, and does not indicate that cliffs are perceived to be any less vulnerable to climate change than they were in 2015.

Table 1. The calculated scores, rounded to the nearest tenth, for overall vulnerability, sensitivity, exposure, and adaptive capacity for the eight habitats surveyed, ordered by decreasing vulnerability score.

Habitats	Overall Vulnerability	Sensitivity	Exposure	Adaptive Capacity
Beaches and Dunes	5.3 High	3.9 High	4.5 Very High	3.1 Moderate
Estuaries	5.0 High	4.1 High	4.6 Very High	3.6 High
Rocky Intertidal	4.7 High	4.0 High	4.2 High	3.5 High
Kelp Forest	4.7 High	4.1 High	3.9 High	3.3 Moderate
Nearshore	3.7 Moderate	2.9 Moderate	4.2 High	3.3 Moderate
Pelagic Water Column	3.2 Moderate	2.7 Moderate	4.1 High	3.7 High
Offshore Rocky Reefs	2.9 Moderate	2.5 Low	3.0 Moderate	2.7 Moderate
Cliffs	2.6 Moderate	3.2 Moderate	2.3 Low	2.8 Moderate

## Species



Figure 4. Pteropods, black oystercatchers, and Western snowy plovers now rank as the 3 most vulnerable species in the study region. Photos: NOAA

Nearly all species vulnerability scores increased since the 2015 assessment, with the exception of the California hydrocoral and white-lobed sponge (assessed together), which declined negligibly due to a very slight decrease in the sensitivity score. The greatest increase in vulnerability score was for red abalone, which went from being ranked as the 11th most vulnerable species to the fifth most vulnerable due to impacts from the MHW and subsequent loss of kelp. Other significant increases in vulnerability scores within the top 10 species are due both to increases in sensitivity scores, as well as the increased weighting of exposure (see Methods), and includes pteropod (from third to most vulnerable), blue whale (from eighth to fifth), Olympia oyster (from 10th to seventh), and copepod (from 17th to 10th). When compared with the original 2015 assessment scores, all 28 species vulnerability scores increased, and though some vulnerability score increases are due to the methodological change of removing the half-weighting for exposure, this is still a notable outcome of this revision as it reflects our understanding of the increasing importance of and confidence in exposure to climate stressors for a resource's climate vulnerability.

Table 2. The calculated scores, rounded to the nearest tenth, for overall vulnerability, sensitivity, exposure, and adaptive capacity for the twenty-eight species surveyed, ordered by decreasing vulnerability score.

<b>Species</b>	<b>Overall Vulnerability</b>	<b>Sensitivity</b>	<b>Exposure</b>	<b>Adaptive Capacity</b>
Pteropod	6.4 High	4.0 High	5.0 Very High	2.6 Low
Black oystercatcher	6.3 High	4.6 Very High	4.6 Very High	2.9 Moderate
Western snowy plover	5.5 High	4.0 High	4.3 Very High	2.8 Moderate
Blue whale	5.3 High	4.1 High	5.0 Very High	3.8 High
Red abalone	5.2 High	3.8 High	3.8 High	2.4 Low
Sea palm	5.0 High	3.6 High	4.0 High	2.7 Moderate
Olympia oyster	4.5 High	3.2 Moderate	4.3 Very High	2.9 Moderate
Black rail	4.3 High	3.8 High	2.5 Low	2.0 Low
Ashy storm petrel	4.1 Moderate	3.4 Moderate	2.5 Low	1.8 Very Low
Copepod	4.1 Moderate	2.0 Low	5.0 Very High	2.9 Moderate
Southern sea otter	4.1 Moderate	2.9 Moderate	3.6 High	2.5 Low
Cassin's auklet	4.0 Moderate	3.5 High	3.4 Moderate	2.9 Moderate
Tidewater goby	4.0 Moderate	3.0 Moderate	3.0 Moderate	2.0 Low
Pacific herring	3.9 Moderate	2.8 Moderate	4.0 High	2.9 Moderate
California mussel	3.9 Moderate	3.3 Moderate	4.1 High	3.5 High
Ochre sea star	3.7 Moderate	3.0 Moderate	4.1 High	3.3 Moderate
Pacific sardine	3.5 Moderate	3.2 Moderate	3.7 High	3.4 Moderate
Mole crab	3.4 Moderate	2.0 Moderate	4.8 Very High	3.4 Moderate
Red urchin	3.3 Moderate	3.6 High	3.2 Moderate	3.5 High
Coralline algae	3.3 Moderate	2.9 Moderate	3.0 Moderate	2.6 Low
Purple urchin	3.2 Moderate	3.6 High	3.2 Moderate	3.5 High
Brandt's cormorant, Common murre	3.1 Moderate	3.5 High	2.6 Low	3.0 Moderate
California hydrocoral, White lobe sponge	3.1 Moderate	3.1 Moderate	3.1 Moderate	3.2 Moderate
Northern anchovy	2.9 Moderate	2.9 Moderate	3.6 High	3.5 High
Krill	2.8 Moderate	1.8 Very Low	5.0 Very High	4.0 High
Pigeon Guillemot, Tufted puffin	2.8 Moderate	3.4 Moderate	2.5 Low	3.2 Moderate
Widow rockfish	2.7 Moderate	3.0 Moderate	3.2 Moderate	3.5 High
Blue rockfish	2.1 Moderate	3.0 Moderate	2.8 Moderate	3.7 High

# Ecosystem Services



Figure 5. Tidal marsh, pictured here in Bolinas Lagoon, provides carbon storage and sequestration and flood and erosion protection services, both of which are considered highly vulnerable to climate change. Photo: NOAA.

Only two of the five ecosystem services from the 2015 report were included in this assessment, and both saw a slight decrease in vulnerability scores when compared with adjusted 2015 scores (Table 3). This decrease is driven by higher scores for adaptive capacity based on new understanding of how valued these services are to people and people’s willingness to change their behavior to protect and maintain these services. However, this score change is negligible, and both ecosystem services remain rated as having high vulnerability.

Table 3. The calculated scores, rounded to the nearest tenth, for overall vulnerability, sensitivity, exposure and adaptive capacity for the two ecosystem services surveyed, ordered by decreasing vulnerability.

Ecosystem services	Overall Vulnerability	Sensitivity	Exposure	Adaptive Capacity
Flood and erosion protection	5.6 High	4.8 Very High	5.0 Very High	4.3 Very High
Carbon storage and sequestration	5.5 High	3.5 High	5.0 Very High	3.0 Moderate

## *Components of Vulnerability*

To illustrate differences in the component scores (sensitivity, exposure, adaptive capacity), and the impact those differences have on the overall vulnerability scores, resources were grouped by high sensitivity scores, high exposure scores, and low adaptive capacity scores (Figure 6, Foden et al., 2013). This illustrates which resources are vulnerable because they are highly sensitive (a score >3.41, e.g. Brandt's cormorant), highly exposed (a score >3.41, e.g. California mussel), or non-adaptive (a score <3.0, e.g. Ashy storm petrel), which can better inform subsequent adaptation or management measures. Some resources have a combination of these characteristics, such as black rail, which is both highly sensitive and non-adaptive; these species are projected to have low to moderate future exposure to climate stressors and therefore may not currently be at risk but have high latent risk. Other focal resources, such as copepods, are highly exposed and non-adaptive, but not highly sensitive, and therefore characterized as "potential persisters" and may not be at risk. Resources such as the ecosystem services of flood and erosion protection and carbon storage and sequestration are highly sensitive and highly exposed, but have moderate to high adaptive capacity and are characterized as "potential adapters". Finally, resources that have a combination of high sensitivity, high exposure, and are non-adaptive are the most vulnerable resources—black oystercatcher, pteropod, red abalone, sea palm, and Western snowy plover. These resources are also in the top 10 most vulnerable species, and should be prioritized for management action. Resources whose scores do not qualify for any portion of the Venn diagram (Figure 6) may be considered "not currently at risk;" that includes blue and widow rockfish, hydrocoral and sponge, pigeon guillemot and tufted puffin.

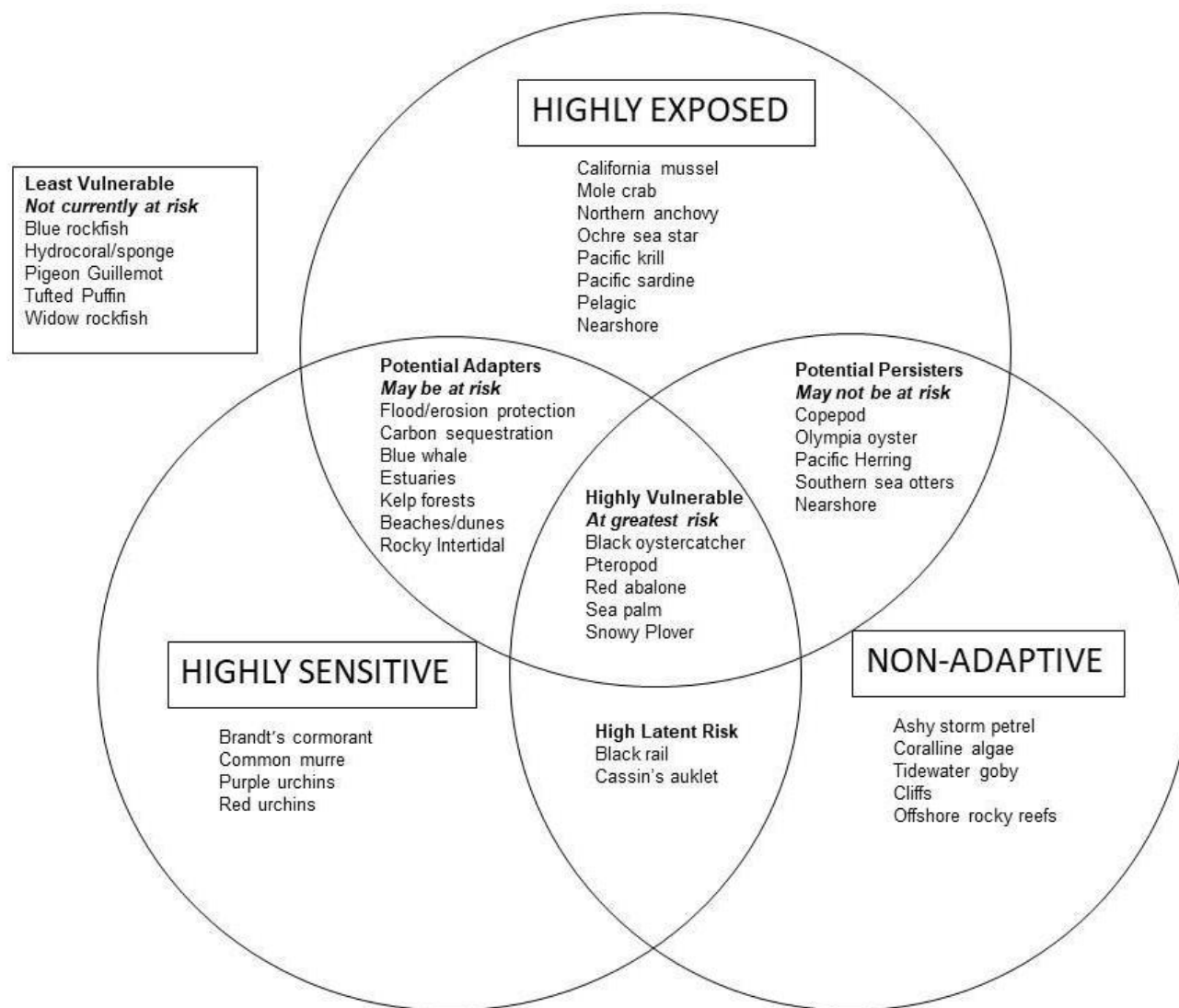


Figure 6. Venn diagram (Foden et al., 2013) of all 35 resources, organized by component vulnerability scores.



## Drivers of Vulnerability

In analyzing the primary climate and non-climate stressors that contribute to resource sensitivity (Tables 4,5), it is clear that sea surface temperature and ocean conditions (currents, mixing, and stratification) are greater concerns than they were in 2015. These two climate stressors are currently ranked second (SST) and fourth (ocean conditions) for their average sensitivity score across all resources; in 2015, these stressors were ranked ninth and seventh, respectively. Other changes in the relative importance of individual climate stressors include increased sensitivity scores for pH, dissolved oxygen, coastal erosion, sea level rise, and air temperature, and slightly decreased sensitivity scores for salinity and wave action based on new information on how habitats and species are impacted by these stressors. In 2015 the top three climate stressors for resource sensitivity were 1) storm severity and frequency, 2) coastal erosion, and 3) wave action, and in 2023 the top three climate stressors are 1) storm severity and frequency, 2) sea surface temperature, and 3) coastal erosion. It is worth noting that sea surface temperature has the highest average sensitivity score for the greatest number of resources (n=27). The leading non-climate stressors driving resource vulnerability have not changed significantly since 2015; roads/armoring, invasive species, and aircraft/vessels still hold the top three spots. There were very few changes to the non-climate average sensitivity scores, with increases to land use change and harvest and a very slight increase to pollution/poisons.

Table 4. Climate stressors, listed by decreasing revised average sensitivity score for those species and habitats that identified the stressor as a sensitivity. The change in score from 2015 is noted.

Climate stressor	Number of resources	2023 average sensitivity score	Change from 2015 score
Storm severity/frequency	6	4.67	0.00
Sea surface temperature	27	3.71	+0.67
Coastal erosion	24	3.45	+0.20
Currents/mixing/stratification	29	3.39	+0.25
Wave action	22	3.32	-0.18
pH	30	3.31	+0.11
Oxygen	24	3.19	+0.11
Salinity	26	3.19	-0.04
Sedimentation	4	3.17	0.00
Sea level rise	18	3.13	+0.19
Air temperature	21	3.05	+0.24
Precipitation	26	2.64	+0.10

Table 5. Non-climate stressors, listed by decreasing revised average sensitivity score for those species and habitats that identified the stressor as a sensitivity. The change in score from 2015 is noted.

<b>Non-climate stressor</b>	<b>Number of resources</b>	<b>2023 average sensitivity score</b>	<b>Change from 2015 score</b>
Roads/armoring	8	3.88	0.00
Invasive & other problematic species	17	3.73	-0.05
Aircraft/vessels	3	3.67	0.00
Land use change	14	3.57	+0.24
Recreation	13	3.54	0.00
Pollution and poisons	31	3.48	+0.05
Harvest	20	3.33	+0.26
Overwater/underwater structures	4	3.25	0.00
Energy production	6	2.00	0.00

## Conclusions and Next Steps

This climate vulnerability revision generated two major findings. First, while the most vulnerable resources are still largely in the coastal region, offshore oceanographic processes and drivers of change are now a much greater concern, relative to 2015, for species in both offshore and coastal habitats. This is reflected in this revision via increased vulnerability scores for pelagic and offshore species (e.g. pteropod), and the increased sensitivity scores, averaged across all resources, for sea surface temperature and dynamic ocean conditions (currents/mixing/stratification). The second major finding is that the 2014-2016 and subsequent MHWs had unprecedented impacts that reached from the rocky intertidal (Sanford et al., 2019) and kelp forests (Lonhart et al., 2019; Rogers-Bennet and Catton, 2019) to the offshore environments in the sanctuaries (Elliott et al., 2022). Very few resources were not impacted by the MHWs, and in particular, kelp forest-associated species were adversely affected. It is clear that sea surface temperature, driven both by discrete events like El Niño and other MHW events as well as persistent ocean warming, will be an ongoing physical stressor on sanctuary health and resilience and a primary management concern. Impacts to resources from this stressor must be prioritized to ensure ecological function persists across all habitats.

Moving forward, the sanctuaries should incorporate this information into a thorough update of the 2016 Climate Adaptation Plan (Hutto, 2016), and highlight the increased urgency of addressing warming ocean waters in the current Management Plan Review process. Ideally, in the next Management Plan, the sanctuaries will develop climate adaptation strategies and actions that target the key vulnerabilities identified in this addendum to ensure sanctuary resources can persist and thrive into the future. Uncertainties persist regarding the timing and severity of change, but continued long-term monitoring of climate indicators through sanctuary efforts, such as the Applied California Current Ecosystem Studies project and the Beach Watch project, will contribute to documentation of both climate and non-climate stressors and their impacts. Monitoring projects such as these, and those that are conducted by partners and external agencies, are increasingly critical to provide the foundational information that informs these assessments. We recommend that the sanctuaries continue to invest in monitoring indicators of change, and plan to conduct a completely new Climate Vulnerability Assessment by the year 2035, or just prior to the Sanctuaries' next management plan review process.



## Revision Summaries

The following section presents CVA revision summaries for the 25 resources whose scores were revised. The remaining 15 original summaries can be viewed in the original report<sup>2</sup>. Summaries are listed in alphabetical order within resource categories, with habitat summaries presented first, followed by species, and then ecosystem services. Three summaries combine information for multiple species due to the similarities in most aspects of vulnerability: Northern anchovy and Pacific sardine, purple and red urchins, and California hydrocoral and white-lobed sponge. Each summary includes the reference pages for the original 2015 vulnerability assessment report (Hutto et al., 2015), which should be reviewed alongside this addendum.

Each individual revision summary is formatted in the same manner, with an introductory statement providing brief context for the revision, followed by score tables that present the revised scores and category descriptors for each component of vulnerability, the confidence in the revised scores, and the numerical change in the scores from the 2015 assessment. Note that the change is calculated using adjusted 2015 scores based on the methodological revision of removing the reduced exposure weighting (see Methods). Following the score tables, the details of the revisions are provided, including justification with relevant references from the literature and/or expert opinion. Finally, corrections to the 2015 assessment that did not change any scores are provided. Literature cited is included for each individual revision summary, for easy reference. The resulting revisions represent an evaluation of vulnerability scores based on existing scientific information and expert input. These revisions are intended to help sanctuary management develop and prioritize adaptation strategies to conserve these resources in the face of climate change, and are intended to be living documents that can be revised and expanded upon as new information becomes available.

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<sup>2</sup> <https://sanctuaries.noaa.gov/science/conservation/vulnerability-assessment-gfnms.html>

## Habitats

### Estuaries

\*\*reference pages 56-63 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Dissolved oxygen was underestimated in the 2015 assessment as a significant stressor for estuaries; slight revisions and corrections were made for this assessment.

Estuaries	Revised Score	Confidence	Change
Sensitivity	4.1 High	High	+0.04
Exposure	4.6 Very High	High	+0.2
Adaptive Capacity	3.6 High	High	-
Vulnerability	5.0 High	High	+0.3

*Sensitivity:* One score revised. Very slight increase in sensitivity score.

1. Dissolved oxygen: Increased from 3 (moderate) to 5 (very high) as dissolved oxygen is a significant and increasing threat in estuaries, especially as temperature increases (E. D. Grosholz/UCD, personal communication, September 30, 2022). The duration and severity of hypoxia were negatively correlated with fish survival and oyster growth, with lethal and sub-lethal effects even on stress-tolerant organisms in the estuary (Jeppeson et al., 2015)

*Exposure:* One score revised. Slight increase in exposure score.

1. Reduced dissolved oxygen: Increased from 3 (moderate) to 5 (very high); exposure to this stressor is expected to increase with increasing water temperature in estuaries (E. D. Grosholz/UCD, personal communication, September 30, 2022).

#### Corrections to 2015 CVA Summary:

*Invasive species* (page 59): Invasive species both out-compete *and consume* native species and decrease native species diversity and abundance. Consumption of native species is likely to have a more significant impact due to invasive species, such as the European green crab and the eastern oyster drill, *Urosalpinx cinerea*.

#### References:

- Jeppeson, R., Rodriguez, M., Rinde, J., Haskins, J., Hughes, B., Mehner, L., & Wasson, K. (2016). Effects of Hypoxia on Fish Survival and Oyster Growth in a Highly Eutrophic Estuary. *Estuaries and Coasts*, 41, 89-98. DOI: 10.1007/s12237-016-0169-y

## Kelp Forest

\*\*reference pages 64-71 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Beginning in 2013, the nearshore area of the northern California coastline underwent a drastic loss (>90%) of kelp forest habitat due to a prolonged MHW compounded by a strong El Niño, loss of important urchin predators, and a boom in urchin (kelp grazer) populations (Rogers-Bennett and Catton, 2019). The scale of this kelp loss is unprecedented based on 35 years of Landsat data, and has resulted in the formation of a persistent urchin barren ecosystem state (McPherson et al., 2021), with little to no recovery of kelp in the region as of 2022 (R. Hohman/GFA, personal communication, October 19, 2022). Significant revisions to the 2015 assessment are warranted, both because of new information but also because of incorrect initial ratings.

Kelp forest	Revised Score	Confidence	Change
Sensitivity	4.1 High	High	+1.2
Exposure	3.9 Mod	High	+1.3
Adaptive Capacity	3.3 Mod	High	-0.6
Vulnerability	4.7 High	High	+3.1

*Sensitivity*<sup>3</sup>: Four scores revised, two scores added, five scores removed. Large increase in sensitivity score and overall rating increased to high.

1. Sea surface temperature: Increased from 4 (high) to 5 (very high) due to documented cascading impacts of the MHW, including ecosystem transition and subsequent severe loss of kelp as both habitat and food (Rogers-Bennett and Catton, 2019; McPherson et al., 2021; Rogers-Bennett and Catton, 2022).
2. Salinity and oxygen: Decreased from 5 (very high) to 3 (moderate), as these are not critical, driving stressors for kelp.
3. Turbidity: Added as 4 (high), as this is a known stressor for kelp recruitment (e.g., Devinsky and Vorse, 1978; Watanabe et al., 2016), growth and resilience (Tait, 2019), and productivity (Blain et al., 2021). In addition, Kiest (1993) documented kelp forest community consequences due to landslides and sediment deposition and transport.
4. Disturbance regimes:
  - . Sensitivity to disease increased from 2 (low) to 4 (high) due to indirect impact of seastar wasting (over-grazing from urchins that were released from predation, which may have led to the transition to urchin barrens)
  - a. Sensitivity to MHW added as a 5 (very high)
5. Sensitivity and current exposure to harvest were removed from the overall sensitivity score, as there is currently in place a temporary (2023-2026) closure of commercial harvest of bull kelp and recreational harvest is presumed to be negligible (not reported).

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<sup>3</sup> The original sensitivity scoring included very low scores for stressors that are likely not a driver of change for kelp forests (i.e. sea level rise, air temperature) or whose impacts were redundant with other stressors (i.e. coastal erosion with turbidity, precipitation with salinity). These scores were either artificially reducing the overall sensitivity score or were emphasizing the impact of some stressors, and have been removed from the final average to ensure a more representative final rating of climate sensitivity for kelp forests.

*Exposure*<sup>4</sup>: Two scores revised, one score added, five scores removed. Large increase in exposure score and overall rating increased to high.

1. Sea surface temperature: Changed from 1 (very low) to 4 (high) based on 2014-2016 MHW (and subsequent heatwave events), and projections that MHWs will increase in severity and frequency (Frölicher et al., 2018).
2. Changes in salinity increased from 1 (very low) to 3 (moderate) due to projections of increased precipitation variability (Swain et al., 2018) and extreme precipitation events (Huang and Swain, 2022).
3. Turbidity added: 4 (high) due to projected increase in the severity of precipitation events (Huang and Swain, 2022), resulting impacts to coastal erosion, and storm-driven waves.

*Adaptive capacity*: Three scores revised. Decrease in adaptive capacity score and overall rating decreased to moderate.


1. Structural and functional integrity: Decreased from 4 (near pristine) to 1 (degraded) due to 90% loss that occurred in 2014 (Rogers-Bennett and Catton, 2019), and the little to no recovery documented since that time (R. Hohman/GFA, personal communication, October 19, 2022). This has led to degradation of the commercial urchin and recreational abalone fisheries, as well as cascading social impacts to local users of sanctuary resources.
2. Habitat recovery: Decreased from 4 (high) to 2 (low); since bull kelp has an annual life history and little is known about the persistence of spores, populations exhibit little adaptive capacity and recovery is inhibited by high rates of herbivory by purple urchins, which can persist at high densities for many years despite limited food availability (Dudley et al., 2021)
3. Functional group diversity: Decreased from 5 (very high) to 3 (moderate) because the kelp forest habitat in the sanctuary is completely reliant on a single canopy-forming algal species, bull kelp, which has been severely impacted by MHW and urchin grazing. Historically (pre-decline), there was relatively high diversity in invertebrates, fish, and important understory kelp species, and there are indications that these groups have also declined (R. Hohman/GFA, personal communication, October 19, 2022).

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<sup>4</sup> The original exposure scoring included scores for stressors that are likely not a driver of change for kelp forests (i.e. sea level rise) or whose impacts were redundant with other stressors (i.e. El Niño with increased SST, precipitation with salinity, coastal erosion with turbidity). These scores were either artificially reducing the overall exposure score or were emphasizing the impact of some stressors, and have been removed from the final average to ensure a more representative final rating of climate exposure for kelp forests.

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## Nearshore Soft-bottom

\*\*reference pages 72-79 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Since 2015, our understanding of the interactive effects between extreme fires and extreme precipitation events that lead to large-scale debris flows warrants slight revisions to this assessment.

Nearshore	Revised Score	Confidence	Change
Sensitivity	2.9 Mod	High	+0.05
Exposure	4.2 High	High	+0.2
Adaptive Capacity	3.3 Mod	High	-
Vulnerability	3.7 Mod	High	+0.2

*Sensitivity:* Two scores added. Very slight increase to sensitivity score.

1. Disturbance regimes: Two new scores added to the disturbance regime score to account for debris flows and MHWs (4, high). Debris flows were added because of the increasing impact of fires followed by extreme rain events leading to debris flows that can smother and negatively impact the nearshore environment. New research indicates an increasing likelihood of large-scale debris flows/landslides in the region, such as the one that occurred from the Big Sur river in 2017, that can cause excessive sediment discharge and burial of the nearshore environment (Warrick et al., 2019). MHWs were added under the assumption that nearshore communities are likely impacted by increased water temperature, lower oxygen levels, and increased stratification/reduced mixing associated with MHWs.

*Exposure:* One score added, one score revised. Slight increase to exposure score.

1. Debris flows: New score added (4, high). Both extreme fire events and extreme rainfall events have increased in California since 1980, and fire followed by rainfall is projected to continue to increase in frequency, with a 100% increase by 2100 (Touma et al., 2022).
2. Exposure to altered currents and mixing: increased from 2 (low) to 3 (moderate) due to observed increased stratification and altered nutrient availability during the 2014-2016 MHW (Dudley et al., 2021).

### References

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## Offshore Rocky Reefs

\*\*reference pages 80-85 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Since 2014, sanctuary staff have developed a better understanding of the impacts to offshore rocky reefs (e.g., Cordell Bank, Rittenburg Bank) from various stressors, as well as increased knowledge around how climate-related stressors are changing and impacting reefs. Some scores for both sensitivity and exposure have therefore been revised.

Offshore	Revised Score	Confidence	Change
Sensitivity	2.5 Low	Moderate	+0.5
Exposure	3.0 Mod	Moderate	+0.8
Adaptive Capacity	2.7 Mod	High	-
Vulnerability	2.9 Mod	High	+1.3

**Sensitivity:** Five scores revised. Increase in sensitivity score.

1. Sensitivity to water temperature: Increased from 1 (very low) to 3 (moderate). Though not yet documented, we can assume warmer water temperatures may result in range shifts of key reef species. For example, Cordell Bank represents an important intersection of the range distribution of hydrocoral species *Stylaster californicus* (the more southerly species) and *S. venustus* (the more northerly species). Knowing that both the southerly and northerly *Stylaster* species occur on Cordell Bank provides the opportunity to monitor abundance and distribution shifts for these two indicator species (Etherington et al., 2011).
2. Sensitivity to dissolved oxygen: Decreased from 5 (very high) to 3 (moderate), because there is no indication that the rocky reef assemblage would be highly sensitive to changes in dissolved oxygen; a moderate rating is more appropriate (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022).
3. Sensitivity to currents/mixing: Increased from 3 (moderate) to 4 (high) as the rocky reef assemblage is highly dependent on the delivery of particulate matter as food for reef organisms (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022).
4. Sensitivity to pollution: increased from 1 (very low) to 3 (moderate); though exposure remains 1 (low), an oil spill occurring in the vicinity of one of these reefs could have moderate impacts (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022).
5. Sensitivity to gear from harvest: Increased from 1 (very low) to 3 (moderate). Though current exposure remains low, it is known from previous surveys that derelict fishing gear such as gillnets, longlines, and monofilament lines can cause damage to Cordell Bank. Therefore, although the risk of gear impacts is low, if this habitat is impacted by gear the damage could be significant (Graiff et al., 2019; Delta submersible surveys on Cordell Bank 2002-2005, unpublished data).

**Exposure:** Two scores revised. Increase in exposure score and overall rating to moderate.

1. Exposure to altered currents and mixing: Increased from 2 (low) to 3 (moderate) due to stratification documented during the 2014-2016 MHW and likelihood of changes to the timing and intensity of upwelling (Pozo-Buil et al., 2021).
2. Exposure to changes in water temperature: Increased from 1 (very low) to 3 (moderate), as the Cordell Bank Condition Report notes that the period 2009-2021 experienced some of the highest variability in the long-term temperature data, and temperature increases

during the MHW reached at least to 100m depth. Bottom temperatures are projected to increase between 1 and 2°C by 2100 (Siedlecki et al., 2021).

References:

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## Pelagic

\*\*reference pages 86-93 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Due to new research publications and observations of the impacts of various oceanographic changes on the pelagic environment since 2014, there is more information to be included in this update, as well as a few scores that warrant revision. It should be noted that there will likely be an increased exacerbative and negative effect of increased pH, decreased dissolved oxygen, and increased temperature on the pelagic environment, with frequency and duration of occurrence expected to increase.

Pelagic	Revised Score	Confidence	Change
Sensitivity	2.7 Mod	High	+0.1
Exposure	4.1 High	High	-
Adaptive Capacity	3.7 High	High	-
Vulnerability	3.2 Mod	High	+0.1

*Sensitivity*: Two scores revised, one score added. Slight increase in sensitivity score.

1. pH and shoaling of aragonite saturation state: Increased from 4 (high) to 5 (very high) due to severe impacts to key species in this system, including increased mortality of pteropods, habitat reduction, and impacts to larval stages of many species, including Dungeness crab, who are susceptible to internal and external exoskeleton carapace dissolution (Bednaršek et al., 2020).
2. Dissolved oxygen: Increased from 4 (high) to 5 (very high). Cold water retains dissolved oxygen more readily than warmer waters, so the increase in temperature of our ocean is leading to a decline in dissolved oxygen. As the ocean warms (particularly surface waters) and becomes more stratified, mixing between different ocean layers is reduced, and deeper waters do not receive the oxygen from the surface layers (IPCC, 2019). Low dissolved oxygen can lead to decreased biodiversity and the functioning of ocean ecosystems, species distribution shifts, reduced fish for fisheries, and expanded algal blooms (which can lead to dead zones; IUCN, 2019).
3. Disturbance regimes: New score added (5, very high) for MHWs. The 2014-2016 MHW showed increases in gelatinous species (Elliott et al., 2022) and undersaturated waters were observed throughout the water column. Impacts to species distribution vary with the extent of warm water: when warming occurs primarily in surface water (e.g. 2005-2006), krill are pushed down to where Cassin's auklets cannot forage them; when water warms throughout the water column (e.g. 2014-2016 MHW), everything is pushed offshore (M. Elliott/Point Blue, personal communication, October 4, 2022).

Corrections and additions to 2015 CVA Summary:

*Potential benefit* (page 86): The mention of increased upwelling potentially benefiting the pelagic environment assumes that increased upwelling will lead to increased upwelling of nutrients, which should stimulate primary production; however, some of the more recent research doesn't support this assumption. There needs to be relaxation events interspersed with upwelling; too much upwelling is too turbulent for primary production to occur (M. Elliott/Point Blue, personal communication, October 4, 2022).

*Climate sensitivities* (page 87): Stronger upwelling conditions were related to the increased abundance of boreal copepod species, which are larger and contain more lipid content than other copepod species in the region (Fontana et al., 2016). Meroplankton species, such as decapods, rely on upwelling as a transport mechanism; regional upwelling also impacts primary production, the main food source for larval decapods (Hameed et al., 2018). Upwelling brings

cold, CO<sub>2</sub>-rich waters to the surface during spring and summer, while MHWs produce different conditions for the pelagic environment. When considering aragonite, undersaturated conditions were deeper during warm water events (e.g., summers of 2014 and 2015), while undersaturated waters were found in shallower waters during La Niña years (Davis et al., 2018). Another problem is when El Niño and MHW are followed by the upwelling event with insufficient relaxation event between them (Bednaršek et al., 2018, 2022), exposing populations to continuous stress. Strong upwelling conditions were associated with a shoaling of the aragonite saturation horizon, and a higher proportion of the water column was observed to have undersaturated aragonite conditions during strong upwelling events (Anderson et al., 2022). *Keystone and foundational species* (page 90): In addition to krill, copepods, rockfish, pteropods and northern anchovy are also key species in the pelagic system.

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## Rocky Intertidal

\*\*reference pages 94-102 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The rocky intertidal habitats in the sanctuary have experienced significant impacts and dramatic community changes since the 2015 assessment, primarily due to the 2014-2016 MHW, but also due to persistent change in the system. Multiple revisions are warranted based on new information that indicates cascading impacts in changes to key species (sea stars, intertidal kelp, urchins) due to sea star wasting combined with prolonged marine heating.

Rocky intertidal	Revised Score	Confidence	Change
Sensitivity	4.0 High	Moderate	+0.1
Exposure	4.2 High	Moderate	+0.1
Adaptive Capacity	3.5 High	Moderate	-0.5
Vulnerability	4.7 High	Moderate	+0.7

*Sensitivity:* Three scores revised, one note. Slight increase in sensitivity score.

1. Sea surface temperature: Increased from 3 (moderate) to 4 (high) due to impacts to habitat, structure, diversity, and abundance from both persistent heating and the 2014-2016 MHW (K. Lindquist/GFA, personal communication, November 29, 2022)
2. Sea level rise: Increased from 3 (moderate) to 4 (high); the 2015 assessment noted that this habitat was only moderately sensitive, “as long as there is room to migrate”; however, most rocky intertidal benches in the sanctuary are backed by cliffs and/or development, and do not have room to migrate (K. Lindquist/GFA, personal communication, November 29, 2022).
3. Disturbance regimes: Sensitivity to MHWs was not included in the 2015 assessment, though disease (sea star wasting) was scored as 5 (very high). Many more impacts to the rocky intertidal were documented during the MHW, including shifts in species composition (Sanford et al., 2019) and slowed recovery rates following disturbance (Menge et al., 2021)
4. Recreation: Sensitivity to recreation was previously scored as 4 (high) with localized high current exposure. While these scores are still accurate, it is important to note that in the most visited rocky intertidal sites (e.g., Duxbury reef, Fitzgerald Marine Reserve), visitation has increased since the start of the pandemic and seems to be continuing (based on preliminary beach watch use data).

*Exposure:* One score added. Slight increase in exposure score.

1. Debris flows: New score added (4, high). Both extreme fire events and extreme rainfall events have increased in California since 1980, and fire followed by rainfall is projected to continue to increase in frequency, with a 100% increase by 2100 (Touma et al., 2022). New research indicates an increasing likelihood of large-scale debris flows/landslides in the region, such as the one that occurred from the Big Sur river in 2016, that can cause excessive sediment discharge and burial of the nearshore environment (Warrick et al., 2019).

*Adaptive Capacity:* Three scores revised. Decrease in adaptive capacity score.

1. Structural and functional integrity: Decreased from 5 (very high) to 4 (high), due to documented impacts following MHW events that have altered community composition and structure (Sanford et al., 2019) including sea star loss and urchin barren increase, with severe degradation at some sites in the northern portion of the sanctuary (K. Lindquist/GFA, personal communication, November 29, 2022).

2. Ability of habitat to recover from disturbance: Decreased from 5 (very high) to 3 (moderate) due to long-term studies that indicate reduced resilience and slowed recovery rates over the last decade (Menge et al., 2021; Corey Garza/CSUMB, personal communication, January 5, 2023).
3. Species and functional group diversity: Decreased from 5 (very high) to 4 (high) due to MHW impacts on community composition (Sanford et al., 2019), algal diversity (Fales and Smith, 2022), and seastar loss from seastar wasting.

References:

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## Species

### Blue Rockfish

\*\*reference pages 131-138 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Though the 2014-2016 MHW had unprecedented impacts on shallow rocky reef and kelp forest-associated species, blue rockfish continue to demonstrate moderate vulnerability to climate impacts, largely because the species is relatively well adapted to change (long larval duration, highly mobile, and wide-ranging). However, revisions were warranted due to new impacts and a number of inconsistencies and inaccuracies in the original 2015 CVA.

Blue rockfish	Revised Score	Confidence	Change
Sensitivity	3.0 Mod	High	-0.04
Exposure	2.8 Mod	High	+0.2
Adaptive Capacity	3.7 High	High	-
Vulnerability	2.1 Mod	High	+0.1

*Sensitivity:* Three scores revised, one additional stressor to note. Very slight decrease in sensitivity score.

1. pH: Decreased from 4 (high) to 3 (moderate); since the 2014 assessment, new research on the effects of ocean acidification on multiple life stages of various rockfish species indicate that blue rockfish are more tolerant than other species to low pH (Hamilton et al., 2017; Cline et al., 2019; Saksa, 2021). The 2014 assessment relied on studies of other fish species, so the score is revised to more accurately reflect current scientific understanding.
2. Dissolved oxygen: Decreased from 5 (very high) to 4 (high); similar to the revised pH score, both juvenile and adult blue rockfish have been found to be relatively more tolerant to reduced dissolved oxygen than other rockfish species (Mattiason et al., 2020; Saksa, 2021).
3. Disturbance regimes: Decreased from 4 (high) to 3 (moderate) because MHWs were not considered in the 2014 assessment, and the rating of 4 (high) was found to be too high for the combined impact of storms and MHWs. Blue rockfish recruitment numbers were not impacted by the 2014-2016 MHW, with 2014 and 2016 average years and 2015 slightly below average but not as low as would be expected if this disturbance regime was a major driver (T. Laidig/NMFS and S. Hamilton/MLML, personal communication, December 9, 2022; Ziegler et al., *in revision*). Additionally, blue rockfish can and do move to deeper waters during disturbance events, which can ameliorate these impacts (M. Carr/UCSC, personal communication, December 22, 2022). Disease is not a current or projected impact.
4. Energy production: Not considered in the 2015 CVA is larval and juvenile entrainment and impingement in once-through cooling systems of coastal power plants and future desalination plants (M. Carr/UCSC, personal communication, December 22, 2022). Though not currently a stressor present in GFNMS and CBNMS, it is an important potential stressor to the species.

*Exposure:* One score revised. Slight increase in exposure score.

1. Sea surface temperature: Increased from 2 (low) to 3 (moderate) based on 2014-2016 MHW, which resulted in unprecedented impacts to the shallow, nearshore environment in the sanctuary, and will continue to do so periodically, with increased severity and frequency (Frölicher et al., 2018).



#### Corrections to 2015 CVA Summary:

*Geographic extent* (page 131): The executive summary of the 2015 assessment incorrectly states that blue rockfish have a transcontinental geographic extent; rather, transboundary is the intended term, to describe that the species ranges from the Bering Sea to Baja California. However, recent genetic analyses have determined that blue rockfish is actually two distinct species: deacon rockfish, which occur from Morro Bay up to Alaska, and blue rockfish which occur from Newport, Oregon to Punta Santo Tomas, Baja California (Frable et al., 2015). The fact that blue rockfish are two distinct species was not factored in the score revisions, as any stressors are likely relevant for both species.

*Dispersal* (pages 131 and 135): The executive summary incorrectly states that both the larval and adult stages have high dispersal; rather the larval and pelagic juvenile stages have high dispersal and the adult stage is not nearly as dispersive (M. Carr/UCSC, personal communication, December 22, 2022). The description of dispersal capability on page 5 should be clarified as: Larval and pelagic juvenile dispersal potential is high based on the long pelagic duration (3-4 mo). Adult movement and home range is more limited (< 2 km; Freiwald, 2012; Green et al., 2014).

*Impact of harvest* (page 131): To clarify the intent of the last sentence of the executive summary, climate change impacts are very likely to outweigh harvest impacts, but harvest may need to be adaptively managed so as not to exacerbate climate impacts.

*Sensitivity to pH* (page 132): The Munday et al. (2009) study has received criticism from the scientific community and is focused on a different species from a different region, and therefore should not be relied upon to make any inferences about the impact of pH on blue rockfish.

*Sensitivity to storms* (page 132): Blue rockfish recruit to rocky reef habitat, not kelp. Increased storm energy and frequency will directly impact all life stages of blue rockfish through (i) physical disturbance, (ii) possible increase in sedimentation that reduces the availability of rocky substratum, and (iii) increased water turbidity that can reduce foraging efficiency of planktivores (M. Carr/UCSC, personal communication, December 22, 2022).

*Dependencies* (pages 132/133): The 2015 CVA incorrectly states that blue rockfish are highly dependent upon kelp forest. Rather, adult fish and recruitment are dependent upon high relief, shallow rocky reefs (habitat specialist, Carr, 1991). Kelp forest, while likely not a strong influence, does provide some value by extending habitat up into the water column (M. Carr/UCSC, personal communication, December 22, 2022). In recent years in areas with little to no kelp, rockfish recruitment has remained average or above average, with 2020 as the best year for recruitment in reefs along the Monterey peninsula in 20 years (T. Laidig/NOAA, personal communication, December 9, 2022). Rockfish are less dependent on specific food sources (prey generalist, Hallacher and Roberts, 1985).

*Fecundity* (page 136): The 2015 CVA incorrectly states that blue rockfish produce relatively few offspring; rather, though the species is viviparous and long-lived, females have high fecundity, expelling large numbers of larvae in each reproductive season (Love et al., 2002).

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## Blue Whale

\*\*reference pages 124-130 of the [2015 Assessment Report](#) (Hutto et al. 2015)

New science and literature are available regarding changes in timing, response to ocean climate and impacts of human activities, warranting slight revisions and some additional information. Blue whale arrival to the Gulf of the Farallones region is earlier now than in the early 1990s due to changes in climate (Ingman et al., 2021).

Blue whale	Revised Score	Confidence	Change
Sensitivity	4.1 High	High	+0.2
Exposure	5.0 Very High	High	-
Adaptive Capacity	3.8 High	High	-
Vulnerability	5.3 High	High	+0.2

*Sensitivity*: One score revised, one new score added. Slight increase in sensitivity score.

1. Dynamic ocean conditions (currents, mixing, stratification): increased from 2 (low) to 3 (moderate) due to the sensitivity of blue whale's primary prey, krill, as well as new research that indicates blue whale observations are significantly related with upwelling indices (Rockwood et al., 2020).
2. Salinity: new score added as 3 (moderate) due to new research that indicates blue whale observations are significantly related with midwater salinity (Rockwood et al., 2020).

### Corrections and additions to 2015 CVA Summary:

*Climate stressors* (page 124, bottom): Though blue whales are more directly sensitive to non-climate stressors (e.g., ship strikes), climate-related changes are having indirect impacts on whales due to their primary prey, krill. Krill are more closely linked to climate-driven changes; krill abundance in the Gulf of the Farallones region was associated with climate variables (PDO, NPGO, SOI), upwelling indices, and midwater oceanographic variables. In addition, krill were associated with the continental shelf break, which were also blue whale hotspots (Rockwood et al., 2020).

*Sea surface temperature* (page 125): While less productive conditions (e.g., positive PDO, negative NPGO) as those observed in 2005-06 and 2014-16 were associated with low blue whale sightings, improved conditions do not always result in increased blue whale densities; this species is more closely associated with dense krill populations than with specific ocean/climate variables (Elliott et al., 2022).

*Human interaction* (page 126): The statement that 4 blue whales are killed by vessel strike every year is not accurate; rather, *up to* 4 blue whales are recorded killed by vessel strike each year, though this number is likely higher due to unreported or unknown collisions. Conservative model results estimate that total ship strike fatalities on blue whales is approximately 4 times the current Potential Biological Removal value for this species (Rockwood et al., 2017; NMFS Stock Assessment Reports, 2021).

*Management potential* (page 128): Modeling efforts have shown that most blue whale ship strike mortality occurs in only 10% of the study area, suggesting that management efforts (e.g., vessel speed reductions) in this area could have a big impact on saving blue whales (Rockwood et al., 2017).



References:

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## California Hydrocoral and White Lobed Sponge

\*\*reference pages 139-144 of the [2015 Assessment Report](#) (Hutto et al., 2015)

For this assessment update, scores were revised based on increased understanding of climate sensitivities to hydrocorals and sponges generally, using the white lobed sponge as a representative structure forming sponge. White lobed sponge (*Xestospongia* spp.) replaces red sponge because it is more commonly encountered on offshore reefs in the Sanctuaries, particularly *Xestospongia edapha* on Cordell Bank. Red sponge extends to the intertidal and likely has very different exposure and sensitivity; also, as an encrusting sponge, it's not easily identifiable and is not quantified in video analyses from benthic surveys. The species selected as indicators in this assessment are at the shallow end of the range of corals and sponges in CBNMS and GFNMS; deeper species may respond differently (e.g., lower exposure to changing temperatures but higher sensitivity).

Hydrocoral/Sponge	Revised Score	Confidence	Change
Sensitivity	3.1 Mod	Moderate	-0.06
Exposure	3.1 Mod	High	-
Adaptive Capacity	3.2 Mod	Moderate	-
Vulnerability	3.1 Mod	Moderate	-0.06

*Sensitivity:* Four scores revised, one added. Very slight decrease in sensitivity score.

1. Sensitivity to dissolved oxygen: Increased from 3 (moderate) to 4 (high), as corals and sponges are sensitive to hypoxia and cannot escape low DO waters (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022).
2. Sensitivity to pH: Increased from 3 (moderate) to 4 (high) for hydrocoral only, because of the sensitivity of its calcium carbonate structure (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022).
3. Sensitivity to invasive species: Decrease from 5 (very high) to 4 (high); the presence of an unknown species of encrusting tunicate that resembles the colonial tunicate, *Didemnum vexillum*, a species that has smothered areas of George's Bank in the Gulf of Maine and has been documented in the San Francisco Bay area (Bullard et al., 2007). There is no direct evidence that the impacts of the encrusting tunicate in the Sanctuaries is serious enough to warrant the highest rating (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022; Graiff et al., 2019). Current exposure to the invasive tunicate, *Didemnum vexillum*, remains low.
4. Sensitivity to pollution: Decrease from 4 (high) to 3 (moderate); while corals and sponges are known to be sensitive to poor water quality and oil spills, this threat is more moderate in nature compared to other stressors. Current exposure to this stressor remains low.
5. Sensitivity to water temperature: This stressor was added as 3 (moderate), as it was not previously included in the 2015 assessment, and as a cold-water species, the hydrocoral may be affected by water temperature variability directly at depth and indirectly if warm water temperatures have a negative impact to their planktonic food sources in surface waters (K. Graiff and D. Lipski/ONMS, personal communication, November 18, 2022). Impacts are also suspected for sponges, though there is no direct evidence for deep-water sponges (Clark et al., 2017).

*Adaptive capacity*: No score revisions; 2 additions to the narrative.

1. Population status: Although there are concerns about climate stressors to corals, data from the region does not indicate major increases or decreases in hydrocorals or sponges since 2010 (Graiff et al., 2019; Graiff and Lipski, 2020; Graiff and Lipski, in review).
2. Species diversity: Cordell Bank is a transition zone of the northern species *S. venustus* and the southern species *S. californica*, although they cannot be distinguished unless collected. Climate change may result in range shifts of these two species, which could alter the species composition of hydrocorals on rocky reefs in the region. It is not expected that this would alter ecosystem dynamics, as the two species are expected to have similar ecosystem function.

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- Graiff, K., & Lipski, D. (in review). Characterization of Cordell Bank, and Continental Shelf and Slope: 2021 ROV Surveys. NOAA Cordell Bank National Marine Sanctuary. 36 pp.

## California Mussel

\*\*reference pages 145-152 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Due to some inconsistencies and assumptions in the 2015 assessment of this species, multiple revisions and corrections were provided, though there were no resulting changes to overall ratings.

California mussel	Revised Score	Confidence	Change
Sensitivity	3.3 Mod	High	+0.2
Exposure	4.1 High	Moderate	-
Adaptive Capacity	3.5 Mod	Moderate	+0.1
Vulnerability	3.9 Mod	High	+0.1

*Sensitivity*: One score removed, one score with important notes (but not changed), two scores revised. Slight increase in sensitivity score.

1. Sea surface temperature: Increased from 3 (moderate) to 4 (high).
2. Wave action: Decreased from 5 (very high) to 3 (moderate). Not only are mussels highly adapted to wave energy, but there is some evidence that mussel beds are more expansive in wave swept areas because predation rates decrease under those conditions (Robles and Desharnais, 2002; Robles et al., 2010). This stressor, therefore, is not likely to drive declines in the species and the score was revised.
3. Invasive species: Score removed from overall sensitivity assessment. There is no evidence of direct impact of invasive species on the California mussel.
4. Harvest: Score to remain at 3 (moderate), though it is important to note that this may change in the future and is a stressor to monitor as an increase in recreational harvest was noted during the pandemic, especially in southern California (M. Miner/UCSC, personal communication, January 5, 2023).
5. Dependency on sensitive habitat: Increase from 1 (very low) to 3 (moderate) due to the sensitivity of the species' primary habitat, the rocky intertidal.
6. Disturbance regimes: Sensitivity to MHWs was not included in the 2015 assessment, and was added as 5 (very high) with no impact to overall disturbance regime score, which was already scored as high.

*Adaptive Capacity*: Two scores revised. No change to adaptive capacity score.

1. Population status: Decreased from 5 to 4 (1 = endangered, 5 = robust) due to substantial loss in Southern California, and evidence of slower and more variable recovery of mussel beds following disturbance, compared to algal and barnacle-dominated assemblages (Conway-Cranos, 2012). Additionally, a mass mortality event of mussels occurred in June 2019 during a significant heat wave that may have negatively impacted the population.
2. Species value: Increased from 3 (moderate) to 5 (very high) due to increasing recognition that this species is a key foundation species in the rocky intertidal, supporting hundreds of other species.

### Corrections to 2015 CVA Summary:

*Adaptive capacity* (page 151, bottom): Mussel beds are largely restricted to the mid-intertidal zone by predation from the Ochre sea star along the lower edge of the mussel bed. Any negative impacts on the sea star due to climate change (i.e. increased virulence and sea star wasting (SSW) events) could result in the expansion of mussels into the lower intertidal zone.



References:

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## Cassin's Auklet

\*\*reference pages 153-160 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The 2014-2016 MHW led to a mass mortality event of Cassin's Auklets from California to British Columbia; in light of these impacts as well as updated climate projections for the region for several key climate stressors, this assessment required revisions.

Cassin's auklet	Revised Score	Confidence	Change
Sensitivity	3.5 High	High	+0.1
Exposure	3.4 Mod	High	+0.8
Adaptive Capacity	2.9 Mod	High	-
Vulnerability	4.0 Mod	High	+0.9

*Sensitivity:* Two scores revised, one score added. Slight increase in sensitivity score.


1. Air temperature: Increased from 1 (very low) to 3 (moderate). Though auklets aren't necessarily inherently sensitive to air temperature in their natural habitat, in the region of the sanctuaries, much of the population is dependent on artificial habitat (wooden nest boxes). These boxes can become superheated on extreme hot days, which increases the species' sensitivity to extreme heat events, with documented impacts including breeding failure and adult breeding bird mortality (P. Warzybok/Point Blue, personal communication, November 30, 2022).
2. Sea surface temperature: Increased from 3 (moderate) to 4 (high) due to the massive mortality event related to the 2014-16 MHW and persistent declines globally due to increasing water temperatures (Jones et al., 2017).
3. Disturbance regimes: Added MHW as a significant disturbance event (rated 5, very high) due to the documented mass mortality event caused by starvation following the shift in zooplankton composition associated with the MHW (Jones et al., 2017).

*Exposure:* Six scores revised. Increase in exposure score, and an increase in the overall rating to moderate.

1. Increased air and sea surface temperatures: Increased from 3 (moderate) to 5 (very high) (Howard et al., 2020)
2. Decreased pH: Increased from 3 (moderate) to 4 (high) (Gruber et al., 2021)
3. Changes in precipitation: Increased from 2 (low) to 3 (moderate) (Warner et al., 2015)
4. Increased coastal erosion and run-off, increased flooding, and increased storminess: Increased from 2 (low) to 3 (moderate) (Huang et al., 2020; Huang and Swain, 2022).

### References:

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## Coralline Algae

\*\*reference pages 178-183 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Due to inconsistencies in the 2015 assessment of this species group and a robust body of literature since that time, revisions were warranted. It is important to note that this assessment and review were conducted for coralline algae as a species complex, as species identification can be challenging. It is quite likely that values for individual species would vary, with some being more susceptible to impacts of climate change, and some less. In some cases, this variable response has been documented (McCoy and Pfister, 2014 documented varying responses of coralline algae species to OA). Additionally, it is very likely that species range shifts into and out of the sanctuaries and species loss from climate change will be missed.

Coralline algae	Revised Score	Confidence	Change
Sensitivity	2.9 Mod	High	+0.6
Exposure	3.0 Mod	Moderate	-
Adaptive Capacity	2.6 Low	High	+0.2
Vulnerability	3.3 Mod	High	+0.4

**Sensitivity:** Two scores revised, one score added. Increase in sensitivity score and overall rating increased to moderate.

1. Sea surface temperature: Increased from 4 (high) to 5 (very high). Mesocosm experiments with *C. tuberculosa* (a species present throughout the California Current System), show a significant reduction of both calcification and growth under warming and reduced pH conditions, with an antagonistic effect and a stronger impact from warming than OA (Donham et al., 2022). Additional research supports high sensitivity to OA (i.e. McCoy and Kamenos, 2015; McCoy and Kamenos, 2018; Pena et al., 2021), and very high sensitivity to warming (i.e. Huggett et al., 2018; Cornwall et al., 2019; Page and Diaz-Pulido, 2020).
2. Disturbance regimes: Added a new score for MHW as 4 (high). The 2015 CVA did not identify any significant sensitivities to disturbance regimes, and literature cited above indicate strong sensitivity to ocean warming. Coralline algae can bleach during short-term disturbance events, but can also recover relatively quickly (M. Miner/UCSC, personal communication, January 5, 2023).
3. Urchin overgrazing: New score added as 4 (high) for documented impact of urchin overgrazing due to extreme increases in urchin densities (L. Rogers-Bennett/CDFW, personal communication, January 25, 2023), which has also been documented in East Africa (O'Leary and McClanahan, 2010).

**Adaptive capacity:** One score revised, one score added. Slight increase in adaptive capacity score.

1. Phenotypic plasticity: Increased from 2 (low) to 4 (high). As indicated in the 2015 summary, and confirmed via expert elicitation (M. Miner/UCSC, personal communication, January 5, 2023) and supporting literature (i.e. diversity in morphology and reproductive strategies, Miklasz, 2012; Steneck et al., 1986), the initial rating by workshop participants was too low, and high plasticity is much more representative of this group of algae.
2. Other adaptive capacity: New score added (2, low) to reflect the slow-growing nature of this species complex, and slow recovery from disturbance (L. Rogers-Bennett/CDFW, personal communication, January 25, 2023).

### Corrections to 2015 CVA Summary:

*Species sensitivity* (page 178): The reference to Miklasz (2012) suggesting that coralline algae could benefit from climate impacts due to decreased competition is inconsistent with much of the literature. Rather, studies suggest that coralline algae could suffer under future climate scenarios due not only to direct impacts from warming and OA (see references above), but also increased competition from species, such as fleshy seaweeds, that may be less impacted by changing ocean chemistry (Kuffner et al., 2008; Koch et al., 2013; M. Miner/UCSC, personal communication, January 5, 2023).

*Species dependence* (page 179): Text regarding dependence on sensitive habitats incorrectly states that coralline algae are dependent upon kelp forest habitat. Rather, most species are dependent on availability of bare rock, both within and outside of kelp forests.

### References:

- Cornwall, C., Diaz-Pulido, G., & Comeau, S. (2019). Impacts of Ocean Warming on Coralline Algal Calcification: Meta-Analysis, Knowledge Gaps, and Key Recommendations for Future Research. *Frontiers in Marine Science*, 6, 186. DOI: 10.3389/fmars.2019.00186.
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## Krill

\*\*reference pages 192-197 of the [2015 Assessment Report](#) (Hutto et al., 2015)

New information is available regarding the influence of large-scale oceanographic processes as well as local conditions on euphausiid biomass and abundance that warrants revision of some scores.

Krill	Revised Score	Confidence	Change
Sensitivity	1.8 Very Low	High	+0.15
Exposure	5.0 Very High	High	-
Adaptive Capacity	4.0 High	Moderate	-
Vulnerability	2.8 Mod	High	+0.15

*Sensitivity:* Two scores revised, one score added. Slight increase in sensitivity rating.

1. Dynamic ocean conditions: Increased from 3 (moderate) to 5 (very high). Higher euphausiid densities were found in periods of increased upwelling and more productive ocean conditions, as well as in conditions consistent with stratified, mature upwelled waters (Rockwood et al., 2020). Euphausiid biomass was associated with both large scale (i.e., Southern Oscillation Index, PDO) and local processes and conditions (i.e., regional upwelling index; surface values of temperature, salinity, and fluorescence; Manugian et al., 2015).
2. Sea surface temperature: Increased from 3 (moderate) to 5 (very high). Related to comments above regarding dynamic ocean conditions, euphausiid biomass was associated with sea surface temperature, with higher biomass associated with colder water temperatures (Manugian et al., 2015).
3. pH: Score added as 3 (moderate), as there is some indication that krill abundance decreases in aragonite-undersaturated conditions (Anderson, 2019).

*Exposure:* One score added. No change to exposure score or overall rating.


1. pH: score added as 5 (very high), the same score provided for pelagic habitat, as pH is expected to continue to decline.

*Adaptive Capacity:* No revisions to scores, but important to note the following:

1. Update on krill population dynamics and latest biomass information based on the latest Ocean Climate Indicators Status Report (Elliott et al., 2022): Euphausiid biomass in the region, measured by acoustics, peaked in June 2021, and adult krill, which are larger and higher in lipid content than juveniles, dominate the zooplankton samples during cold water years, including 2021. Cold ocean conditions result in larger adult euphausiids compared to periods with warm conditions.

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## Northern Anchovy and Pacific Sardine

\*\*reference pages 206-213 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Climate projections for the region have improved over the last 7-8 years, and new studies have been published that evaluate likely or plausible climate change impacts on both Pacific sardine and northern anchovy. Thus, revisions to the assessments for both species is warranted. It should be noted, however, that significant uncertainties remain regarding the mechanisms driving recruitment and population dynamics for these species. The prior working paradigm, that anchovy are more abundant in cold water years and sardine are more abundant in warm water years (Chavez, 2003; cited in 2015 assessment report on page 207), is no longer holding true, as anchovy have, in the last 20 years, experienced high recruitment in warm water years, and sardine have experienced persistent recruitment failure since the mid-2000s (A. Thompson/NMFS, personal communication, January 10, 2023). There is some indication that anchovy may be more resilient to population collapse (McClatchie et al., 2017).

Northern anchovy	Revised Score	Confidence	Change
Sensitivity	2.9 Mod	High	-
Exposure	3.6 High	High	+0.3
Adaptive Capacity	3.5 High	High	+0.1
Vulnerability	2.9 Mod	High	+0.1

Pacific sardine	Revised Score	Confidence	Change
Sensitivity	3.2 Mod	High	+0.1
Exposure	3.7 High	High	+0.3
Adaptive Capacity	3.4 Mod	High	-0.4
Vulnerability	3.5 Mod	High	+0.9

**Sensitivity:** One score added for sardine only. Slight increase in sensitivity score.

1. Disturbance regimes: MHWs were not included in the 2015 assessment, and were added as a 5 (very high) for sardine only. The 2014-2016 MHW was associated with earlier sardine spawning and an unprecedented northern shift of the sardine spawning area (Auth et al., 2018; McClatchie et al., 2016). In contrast, during this time, anchovy had several strong recruitment classes that resulted in historically high adult abundances by 2021 (Thompson et al., 2022 a,b).
2. New research predicts a northward shift of Pacific Sardine (500-800 km in the 21st century, depending on the rate of warming, Fiechter et al., 2021) and decreased landings (30-70%) in the coming decades due to reduced habitat suitability in the region of the Sanctuary (Smith et al., 2021; Smith et al., 2023). This finding is consistent with a robust body of literature that suggests both species undergo orders of magnitude fluctuations in abundance and productivity in response to ocean condition over both short (interannual) and longer (interdecadal) time scales (Checkley et al., 2009; Lindegren et al., 2013; McClatchie et al., 2017). While both species were rated as having high sensitivity to climate-driven changes, the overall sensitivity score remains at moderate (3) due to other components of sensitivity that are rated very low to moderate (e.g. very low sensitivity to pollution, moderate dependency on specific prey, very low current harvest).

**Exposure:** YTwo scores revised. Slight increase in exposure score and increase in overall rating from moderate to high.

1. Decreased dissolved oxygen: Increased from 4 (high) to 5 (very high). The metabolic index, a measure of the environment's capacity to meet temperature-dependent oxygen demand, is projected to decrease below critical levels in 30-50% of anchovies' present range by 2100, with a complete loss of aerobic habitat in the southern region of the California Current System (Howard et al., 2020). It is assumed that sardine will have similar exposure.
2. Altered currents and mixing: Increased from 2 (low) to 3 (moderate) due to observed increased stratification and altered nutrient availability during the 2014-2016 MHW (Dudley et al., 2021).

*Adaptive Capacity:* One score revised, one new score added. Overall rating for anchovy increased to high; overall rating for sardine decreased to moderate.

1. Population status: Populations of both species have changed dramatically in recent years (consistent with the strong sensitivity of these populations to climate forcing). Pacific sardine abundance has declined very steeply since the 2015 assessment, and the stock is now considered overfished (Kuriyama et al., 2021) - the score for population status has therefore decreased from 3 to 2 (1 = endangered, 5 = robust). By contrast, the northern anchovy stock was recently assessed for the first time in over 30 years, and found to be at very high abundance levels (Kuriyama et al., 2022) - the score for population status has therefore increased from 3 to 4 (1 = endangered, 5 = robust).
2. Resilience and recovery: New adaptive capacity scores added to the rating as 4 (high) for anchovy and 2 (low) for sardine based on paleo and modern studies of varying population responses of the two species. Though "collapse" of these populations is a normal state repeatedly experienced by anchovy and sardine throughout history, paleo data for years 1000 to 1500 indicate anchovy were in a boom state much more than sardine and the mean recovery time was 8 years, about a third that of sardine (22 years, McClatchie et al., 2017). Since 1951, anchovy have been abundant much more than sardine, from 1960-1990, 2003-2005, and 2015-present while sardine were high only from the mid 1990s to about 2009 (A. Thompson/NMFS, personal communication, January 10, 2023).

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## Ochre Sea Star

\*\*reference pages 214-219 of the [2015 Assessment Report](#) (Hutto et al., 2015)

In 2014, when the initial assessment was undertaken, little was known about Sea Star Wasting disease (SSW), its long-term impacts and the capacity of the ochre sea star to recover and adapt. While the cause of SSW is still not known, we now have more information about the impact of the disease on ochre stars and their surrounding community. Coast-wide, ochre star populations remain depressed compared to pre-SSW levels and low levels of sick stars persist, but many areas, including some within the sanctuary, are showing signs of recovery (but note that recovery rates are highly variable; Miner et al., 2018). This additional knowledge, along with corrections to some assumptions made regarding other stressors, warrants multiple revisions for this species assessment.

Ochre sea star	Revised Score	Confidence	Change
Sensitivity	3.0 Mod	High	-
Exposure	4.1 High	Moderate	-
Adaptive Capacity	3.3 Mod	High	-0.2
Vulnerability	3.7 Mod	Moderate	+0.2

*Sensitivity:* Three scores revised. No change to sensitivity score.

1. Sea surface temperature: Increased from 3 (moderate) to 4 (high). Association of elevated water temperatures with the current (2013-present) SSW event has been mixed (see Miner et al., 2018 for discussion of various findings and literature), but prior SSW events have been strongly correlated with warm water events (e.g., Eckert et al., 1999).
2. Wave action: Decreased from 5 (very high) to 3 (moderate). Ochre sea stars are highly adapted to wave action, and there is no indication that the species is particularly sensitive (M. Miner/UCSC, personal communication, January 5, 2023).
3. Precipitation: Increased from 2 (low) to 3 (moderate). The original rating considered only the direct impacts of precipitation on the species, and did not include impacts from debris flows caused by fire and extreme precipitation, leading to sedimentation and burial of the nearshore environment (Warrick et al., 2019).
4. Disturbance regimes: No score revision (already scored as 5, very high), but it should be noted that a 2011 harmful algal bloom was documented to coincide with a significant mortality event of multiple invertebrate species, including the ochre sea star (Rogers-Bennett et al., 2012).

*Adaptive capacity:* One score revised. Slight decrease in adaptive capacity score and overall rating decreased to moderate.

1. Population status: Decreased from 5 to 3 (1 = endangered, 5 = robust). Sea stars have experienced massive die-offs since 2010 due to SSW. SSW continues to persist in the system and to impact ochre stars at low levels with some sites in the sanctuary trending toward recovery, while others have shown very little sign of recovery (M. Miner/UCSC and E. Sanford/BML, personal communication, January 5, 2023).

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## Olympia Oyster

\*\*reference pages 220-226 of the [2015 Assessment Report](#) (Hutto et al., 2015)

No revisions were made, but there are a number of corrections and recent studies of Olympia oysters in Tomales Bay to document in this revision, as we now have a much more robust body of literature confirming many of the scores from the 2015 assessment.

Olympia oyster	Revised Score	Confidence	Change
Sensitivity	3.2 Mod	High	-
Exposure	4.3 Very High	High	-
Adaptive Capacity	2.9 Mod	High	-
Vulnerability	4.5 High	High	No change

Though no changes to the 2015 scores are proposed, there are a number of new studies of Olympia oysters that are important to note in this update, which vastly improves our understanding of climate impacts to the species as well as the species distribution within GFNMS.

- There is clear evidence of Olympia oyster presence in Tomales Bay, with improved abundance and distribution data for the species which was not available for the 2015 summary (Kornbluth et al., 2022; Olympia and Pacific Oyster Data Portal: <https://arcg.is/oDai4O>).
- Different climate-related stressors impact oyster health at different times of the year; in winter, salinity, nutrients, and alkalinity driven by run-off are driving forces, whereas temperature, pH, and dissolved oxygen are dominant in summer (Hollarsmith et al., 2020).
- The spatio-temporal variation in oyster recruitment and adult growth and mortality is based on a number of factors, including predation by non-native oyster drills. In Tomales Bay, adult oyster mortality is highest in the inner bay, where predators are abundant, and lowest in the middle bay, where oysters experience greatest growth. Juvenile mortality is constant throughout the bay, and recruitment is highest in the inner bay (Kimbrow et al., 2019).
- Low salinity and high air temperature have synergistic negative effects on Olympia oyster mortality, suggesting temporal variation in climate-driven stressors will likely drive impacts to oysters (Bible et al., 2017).
- A near 100% mass mortality event of Olympia oysters occurred in northern San Francisco Bay immediately following a series of atmospheric rivers that led to extreme freshwater discharge and sustained extremely low salinities (below 6.3 psu for eight consecutive days; Cheng et al., 2017).

### Corrections to 2015 CVA Summary:

*Invasive species* (page 222): The following sentence is incorrect because Pacific oysters are not naturalized in any estuaries in GFNMS (E. D. Grosholz/UCD, personal communication, September 30, 2022): “Finally, the Olympia oyster is directly displaced by larger non-native oysters, including the Pacific oyster (Pacific Biodiversity Institute, Trimble et al., 2009).” This paper by Trimble refers to Olympia oysters in Washington state only.

*Adaptive capacity* (page 224): The reference at the top of the page (Cheng, NERRS Science Collaborative, unpublished data) is incorrect, and should read “Chang”, not “Cheng”. The trace

element work was conducted by Andy Chang at the Smithsonian Environmental Research Center.

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## Pacific Herring

\*\*reference pages 227-233 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The status of the local stock in San Francisco Bay has changed since the information in the 2015 report was provided, and our understanding of the linkages between population trends and environmental indicators has improved.

Pacific herring	Revised Score	Confidence	Change
Sensitivity	2.8 Mod	High	+0.3
Exposure	4.0 High	High	+0.3
Adaptive Capacity	2.9 Mod	High	-
Vulnerability	3.9 Mod	High	+0.6

*Sensitivity:* Three scores revised, one score added. Slight increase in sensitivity score and overall rating increased to moderate.

1. Sea surface temperature and salinity: Increased from 3 (moderate) to 4 (high). Standing stock biomass (SSB) was significantly correlated with Sacramento River outflow, offshore SST, and in-bay salinity (Sydeman et al., 2018). Herring are sensitive to run-off and salinity in the bays, and sensitive to temperature associated with changing ocean conditions (which also affects their prey).
2. Disturbance regimes: Added MHW and drought as 4 (high). Drought and MHW were not included in the 2015 assessment, and Sydeman et al. (2018) indicates sensitivity to SST and salinity, both driven in part by these disturbance regimes. The 2019 Fisheries Management Plan (FMP) indicates that oceanographic conditions are becoming more variable, which is impacting herring SSB, and that herring have become more sensitive to environmental variation since 1990 compared to prior to 1990 (Hare and Mantua, 2000)
3. Harvest: Sensitivity to harvest increased from 1 (very low) to 2 (low), while current exposure to harvest remains a 1 (very low). The 2019 FMP proposes a precautionary management approach to reduce impacts of harvest to the SSB of Pacific herring, including catch limits, size limits, and spatial and temporal closures, suggesting that herring are sensitive to harvest.

*Exposure:* Two scores revised. Slight increase in exposure score.

1. Precipitation variability and coastal run-off: Both scores increased from 3 (moderate) to 4 (high) due to projections of increased precipitation variability (Swain et al., 2018) and extreme precipitation events (Huang and Swain, 2022), which will likely exacerbate run-off.

*Adaptive capacity:* Two scores revised. No change to adaptive capacity score.

1. Population status: Decreased from 3 to 2 (1 = endangered, 5 = robust). Most recent and available data indicates that SSB is low (the past 6 years have been well below the average biomass) and the population has been in decline since the 2015 assessment (CDFW Season Summaries). Biomass has not been estimated since the 2019–2020 season due to decreased fishery effort and a tiered management system under the 2019 Herring Fishery Management Plan that scales management effort to fishery effort. Anecdotal reports of good spawning in Tomales some years and annual surveys in SF bay indicate fair to good spawning quality (A. Weltz/CDFW, personal communication, October 17, 2022)

2. Species value: Increased from 1 (very low value) to 2 (low value), as recreational birders and other outdoor consumptive and non-consumptive recreational users are well aware of the occurrence and value of herring spawns in the winter (A. Weltz/CDFW, personal communication, October 17, 2022)

Corrections to 2015 CVA Summary:

*Biomass estimates* (pages 227 and 230) are incorrectly attributed to commercial fishery data, when they are actually based on spawn deposition (A. Weltz/CDFW, personal communication, October 17, 2022; Herring FMP, 2019).

*SST* (page 228): A 1956 reference is used to support the SST exposure of herring (46-50° F); temperatures are certainly higher 70 years later, with nearshore temperatures 60-70° F during MHW events, and routinely in SF bay even in 'normal' years (A. Weltz/CDFW, personal communication, October 17, 2022).

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## Pteropod

\*\*reference pages 234-238 of the [2015 Assessment Report](#) (Hutto et al., 2015)

New information is available regarding the impact of multiple ocean condition parameters on pteropod survival and abundance that warrants revision of some scores. Overall, because of high expected future exposure to unfavorable conditions combined with high sensitivity and low adaptive capacity, pteropods are under high risk due to the impact of OA in combination with multiple stressors (see also Bednaršek et al., 2021).

Pteropod	Revised Score	Confidence	Change
Sensitivity	4.0 High	High	+0.4
Exposure	5.0 Very High	High	-
Adaptive Capacity	2.6 Low	High	-0.1
Vulnerability	6.4 High	High	+0.5

*Sensitivity*: One new score added, two scores revised, one note. Slight increase in sensitivity score.

1. Sea surface temperature: Score added as 5 (very high). Pteropods are sensitive to warm ocean temperatures, and the two stressors of high temperature and low aragonite saturation state have been shown to create conditions of high mortality in this species (Bednaršek et al., 2022).
2. Dynamic ocean conditions: Increased from 4 (high) to 5 (very high). A relationship using easily-measured water properties (e.g., temperature, salinity, and dissolved oxygen) to estimate aragonite saturation state specific to Northern California was created in order to monitor ocean acidification in this region; the aragonite saturation horizon was deeper and surface aragonite saturation state estimates were higher during anomalously warm conditions (i.e., marine heat waves; e.g., summers of 2014 and 2015; Davis et al., 2018) or El Niños (e.g., 2016). Another study showed similar results, with a shoaling aragonite saturation horizon in strong upwelling conditions, and a higher proportion of the water column was observed to have undersaturated aragonite conditions during strong upwelling events (Anderson et al., 2022). Pteropods have been shown to be very sensitive to combined effects of MHW or El Niño, which are preceded by upwelling (low aragonite), increasing the impact on population dynamics (Bednaršek et al., 2018; 2022), and in general, multi-stressor exposure is expected to negatively impact the species (Bednaršek et al., 2016).
3. Dependence on sensitive habitat: Increased from 2 (low) to 3 (moderate) due to the species dependence on pelagic water conditions, specifically pH and temperature dependencies.
4. pH: Though no change to the score is made (scored as 5, very high), it is worth noting recent studies that continue to demonstrate the severe impact of ocean acidification on pteropods, including reduced calcification (Mekkes et al., 2021; Bednaršek et al., 2017; 2021), severe dissolution (Bednaršek et al., 2014; 2017), reduced survival (Bednaršek et al., 2017a) and increase in stress status (Bednaršek et al., 2018; Engstroem-Ost et al., 2019). The sensitivity of these impacts matches the magnitude of thresholds in aragonite saturation state that have been selected in the meta-analyses study (Bednaršek et al., 2019), further supporting experimental results.



*Exposure*: One score added, no change to score.

1. Increased sea surface temperature: new score added as 5 (very high), the same score provided for pelagic habitat, as sea surface temperature is predicted to continue to increase in the study region (Howard et al., 2020; Siedlecki et al., 2021).

*Adaptive capacity*: One score revised. Slight decrease in adaptive capacity score, and a decrease in the overall rating to low.

1. Genetic diversity: Decreased from 3 (moderate) to 2 (low). Two studies focusing on pteropod genetic structure across the California Current Ecosystem and northwards into the eastern North Pacific (Bednaršek et al., 2021; Mekkes et al., 2020) both show similar results, where the genetic analyses based on mitochondrial haplotypes identified all individuals of the dominant species (*Limacina helicina*) as a single species with no genetic differentiation between them. This genetic uniformity within the most abundant and dominant species indicates relatively low genetic adaptive capacity.

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## Purple and Red Urchins

\*\*reference pages 246-252 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The 2014-2016 MHW, and subsequent MHW events, resulted in dramatic changes to the nearshore environment, with unprecedented impacts on shallow rocky reef and kelp forest-associated species, including both purple and red urchins. The MHW resulted in two big ecological shifts: 1) sea star wasting syndrome removed an important urchin predator and resulted in a trophic release of both red and purple urchins; 2) kelp loss resulted in a significant reduction of drift algae which is the urchins' main food source (Dudley et al., 2021). Purple urchins responded by shifting from passive detritivores to active grazers of live kelp, removing almost all macroalgae from reefs (Rogers-Bennett and Catton, 2019; McPherson et al., 2021), effectively out-competing red urchins. Though the commercial red sea urchin fishery has collapsed due to starvation conditions leading to poor gonad production and unmarketable sea urchins (Rogers-Bennett and Catton, 2019), some of the population has persisted by moving to deeper waters to avoid competition with purple urchins (M. Carr/UCSC, personal communication, December 22, 2022) and during times of starvation (Ebert, 1967; Dudley et al., 2021). Once kelp recovers, it is presumed that red urchins will redistribute to shallower depths and both species will reallocate energy to gonad development. Multiple scores were revised to reflect these indirect effects of increased water temperatures.

Purple urchin	Revised Score	Confidence	Change
Sensitivity	3.6 High	High	+0.4
Exposure	3.2 Mod	High	+0.8
Adaptive Capacity	3.5 High	High	+0.4
Vulnerability	3.2 Mod	High	+0.8

Red urchin	Revised Score	Confidence	Change
Sensitivity	3.6 High	High	+0.4
Exposure	3.2 Mod	High	+0.8
Adaptive Capacity	3.4 High	High	+0.3
Vulnerability	3.3 Mod	High	+0.9

**Sensitivity:** Three scores revised, one score added. Increase in sensitivity score, and overall rating increased to high.

1. Sea surface temperature: Increased from 3 (moderate) to 4 (high) due to indirect effects of MHW-driven kelp loss on reproduction and gonad health (Rogers-Bennett and Catton, 2019). However, it should be noted that it is not SST per se that influences the reduced productivity of macroalgae, rather the lower nutrient levels associated with increased SST (M. Carr/UCSC, personal communication, December 22, 2022; Garcia-Reyes et al., 2014).
2. Disturbance regimes: Added MHW as a new score (5, very high), which increased rating from 4 (moderate) to 5 (very high).
3. Dependence on forage: Increased from 1 (very low) to 4 (high) due to the observed decline in body condition and reproduction following the loss of its prime forage, kelp (Rogers-Bennett and Catton, 2019; Dudley et al., 2021).
4. Other sensitivities (reds only): Sensitivity to competition added to red urchins (4, high). Purple urchins have out-competed red urchins following the loss of kelp as both habitat and food source, and have driven red urchins to deeper waters in search of alternative food sources (M. Carr/UCSC, personal communication, December 22, 2022).

*Exposure:* Two scores revised. Increase in exposure score and overall rating increased to moderate.

1. Increased sea surface temperature: Increase from 1 (very low) to 4 (high) based on 2014-2016 MHW, and projections that MHWs will increase in severity and frequency (Frölicher et al., 2018).
2. Altered currents and mixing: Increase from 1 (very low) to 3 (moderate) due to increased stratification from MHW, which led to low nutrient availability and reduced kelp productivity (Dudley et al., 2021)

*Adaptive Capacity:* Two scores revised. Increase in adaptive capacity score, and overall rating increased to high.

1. Population status: Red urchins remain at 4; purple urchins increase to 5 (1 = endangered, 5 = robust). Urchin density data at Fort Ross, collected by Reef Check California, shows moderate increases in red urchins since 2014, and very significant increases in purple urchins (R. Hohman/GFA, personal communication, October 19, 2022). Data from the southern end of the species range (from Monterey south to Cambria, outside this study region) indicate populations for both species are higher post-2015 (D. Malone/UCSC, personal communication, December 23, 2022)
2. Behavioral plasticity: Increase from 2 (low-moderate) to 4 (moderate-high). Evidenced by their persistent high numbers through and after the MHW, both species have shown the ability to persist during times of starvation, and to change their foraging behavior (passive to active grazer) to track food availability across depth zones (Smith and Tinker, 2022).


#### Corrections to 2015 CVA Summary:

*Harvest* (page 248): Red urchin is fished in many areas within its range, not throughout its entire range, as the species is not harvested in central California

*Dispersal* (page 249): Clarification that the maximum dispersal distance of 100km is for urchin larvae, not adults or juveniles.

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## Red Abalone

\*\*reference pages 239-245 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The 2014-2016 MHW resulted in dramatic changes to the nearshore environment, with unprecedented impacts on shallow rocky reef and kelp forest-associated species. Red abalone are now at extremely low abundances and survivors have poor reproduction, the recreational fishery for red abalone has collapsed, and surviving populations are not recovering.

Red abalone	Revised Score	Confidence	Change
Sensitivity	3.8 High	High	+0.2
Exposure	3.8 High	High	+0.8
Adaptive Capacity	2.4 Low	High	-0.3
Vulnerability	5.2 High	High	+1.4

*Sensitivity:* Two scores revised, one score added, one note. Slight increase in sensitivity score.

1. Sea surface temperature (SST): Increased from 4 (high) to 5 (very high) due to documented cascading impacts of the MHW, including ecosystem transition and subsequent severe loss of kelp as both habitat and food (Rogers-Bennett and Catton, 2019; McPherson et al., 2021; Rogers-Bennett and Catton, 2022). The 2015 score for SST reflected only the direct impact of SST; this increase is due to the many other indirect impacts that have been documented and are now well understood.
2. Disturbance regimes: Though the 2015 score was already the highest rating possible (5, very high), MHW were not a part of the score. The 2014-2016 MHW was a major disturbance event, from which red abalone have not recovered (Rogers-Bennett and Catton 2022; L. Rogers-Bennett/CDFW, personal communication, January 25, 202).
3. Dependence on prey or forage: Increased from 2 (low) to 4 (high) due to current impact of kelp loss on red abalone body condition and reproduction, indicating a very strong dependence on forage (Rogers-Bennett et al., 2021).
4. Harvest: No change in score (remains 5, very high), but a note that the recreational fishery was closed in 2018 as a result of the MHW-driven kelp loss, and will remain closed until 2026.

*Exposure:* One score revised. Increase in exposure score and overall rating increased to high.


1. Sea surface temperature: Increased from 1 (low) to 4 (high) due to projected increase in frequency and severity of MHW (Frölicher et al., 2018).

*Adaptive Capacity:* Two scores revised. Decrease in rating to low.

1. Population status: Decreased from 3 to 1 based on recent losses (1 = endangered, 5 = robust). Abalone are now at extremely low abundances and survivors have poor body condition and reproduction (Rogers-Bennett et al., 2021; Rogers-Bennett and Catton, 2022).
2. Likelihood of managing or alleviating impacts: Decreased from 3 (moderate) to 2 (low) due to the extreme impacts resulting from kelp loss and ecosystem transition that is difficult to manage directly. Managing impacts to red abalone will require flexible management strategies, significant intervention, and novel restoration tools (Rogers-Bennett et al., 2022).

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## Sea Palm

\*\*reference pages 253-259 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Since the 2015 CVA, the impacts of warm water on this species have become much more apparent, with documented declines state-wide and local extirpation in its southern range. Scores have been revised to reflect this increased knowledge, though with no impact to overall vulnerability, due to the already relatively high scores for this species.

Sea palm	Revised Score	Confidence	Change
Sensitivity	3.6 High	High	+0.1
Exposure	4.0 High	Moderate	-
Adaptive Capacity	2.7 Mod	High	-0.2
Vulnerability	5.0 High	High	+0.4

*Sensitivity:* Two scores revised. Slight increase in sensitivity score.

1. Sea surface temperature: Increased from 3 (moderate) to 5 (very high) due to long-term monitoring data collected by the Multi-Agency Rocky Intertidal Network (MARINe) showing a strong correlation between *Postelsia* decline and warm water events (M. Miner/UCSC, personal communication, January 5, 2023).
2. Disturbance regimes: Added new score for MHW and ENSOs, as they were not considered in the initial rating of disturbance regimes; however, this rating was already a 5 (very high), so inclusion of these additional disturbance regimes does not impact the score.
3. Harvest: Though sensitivity to harvest remains at 5 (very high), the score for current exposure was increased from 2 (low) to 3 (moderate). The 2015 to 2021 average annual reported commercial sea palm harvest in the study region, Alder Creek, Mendocino County to Point Año Nuevo, San Mateo County, was 211 lbs wet weight whereas the average annual sea palm reported harvest statewide for the same time frame was 12,999 lbs (Data source: CDFW Commercial Edible Seaweed/Agarweed Aquatic Plant Harvester's Monthly Reports).

*Adaptive Capacity:* One score revised. Slight decrease in adaptive capacity score.

1. Population status: Decreased from 5 to 3 (1 = endangered, 5 = robust), due to local extirpation at the southern end of the species' range associated with prolonged warm water events, as well as ongoing state-wide decline in density since 2015 (unpublished MARINe long-term monitoring data).

Corrections to 2015 CVA Summary:

*Managing Impacts* (page 258): In the description regarding the likelihood of managing impacts to this species, harvest is described as “very low”. However, CDFW estimates 10,000-20,000 pounds wet weight are harvested commercially each year (Flores-Miller, presentation to Marine Resources Committee, 2022), there are no limits on the number of licenses available for sale and no harvest limits or seasonal closures for sea palm, and Thompson et al. (2010) suggest the species is highly sensitive to harvest. Regulating the timing and scale of harvest would likely be a very impactful management option, and CDFW is, in fact, currently reviewing commercial harvest of sea palm in response to species decline (Committee Staff Summary for March 2022 Marine Resources Committee meeting).





References:

- Marine Resources Committee meeting (2022, March 24). Agenda item.  
<https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=199392&inline>
- Marine Resources Committee meeting (2022, March 24). Meeting summary.  
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## Southern Sea Otter

\*\*reference pages 260-266 of the [2015 Assessment Report](#) (Hutto et al., 2015)

With the recent release of the 2022 USFWS Feasibility Assessment: Sea Otter Reintroduction to the Pacific Coast, new information regarding the effect of the 2014-2016 MHW and related climate impacts warrants revision of this assessment. Many corrections to the 2014 summary were also noted.

Southern sea otter	Revised Score	Confidence	Change
Sensitivity	2.9 Mod	High	+0.4
Exposure	3.6 High	Moderate	+0.1
Adaptive Capacity	2.5 Low	Moderate	-
Vulnerability	4.1 Mod	Moderate	+0.5

*Sensitivity:* One score revised, one score added, one stressor to note. Increase in sensitivity score and overall rating increased to moderate.

1. Sea surface temperature: Increased from 1 (very low) to 3 (moderate), due to significant indirect effects that were not considered in the original assessment. Following the 2014 MHW, subsequent loss of kelp canopy in the region is believed to have made sea otters more exposed to white shark bites (Nicholson et al., 2018). In addition to this increased exposure, shark-bite mortality is likely to increase in the region as waters warm, which increases the spatial and temporal overlap between juvenile white sharks and sea otters (Tinker et al., 2016; Moxley et al., 2019; Tanaka et al., 2021). Shark bite mortality has changed from being largely seasonal to a year-round threat (Miller et al., 2020) and has been recognized as a major factor limiting sea otter range expansion and abundance in California (Tinker et al., 2016; Tinker et al., 2021). Increased sea surface temperatures are also expected to cause harmful algal and cyanobacterial blooms, which produce biotoxins such as domoic acid (SIMoN, 2014; Preece et al., 2017; Trainer et al., 2020), with documented impacts on sea otters (Miller et al., 2020; Moriarty et al., 2021).
2. Disturbance regimes: Added 4 (high) sensitivity to MHW based on observed impacts following 2014-2016 MHW.
3. pH (no score change): The 2015 assessment accurately recognizes that ocean acidification could affect sea otter prey; this effect could be devastating, by impacting a broad range of calcifying marine organisms (USFWS, 2022). However, ecological interactions could mean that some beneficial effects could occur alongside the mostly negative effects (Marshall et al., 2017). There remains great uncertainty regarding the food web dynamics in response to changing ocean conditions, such as acidification.

*Exposure:* One score added. Slight increase in exposure score.

1. Increased sea surface temperature: Added as 4 (high) in light of the 2015-2016 MHW and likelihood for MHWs to be more frequent and severe in the future (Frölicher et al., 2018).

### Corrections to 2015 CVA Summary:

*Sensitivity to climate* (page 260): The 2015 climate assessment states that increasing SST may expand the range of suitable habitat for the sea otter. While this may be true for the northern sea otter subspecies because it inhabits areas adjacent to those where the loss of sea ice may increase available habitat, this is not applicable to the southern subspecies (L. Carswell/USFWS, personal communication, January 5, 2023).

*Sensitivity to precipitation* (page 261): While many otters are infected with *Toxoplasma gondii*, this parasite causes very little disease or death; rather, *Sarcocystis neurona*, another terrestrial-derived protozoal parasite, was found to be responsible for 5x more sea otter deaths than *Toxoplasma* in the most recent mortality study (Miller et al., 2020).

*Sensitivity to disease* (page 262): From 1998 to 2012, infectious disease was a primary or contributing cause of death for 63% (n=354/560) of otters examined (Miller et al., 2020). In that study, infectious disease was not identified as a risk factor for other causes of death such as shark bite or boat strike, as previously suggested. The most significant infectious disease affecting sea otters during that timeframe was acanthocephalan peritonitis, which is caused by trans-intestinal parasite migration by the acanthocephalan *Profilicollis* sp. (Mayer et al., 2003), a thorny-headed worm transmitted to otters by the ingestion of marine crustaceans. The protozoal parasites *Toxoplasma gondii* and *Sarcocystis neurona* were also important causes of death (Miller et al., 2020); these parasites have feline (VanWormer et al., 2016) and opossum (Rejmanek et al., 2010) terrestrial definitive hosts and enter the marine environment through freshwater runoff. Other diseases that affect sea otters include cardiomyopathy and domoic acid toxicosis (Miller et al., 2020).

*Population range and status* (page 263): The Southern sea otter ranges from Pigeon Point to Gaviota, and now numbers around 2,962 individuals (Hatfield et al., 2019).

*Dispersal distance* (page 263): Sea otters exhibit strong site fidelity, with adult females rarely dispersing more than 20 km within a 1-year period (Riedman and Estes, 1990; Tinker et al., 2019), and an average home range of 8.6 km (Tarjan and Tinker, 2016). Males may disperse further to new areas, but range expansion relies on females establishing a breeding population which may take years to occur following male dispersal (Lafferty and Tinker, 2014).

*Life history* (page 264): Females have a pup roughly every one year with a pup dependency period of approximately six months (Riedman et al., 1994).

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## Western Snowy Plover

Updated scientific name: *Charadrius nivosus nivosus*

\*\*reference pages 282-288 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The 2015 assessment is largely still accurate, with minor revisions related to precipitation impacts.

Western snowy plover	Revised Score	Confidence	Change
Sensitivity	4.0 High	High	+0.2
Exposure	4.3 Very High	High	+0.3
Adaptive Capacity	2.8 Mod	High	-
Vulnerability	5.5 High	High	+0.5

**Sensitivity:** One score revised, one score removed. Slight increase in sensitivity score.

1. Precipitation: Increased from 2 (low) to 3 (moderate) due to flooding of nesting areas, especially if precipitation occurs later in the spring season when chicks hatch (K. Lindquist/GFA, personal communication, November 29, 2022).
2. pH: Sensitivity score was removed entirely from the assessment, as pH has no documented impact on Snowy Plovers, and should not be included (K. Lindquist/GFA, personal communication, November 29, 2022).

**Exposure:** One score revised, one score removed. Slight increase in exposure score.

1. Changes in precipitation: Increase from 2 (low) to 3 (moderate) due to wetter wet years and drier dry years already being observed and projected to intensify (Warner et al., 2015). The likelihood of extreme precipitation is projected to increase (Swain et al., 2018).
2. pH: Exposure score was removed entirely from the assessment, as pH has no documented impact on Snowy Plovers, and should not be included (K. Lindquist/GFA, personal communication, November 29, 2022).

**Adaptive Capacity:** no revision, but important to note the following:

1. Point Reyes National Seashore recently recorded the highest fledge rate since 2012 and the highest total number of fledged chicks since 1997. This success is likely due to park managers working quickly to find and protect nests with mini-enclosures within the park, to protect the nests from predation. However, not all nesting sites throughout the Sanctuary are so closely managed, and the adaptive capacity of this species is likely highly dependent on these management interventions.

### References:

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## Ecosystem Services

### Carbon Storage and Sequestration

\*\*reference pages 297-303 of the [2015 Assessment Report](#) (Hutto et al., 2015)

The 2015 assessment of the ecosystem service “carbon storage and sequestration” focused solely on the provisioning of this service by saltmarsh and eelgrass plants. Based on findings from the Blue Carbon in MPAs report series (Hutto et al., 2021), this addendum revises the findings and scores of the original assessment to incorporate the provisioning of this service by the sanctuary’s bull kelp, large baleen whales, and phytoplankton. These processes are known to contribute to carbon sequestration in marine environments via carbon export to the deep sea, where carbon may be stored in seabed sediments for millennia (Hutto et al., 2021). Though there are myriad additional pathways for carbon sequestration in the marine environment (i.e. mesopelagic fish, zooplankton), this update is limited to those species/processes for which we have sufficient information to assess.

Carbon storage and sequestration	Revised Score	Confidence	Change
Sensitivity	3.5 High	Moderate	+0.5
Exposure	5.0 Very High	High	-
Adaptive Capacity	3.0 Mod	Moderate	+0.7
Vulnerability	5.5 High	High	-0.2

*Sensitivity:* One score revised. Increase in sensitivity score and of overall sensitivity rating to high.

1. Climate stressors: Overall sensitivity to climate stressors increased from 2 (low) to 4 (high) for the following reasons:
  - a. The high sensitivity of the sanctuary’s bull kelp to sea surface temperature, as evidenced during the 2014-2016 MHW, and the resulting decline in carbon export (Hutto et al., 2021).
  - b. The documented shift in dominant phytoplankton taxa from larger species to smaller species during the MHW (Cavole et al., 2016), which will likely impact carbon export and sequestration (Bolanos et al., 2020).
  - c. The moderate sensitivity of blue whales to climate stressors, including dynamic ocean conditions due to impacts to prey (krill).
2. Non-climate stressors: The 2015 assessment rated sensitivity to land-use change, roads/armoring, invasives, pollution, recreation, aquaculture, and dredging as moderate-high. Though this addendum does not propose changing this component of the overall sensitivity rating, the following should be noted:
  - a. Pollution, and its impacts on water quality, was rated as a high sensitivity for kelp.
  - b. There are additional non-climate stressors to consider for whales, including ship strikes, entanglements, and noise, which were rated as high in the blue whale assessment.
  - c. There are potential sensitivities for the seabed carbon sink, such as trawling and incidental disturbance events.

*Adaptive Capacity:* Two scores revised. Increase in adaptive capacity score and of overall rating to moderate.

1. Service value: increased from 2 (low) to 3 (moderate) due to rapidly increasing interest in blue carbon in recent years, as well as increased awareness by the general public,

policy-makers, funders, and sanctuary managers. A search of the Web of Knowledge database found that only 28 papers were published with the term "blue carbon" in their titles prior to 2015 while, since that time, 357 such papers have been published. Anecdotally, requests from media, funders and educational groups have increased significantly for sanctuary staff.

2. Willingness to change behavior: Increased from 1 (very low) to 2 (low): Desire to better protect carbon sequestration processes and sinks has increased, as well as knowledge of the best management practices to protect and maintain the service (Hutto et al., 2021).

#### References:

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## Flood and Erosion Protection

\*\*reference pages 304-311 of the [2015 Assessment Report](#) (Hutto et al., 2015)

Though there have been significant scientific advances in local climate science predictions in the last 15 years that impact and worsen predictions of coastal erosion (Thorne et al., 2016), the 2015 scores for sensitivity and exposure were so high, that no further modification can be made to further increase these scores. However, there have been improvements in the potential to manage for these impacts, which this revision notes.

Flood and erosion protection	Revised Score	Confidence	Change
Sensitivity	4.8 Very High	High	-
Exposure	5.0 Very High	High	-
Adaptive Capacity	4.3 Very High	High	+0.9
Vulnerability	5.6 High	High	-0.9

*Adaptive Capacity*: One score revised. Increase in adaptive capacity score, but no change to overall rating.

1. Willingness to change behavior: Increased from 2 (low) to 4 (high), as public and agency awareness of the issue of coastal protection has gained attention and there is increased local, state, and national interest and funding in using natural and nature-based solutions to mitigate impacts (Newkirk et al., 2018; California Coastal Commission, 2018).

### References:

- California Coastal Commission (2018). *California Coastal Commission Sea Level Rise Policy Guidance*. Adopted by the California Coastal Commission on 7 November 2018. Sacramento, CA. 307 pp.
- Newkirk, S., Veloz, S., Hayden, M., Heady, W., Leo, K., Judge, J., Battalio, R., Cheng, T., Ursell, T., & Small, M. (2018). *Toward Natural Infrastructure to Manage Shoreline Change in California* (California's Fourth Climate Change Assessment Publication No. CCCA4-CNRA-2018-011). California Natural Resources Agency.
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## *Climate Vulnerability Assessment for Maritime Heritage Resources*

As part of the revision to the 2015 Climate Vulnerability Assessment presented in this addendum, three new maritime heritage resource categories were assessed for the first time: doghole ports, nearshore shipwrecks, and offshore shipwrecks. This is the first assessment of climate vulnerability for tangible maritime heritage resources (MHRs) in GFNMS, CBNMS, and the northern portion of MBNMS, and is modeled after similar assessments undertaken at Olympic Coast NMS. These resources were assessed internally by ONMS staff, using the same climate vulnerability model from the 2015 assessment for the exposure and sensitivity components<sup>5</sup> (Hutto et al., 2015). However, as is general practice among heritage resource managers, adaptive capacity was not included because non-renewable resources such as heritage resources are non-adaptive and thus cannot be scored for adaptive capacity. In addition, heritage resources retain a high degree of significance based on their historical association with events, individuals, distinctive characteristics of a construction method or period, and/or their ability to yield information on the past. As this historical association is reliant on site integrity (i.e. location, design, setting, materials, workmanship, feeling, and association), modifying heritage resources through external management actions (e.g. adding stabilization braces or reburying visible materials to prevent further degradation) reduces resource integrity and significance. Thus, adaptive capacity of tangible heritage is not assessed. The vulnerability of the resource category, therefore, is the same as the potential impact that resource category is likely to experience and is simply a combination of exposure and sensitivity. In place of adaptive capacity, however, this assessment does include qualitative descriptions of other important considerations, including resource value and significance and data management potential. While this information does not factor into the vulnerability score, it supports a broader discussion on resource management in a changing climate.

Across the three MHR categories of resources assessed, exposure and sensitivity to climate-driven changes was rated as highest for doghole ports and lowest for offshore shipwrecks. This is due to the significant disturbances expected in coastal and nearshore areas from increased wave action and erosion, increased sedimentation, and inundation. These stressors are much less of a concern for deeper water shipwrecks further offshore. Dissolved oxygen and pH are concerns common across the three resource categories, with moderate to high sensitivity and very high exposure. It should be noted that confidence in future climate exposure was much lower for offshore shipwrecks due to the uncertainty of climate-driven processes at depth. Sensitivity to non-climate stressors was similar across the three resource categories, with artifact movement and biochemical degradation sensitivity rated as very high, though current exposure to these stressors is variable across resource categories: high for doghole ports, moderate for nearshore shipwrecks, and low for offshore shipwrecks. The potential impact of climate change (Table 5), which is defined as the exposure and sensitivity to climate and non-climate stressors, is high for both nearshore shipwrecks and doghole ports, and low for offshore shipwrecks.

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<sup>5</sup> Reference pages 18-22 of the 2015 Climate Vulnerability Assessment Report (Hutto et al., 2015) for a full description of the CVA model and methodology applied here.

Table 5. The mean exposure and sensitivity scores for each MHR category, as well as the expert confidence in those scores. Potential impact is the calculated projected impact of climate change based on exposure and sensitivity.

Resource Category	Exposure	Confidence	Sensitivity	Confidence	Potential Impact
Doghole Ports	4.3 Very High	High	3.3 Mod	High	High
Nearshore Shipwrecks	3.7 High	High	3.0 Mod	Moderate	High
Offshore Shipwrecks	2.7 Mod	Low	2.6 Low	Moderate	Low

Recognizing that heritage resources cannot adapt to changing conditions, the most likely course of action in response to this assessment is to document and commemorate these resources so the intangible values can persist through stories and educational opportunities, even as the resources themselves inevitably degrade. Mitigating data loss and preserving the memories and stories of these resources should be the priority for sanctuaries moving forward. In addition, sanctuaries should investigate management opportunities where site modification could be considered a net-positive management action when weighed against resource degradation and, when applicable, implement these measures before further degradation occurs.

Recommendations, which should be considered for inclusion in the upcoming GF/CBNMS management plan review and update process, include:

- To fill knowledge gaps, develop an overall plan for continued assessment of the presence and condition of maritime heritage resources within GFNMS, CBNMS and northern MBNMS, including initial prioritization of sites for management actions.
- As a part of the maritime heritage resources assessment plan, develop and include climate-related variables among those intended to track changes in the resources' condition.
- Integrate maritime heritage historical research and field research into planning for and implementing biological/ecological field research projects; this may require an organizational shift.
- Management actions that depend on acquiring data at the locations (sites) of historic or potentially historic resources will be impacted by climate change (e.g., mapping, site recording, remote sensing) because of the physical changes that will affect both accessing the sites and the data to be gathered. Therefore, documenting maritime heritage resources should be a high priority for sanctuaries, so this information can be captured before complete degradation occurs.
- Interpretation and outreach should be conducted to maintain the intangible value of these resources, and to increase public support for documenting these maritime heritage sites and resources.

The following reports for the three assessed heritage resource categories are evaluations (represented as scores) and comments from an internal expert-elicitation workshop on the exposure and sensitivity to climate and non-climate stressors. Supporting information was either gathered from Roth (2021)<sup>6</sup>, or was provided by workshop participants.

<sup>6</sup> Roth, M. (2021). Draft Climate Change Impacts to Maritime Heritage Resources: Gap Analysis. Department of Commerce, NOAA, Office of National Marine Sanctuaries. Unpublished internal agency document.

## Doghole Ports



Figure 7. Trough chutes at Stewart's Point Landing and unknown schooner loading tanbark. Photo: San Francisco Maritime National Historical Park SAFR 21374.

Doghole ports are archaeological sites along the rugged and largely inaccessible north-central and northern coasts of California. These sites are small embayments where the lumber industry of the 19th and 20th centuries transferred lumber as well as produce, other products, and people from shore to ship through extensive networks of wharves, wire chutes, rail lines, and steam winches. There are 24 such sites within GFNMS boundaries, but only the 14 sites in Sonoma County have been surveyed by federal and state partners. Various archaeological evidence has been documented at these sites, including remnants of chutes and associated maritime infrastructure including anchor chains and mooring bolts. The sites were submitted in a multiple property listing for inclusion in the National Register of Historic Places (listed April 11, 2022). Two Landing Historical and Archaeological District sites were listed to the Register: Fort Ross on April 7, 2023 and Salt Point on April 11, 2022.

With the archaeological remnants of these sites spanning from the coastal bluffs (outside GFNMS boundaries) down to the subtidal submerged environment, these sites will be exposed to climate and non-climate impacts occurring with variable intensity and timing. Overall, future exposure of the remnants within GFNMS to climate change is expected to be very high, with the sensitivity of the sites to both climate and non-climate impacts rated as moderate. These sites are expected to be more sensitive to climate impacts than non-climate impacts, such as wave action, erosion, inundation and sedimentation; though there may be some benefit realized through increased concretion and reduced degradation of fully submerged artifacts. This MHR

category is expected to experience the greatest potential impact from climate change in comparison with the other MHR categories assessed.

## Sensitivity to climate and climate-driven stressors

Climate Stressor	Sensitivity (score, rating <sup>7</sup> )	Confidence <sup>8</sup>
Air temperature	1, very low	moderate
Sea temperature	3, moderate	moderate
Precipitation	1, very low	moderate
Salinity	3, moderate	moderate
Dissolved oxygen	4, high	moderate
pH	3, moderate	moderate
Increased water depth (SLR)	5, very high	high
Wave/tidal action	5, very high	high
Water flow velocity	3, moderate	moderate
Site erosion	5, very high	high
Sedimentation	5, very high	high
Storm surge/inundation	5, very high	high
<b>Overall sensitivity</b>	<b>4, high</b>	<b>moderate</b>

Many of these stressors will have variable impacts on doghole port remnants based on the location and condition, with greater impacts expected on those materials that are higher in the intertidal zone, and fewer impacts on those materials already submerged in the subtidal environment.

- Impacts from reduced pH may be variable; a loss of calcifying colonizers will destabilize concretion processes, but adverse impacts on wood-boring bivalves may reduce degradation.
- Decreased dissolved oxygen content may slow material corrosion rates.
- Increased water depth (SLR) may result in inundation and flooding of intertidal portions of the doghole port sites
- Coastal erosion will be exacerbated through destabilization of the sediment and vegetation matrix. The potential for novel site discovery is increased as is the risk of looting and movement of artifacts.

<sup>7</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>8</sup> Confidence level indicated by workshop participants.

- Storm surge and currents will physically alter site structure and may disperse materials.

Climate-driven stressors that may benefit the resource: Sedimentation, dissolved oxygen, pH, increased water depth

- Sedimentation could benefit doghole port remnants if burial protects against degradation.
- Dissolved oxygen is projected to decrease and, as the main driver of colonization and concretion, may result in slower degradation rates.
- pH may have negative impacts on calcifying organisms, such as *Teredo* spp. (marine wood-boring bivalves) and invasive mussels that cause resource degradation; any negative effects on these species may benefit the resource.
- Increasing water levels could benefit resources that are intertidal and cycle between water and air, as being fully inundated may result in less degradation over time.

## Exposure to climate-driven stressors

Climate Stressor	Exposure (score, rating <sup>9</sup> )	Confidence <sup>10</sup>
Air temperature	2, low	low
Sea temperature	5, very high	high
Precipitation	2, low	moderate
Salinity	5, very high	high
Dissolved oxygen	5, very high	high
pH	5, very high	high
Increased water depth (SLR)	3, moderate	moderate
Wave/tidal action	5, very high	high
Water flow velocity	3, moderate	moderate
Site erosion	5, very high	high
Sedimentation	5, very high	high
Storm surge/inundation	5, very high	high
<b>Overall sensitivity</b>	<b>5, very high</b>	<b>high</b>

<sup>9</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>10</sup> Confidence level indicated by workshop participants.

Some scores were considered as averages across intertidal and subtidal remnants; for resources that are intertidal and already exposed, future air temperature and precipitation exposure can be considered very high. Exposure to increased water depth also varies between shallow and deep resources.

## Sensitivity and current exposure to non-climate stressors

Non-climate Stressor	Sensitivity (score <sup>11</sup> , rating <sup>12</sup> )	Confidence	Current exposure (score, rating)	Confidence
Artifact movement	5, very high	high	4, high	high
Biochemical degradation	5, very high	high	4, high	high
Neglect	3, moderate	high	3, moderate	high
Pollution/run-off	2, low	low	1, very low	high
Research	4, high	moderate	2, low	high
Visitation	2, low	low	1, very low	moderate
Algal growth	1, very low	low	3, moderate	low
<b>Overall</b>	<b>3, moderate</b>	<b>moderate</b>	<b>3, moderate</b>	<b>high</b>

Fishing is a potential non-climate stressor, but impacts have not been documented in the region, nor has it been documented at specific doghole port sites in GFNMS and was therefore omitted from the list, but should be considered if data becomes available. *Teredo* spp. are of specific concern when it comes to biological degradation. The rating for “neglect” refers to The National Historic Preservation Act of 1966 (NHPA) which states that sanctuaries have a responsibility to manage these resources, and are currently doing so in a very limited capacity. Visitation is rated as low because it is only possible at a few sites, and most are difficult to access by land.

## Heritage significance

Maritime heritage resources with high structural integrity often hold greater archaeological or historical value, and therefore greater significance to constituents. The perception of adverse impacts from climate change on these resources may be greater if they are damaged or lost; however, they may also garner better public support for management actions.

How much do people value this resource category: Low

- Confidence of workshop participants: High

<sup>11</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>12</sup> Confidence level indicated by workshop participants.

The doghole port resource category is relatively little known by the public compared to shipwrecks, as they are not one single structure but specific locations with closely associated multiple features. Only relatively recently, after the GFNMS boundaries were expanded by NOAA in 2015, have publications and web information been released about them. There is great historical, aesthetic, educational, and recreational value, with some diving and snorkeling around doghole ports. The National Register of Historic Places evaluation for the majority of locations is in process, and this implies there is great historical value for these resources. This low rating applies to the general public, but there is much greater value for the maritime heritage community and the broader sanctuary community.

Likelihood of maintaining resource significance under a changing climate: High

- Confidence of workshop participants: High

There is a high likelihood of maintaining intangible values, though resources will continue to physically degrade. The difficulty of visiting sites will continue and may worsen. Diving may become more difficult due to changing ocean conditions. However, there is great opportunity and potential to increase this resource category's educational value. The doghole port site at Fort Ross is a great example of historical and educational value, and the California Department of Parks and Recreation (California State Parks) is a critical partner in education and recognition.


## Data management potential

Current restrictions in assessing or conducting research on the resource category: Regulations, permits, funding, reduced accessibility.

- It is best practice to leave maritime heritage resources in place. While this assists managers in retaining integrity of place and setting, it creates limitations in the preservation of archaeological remnants. *In-situ* preservation is the preferred treatment for archaeological resources; however, it remains time, energy, and resource intensive for effective management.
- Sanctuary regulations prohibit possessing, moving, removing, or injuring, or attempting to possess, move, remove or injure, a sanctuary historical resource (15CFR922.82(a)(9); 15CFR922.112(a)(7); and 15CFR922.132(a)(3)).<sup>13</sup>
- National Marine Sanctuary permits may be issued for activities that would otherwise be prohibited, without a permit, by sanctuary regulations (15CFR922.30 - 922.35). Activities that are not prohibited by the regulations do not require a National Marine Sanctuary permit, though they may require permits or other approvals by other agencies.
- Funding is a restriction, as the research required is often expensive.
- Safe access to some sites is a restriction due to ocean conditions. Some sites may not ever be able to be assessed due to environmental conditions.
- Reduced accessibility to conduct research due to private land ownership upland of some sites may also be a restriction.

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<sup>13</sup> The MBNMS prohibition does not apply to, moving, removing, or injury resulting incidentally from kelp harvesting, aquaculture, or lawful fishing activities.



Likelihood of managing data loss due to climate impacts: Very Low

- Confidence of workshop participants: High

Likelihood of managing or alleviating climate impacts: Very Low

- Confidence of workshop participants: High

In just the last decade this resource category has been recognized as being historically significant. There is opportunity to continue to capitalize on the novelty of this heritage resource and focus messaging in a strategic way to educate communities.



## Nearshore Shipwrecks

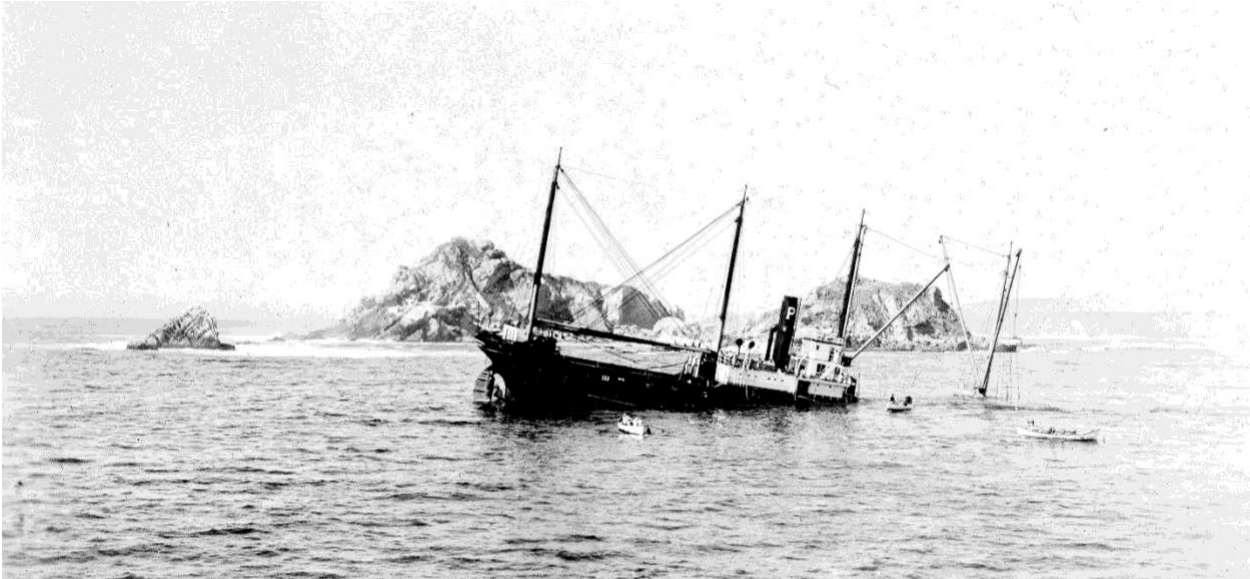


Figure 8. SS Dorothy Wintermote, lost in 1938, in Greater Farallones National Marine Sanctuary. Photo: San Francisco Maritime National Historic Park.

Nearshore shipwrecks are defined as those that are shallower than 30 meters<sup>14</sup>. There are 24 nearshore shipwrecks known to exist in GFNMS, none in CBNMS, and 8 in the northern portion of MBNMS. Loss records indicate that there could be more nearshore shipwrecks within the sanctuaries yet to be discovered. Sixteen shipwrecks were formally documented by federal, state, or private sector partners. Summary findings of the condition of 13 wrecks (7 of which are nearshore wrecks) have been made, and all 13 were found to have experienced physical degradation. These wrecks are composed of a variety of materials, including wood, iron and steel.

For nearshore shipwrecks, future exposure to climate change is expected to be high (less than that of doghole ports, but greater than offshore wrecks), with the sensitivity of these resources to both climate and non-climate impacts rated as moderate. These sites are expected to be slightly more sensitive to climate impacts than non-climate impacts, including dissolved oxygen, wave action, erosion and sedimentation; though there may be some benefit realized through reduced degradation of artifacts protected by sedimentation. This resource category is projected to experience high potential impact from climate change, slightly less than that of doghole ports but greater than offshore wrecks.

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<sup>14</sup> This is consistent with the Climate Vulnerability Assessment (Hutto et al., 2015), which defines the nearshore environment as less than 30 m; however, is different from that of the GFNMS Condition Report (ONMS 2010) in which it is defined as less than 20 m.

## Sensitivity to climate-driven stressors

Climate Stressor	Sensitivity (score, rating <sup>15</sup> )	Confidence <sup>16</sup>
Sea temperature	3, moderate	moderate
Salinity	3, moderate	moderate
Dissolved oxygen	4, high	moderate
pH	3, moderate	moderate
Increased water depth (SLR)	1, very low	low
Wave/tidal action	4, high	high
Water flow velocity	2, low	moderate
Site erosion	5, very high	high
Sedimentation	5, very high	high
<b>Overall sensitivity</b>	<b>4, high</b>	<b>moderate</b>

The nearshore environment is highly dynamic, and there are likely impacts from storms due to water and sediment movement, and erosion and sedimentation from the coastal environment. Depth of the resource is a driving degradation factor; shallow resources are likely to be more exposed to these impacts. For example, part of the *Tennessee* shipwreck sits above the water line and, as such, is subject to terrestrial and submerged degradative forces. In addition to continual processes, seasonal storm activity that removes sediment from beaches may uncover previously covered shallow nearshore wrecks, possibly resulting in an increase in visitation and looting. Though sea level rise may not generally be a concern for nearshore wrecks, there is not enough information to know how much sea level rise may impact resources due to the changing gas content of seawater with depth. Workshop participants expressed a higher confidence in the physical processes such as direct damage, and lower confidence in oceanographic processes and impacts.

- Dissolved oxygen is a main driver of corrosion; anaerobic environments are important and decreased dissolved oxygen content may slow material corrosion rates.
- Wave and tidal action can lead to currents, scouring, and changes to gas diffusion (the rate that water passes over differential membranes and impacts corrosion). Storm surge and currents will physically alter site structure and may disperse materials.
- Erosion at the site could undermine, encapsulate, and/or scatter materials.
- Sedimentation could cause increased scouring, or could actually protect the resource (depends on the type of resource, type of encapsulation). High energy shallow water areas

<sup>15</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>16</sup> Confidence level indicated by workshop participants.

may experience increased erosion and sediment loss, while low energy shallow environments may experience enhanced protection from sedimentation.

- Warming ocean waters could increase the abundance of *Teredo* shipworm species.

Climate-driven stressors that may benefit the resource: Sedimentation, dissolved oxygen, pH.

- Sedimentation could benefit nearshore shipwrecks if burial protects against degradation.
- pH may have negative impacts on calcifying organisms, such as *Teredo* and invasive mussels that cause resource degradation; any negative effects on these species may benefit the resource.
- Dissolved oxygen is projected to decrease and, as the main driver of colonization and concretion, may slow these processes and prolong total resource loss.

## Exposure to climate-driven stressors

Climate Stressor	Exposure (score, rating <sup>17</sup> )	Confidence <sup>18</sup>
Sea temperature	5, very high	high
Salinity	5, very high	high
Dissolved oxygen	5, very high	high
pH	5, very high	high
Increased water depth (SLR)	1, very low	moderate
Wave/tidal action	4, high	high
Water flow velocity	2, low	moderate
Site erosion	3, moderate	high
Sedimentation	3, moderate	high
<b>Overall sensitivity</b>	<b>4, high</b>	<b>high</b>

## Sensitivity and current exposure to non-climate stressors

Non-climate Stressor	Sensitivity (score, rating <sup>17</sup> )	Confidence <sup>18</sup>	Current exposure (score, rating)	Confidence
Artifact movement	5, very high	high	3, moderate	low
Biochemical degradation	5, very high	high	4, high	high

<sup>17</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>18</sup> Confidence level indicated by workshop participants.

<b>Non-climate Stressor</b>	<b>Sensitivity (score, rating<sup>17</sup>)</b>	<b>Confidence<sup>18</sup></b>	<b>Current exposure (score, rating)</b>	<b>Confidence</b>
Fishing	5, very high	high	2, low	low
Hazardous materials (cargo, bunker fuel)	2, low	moderate	2, low	low
Neglect	3, moderate	high	5, very high	high
Pollution/run-off	2, low	low	1, very low	high
Research	2, low	low	3, moderate	high
Visitation	2, low	moderate	1, very low	high
Algal growth	1, very low	low	3, moderate	low
<b>Overall</b>	<b>3, moderate</b>	<b>moderate</b>	<b>3, moderate</b>	<b>moderate</b>

There are a number of data and assessment gaps. While evidence of past looting has been documented for several shipwrecks in the sanctuaries (e.g., *SS Klamath*, *SS Pomona*), it is not clear if this is a current stressor. Similarly, two offshore wrecks (*TV Puerto Rican*, *SS Selja*) have derelict fishing gear on parts of the wrecks (actual impacts on the wrecks not assessed), but it is not known how prevalent an impact fishing or derelict gear may be on resource quality. While research activities are occurring in these areas, their impacts on nearshore shipwrecks are not assessed.

## Heritage significance

Maritime heritage resources with high structural integrity often hold greater archaeological or historical value, and therefore greater significance to constituents. The perception of adverse impacts from climate change on these resources may be greater if they are damaged or lost; however, they may also garner better public support for management actions.

How much do people value this resource category: Moderate

- Confidence of workshop participants: Low

The value of nearshore shipwrecks includes consideration of aesthetic, archaeological, commercial, educational, historical, recreational, and traditional values. Resources listed on the National Register of Historic Places include the *Norlina* and the *SS Pomona* in GFNMS, and the *SS Tennessee* in the northern portion of MBNMS. There is also great interest in the historical and archaeological value of nearshore shipwrecks. Some recreational diving occurs, and there is educational value.

Likelihood of maintaining resource significance under a changing climate: Moderate

- Confidence of workshop participants: High

The likelihood of maintaining resource integrity and therefore significance is lower than offshore shipwrecks due to relatively higher disturbance and degradation. Many of these resources still have intangible resource significance, including education, and stories that can be maintained. Some place names are based on shipwrecks, which leaves a lasting legacy. Different ratings could be given for tangible vs intangible resource significance. Historic listings are contingent on a strong degree of integrity (of materials and form) and there is a possibility that resources will become ineligible as they degrade. Effort should focus, therefore, on documenting resources *in situ* and improved understanding of degradation rates.

## Data management potential

Maritime heritage resource management potential is based on current resource condition and the potential to conduct research. The ability to conduct research and better understand the MHR category is one means of reducing the impacts of climate change. For nearshore shipwrecks, partnerships are critical for recognition, awareness, research and education.

Current restrictions in assessing or conducting research on the resource category: Regulations, permits, funding.

- It is best practice to leave maritime heritage resources in place. While this assists managers in retaining integrity of place and setting, it creates limitations in the preservation of archaeological remnants. *In-situ* preservation is the preferred treatment for archaeological resources; however, it remains time, energy, and resource intensive for effective management.
- Regulations for the sanctuaries prohibit possessing, moving, removing, or injuring, or attempting to possess, move, remove or injure, a sanctuary historical resource (15CFR922.82(a)(9); 15CFR922.112(a)(7); and 15CFR922.132(a)(3)).
- National Marine Sanctuary permits may be issued for activities that would otherwise be prohibited, without a permit, by sanctuary regulations (15CFR922.30 - 922.35). Activities that are not prohibited by the regulations do not require a National Marine Sanctuary permit, though they may require permits or other approvals by other agencies.
- Funding is a restriction, as the research required is often expensive.
- Safe access to some sites is a restriction due to ocean conditions. Some sites may not ever be able to be assessed.

Likelihood of managing data loss due to climate impacts: Very Low

- Confidence of workshop participants: High

Likelihood of managing or alleviating climate impacts: Very Low

- Confidence of workshop participants: High

With funding, staffing, more robust partnerships, and prioritization from management, there could be increased management potential.

## Offshore Shipwrecks

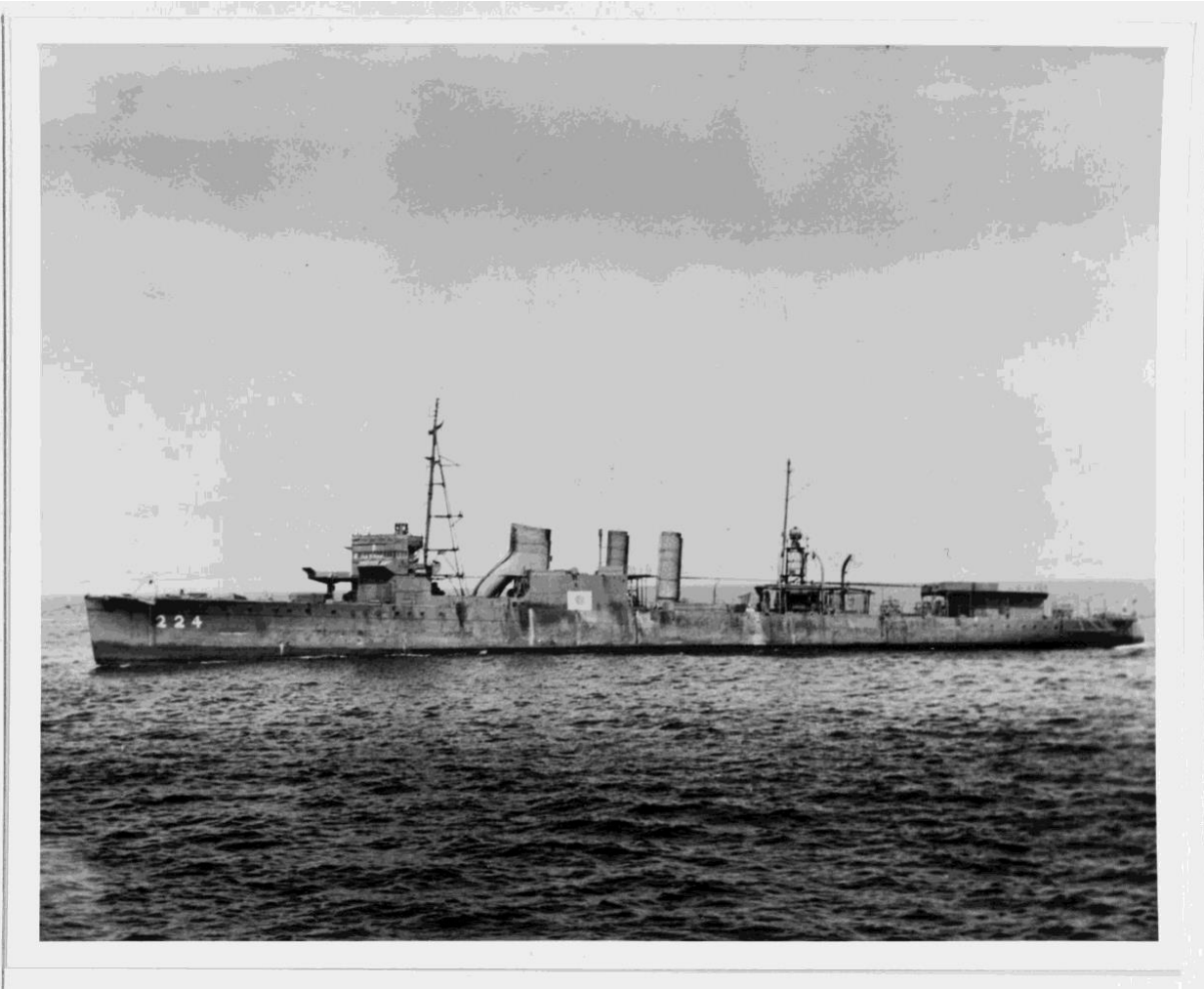


Figure 9. Ex-USS Stewart (DD-224) on May 24, 1946, just before being sunk. Photo: Official U.S. Navy Photograph, National Archives and Records Administration.

Offshore shipwrecks are defined as those that are deeper than 30 meters<sup>19</sup>. There are 10 offshore shipwrecks known to exist in GFNMS, one in CBNMS, and one in the northern portion of MBNMS. Loss records indicate that there could be more offshore shipwrecks yet to be discovered. Sixteen shipwrecks were formally documented by federal, state, or private sector partners. Summary findings of the condition of 13 wrecks (6 of which are offshore wrecks) indicate all have experienced physical degradation. These wrecks are composed of a variety of materials, including wood, iron and steel.

For offshore shipwrecks, future exposure to climate change is expected to be moderate, which is less than that of doghole ports and nearshore wrecks, with the sensitivity of these resources to both climate and non-climate impacts rated as low. These sites are expected to be slightly more

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<sup>19</sup> This is consistent with the Climate Vulnerability Assessment (Hutto et al., 2015), which defines the offshore environment as greater than 30 m; however, is different from that of the GFNMS Condition Report (ONMS 2010) in which it is defined as greater than 20 m.

sensitive to non-climate impacts than to climate impacts due to possible artifact movement and biochemical degradation. However, it should be noted that the climate sensitivity of offshore wrecks is highly uncertain, with the lowest confidence rating in this MHR assessment. This resource category is projected to experience low potential impact from climate change, much less than that of doghole ports and nearshore shipwrecks.

## Sensitivity to climate-driven stressors

Climate Stressor	Sensitivity (score, rating <sup>20</sup> )	Confidence <sup>21</sup>
Sea temperature	3, moderate	moderate
Salinity	3, moderate	moderate
Dissolved oxygen	4, high	moderate
pH	3, moderate	moderate
Water flow velocity	1, very low	moderate
Site erosion	2, low	moderate
Sedimentation	3, moderate	moderate
Storm surge/inundation	5, very high	high
<b>Overall sensitivity</b>	<b>3, moderate</b>	<b>low</b>

Effects of salinity are largely unknown, and there are data gaps on the effects of deep currents and upwelling.

Climate-driven stressors that may benefit the resource: Sedimentation, seawater temperature, dissolved oxygen, pH

- Sedimentation could benefit offshore wrecks if it protects against degradation.
- pH may have negative impacts on calcifying organisms, such as *Teredo* and invasive mussels that cause resource degradation; any negative effects on these species may benefit the resource.
- Dissolved oxygen is projected to decrease and as the main driver of colonization and concretion, two processes affecting the rate of degradation, may prolong time until the resource is lost.

<sup>20</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>21</sup> Confidence level indicated by workshop participants.

## Exposure to climate stressors

Climate Stressor	Exposure (score, rating <sup>22</sup> )	Confidence <sup>23</sup>
Sea temperature	3, moderate	moderate
Salinity	2, low	low
Dissolved oxygen	3, moderate	moderate
pH	5, very high	high
Water flow velocity	2, low	low
Site erosion	2, low	low
Sedimentation	2, low	low
<b>Overall sensitivity</b>	<b>3, moderate</b>	<b>low</b>

## Sensitivity and current exposure to non-climate stressors

Non-climate Stressor	Sensitivity (score, rating <sup>22</sup> )	Confidence <sup>23</sup>	Current exposure (score, rating)	Confidence
Artifact movement	5, very high	high	2, low	low
Biochemical degradation	5, very high	moderate	3, moderate	low
Fishing/trawling	4, high	moderate	2, low	low
Hazardous materials (cargo, bunker fuel)	2, low	moderate	2, low	moderate
Neglect	3, moderate	high	5, very high	moderate
Pollution/run-off	2, low	low	1, very low	high
Research	2, low	low	3, moderate	high
Visitation	2, low	low	1, very low	high
Algal growth	1, very low	low	1, very low	low
<b>Overall</b>	<b>3, moderate</b>	<b>moderate</b>	<b>2, low</b>	<b>moderate</b>

<sup>22</sup> Stressors were scored on a scale of 1-5, with 5 indicating very high sensitivity and 1 indicating very low sensitivity.

<sup>23</sup> Confidence level indicated by workshop participants.



There are a number of data and assessment gaps. Evidence of past looting is less prevalent at deep-water shipwreck sites than nearshore sites due to the required effort to access deeper sites and their associated artifact assemblages; it is not clear if this is a current stressor. Two offshore wrecks (TV *Puerto Rican*, SS *Selja*), have derelict fishing gear on parts of the wrecks (actual impacts on the wrecks not assessed). Without more intensive study of offshore sites, the impact of fishing gear cannot be quantified and it is not known how prevalent an impact fishing or derelict gear may be on resource quality. Future seafloor use, including offshore energy development, carbon sequestration, and materials mining is of concern; however, there are few metrics to delineate potential future impacts. Similarly, while research activities are occurring in these areas, their impacts on offshore shipwrecks are not assessed.

## Heritage significance

Maritime heritage resources with high structural integrity often hold greater archaeological or historical value, and therefore greater significance to constituents. The perception of adverse impacts from climate change on these resources may be greater if they are damaged or lost; however, they may also garner better public support for management actions.

How much do people value this resource category: Moderate

- Confidence of workshop participants: Low

The value of offshore shipwrecks includes consideration of aesthetic, archaeological, commercial, educational, historical, recreational, and traditional values. Several wrecks are listed on the National Register of Historic Places. A very minor amount of recreational diving takes place on these deeper wrecks (less than nearshore wrecks). The USS *Conestoga*, in GFNMS, is a military grave site, a remnant of human history and American heritage and is listed on the National Register of Historic Places. Along with the SS *Ituna*, these two wrecks received much public and media attention, resulting in exposure to a broader audience. The significance of these sites may be enhanced due to this media attention, although the metrics for understanding significance have not been tracked. Overall, offshore wrecks experience less disturbance, and a higher structural integrity may increase their aesthetic and engagement value. The ex-USS *Independence*, an aircraft carrier that was intentionally sunk, holds value for those still alive who served on the vessel in World War II, and serves as a legacy of that time in US history. This is also applicable to the ex-USS *Stewart* (DD-224), also intentionally sunk, which is the only known maritime heritage resource in CBNMS.

Likelihood of maintaining resource significance under a changing climate: High

- Confidence of workshop participants: High

Though a lower rating could be justified because we know that climate change will accelerate degradation, the likelihood of maintaining resource significance is higher than nearshore shipwrecks due to relatively lower disturbance and degradation. Many of these resources still have intangible resource significance, including education, and stories that can be maintained. Emphasis on historical research may result in maintaining significance and cultural value.

## Data management potential

Maritime heritage resource management potential is based on current resource condition and the potential to conduct research. The ability to conduct research and better understand the MHR category is one means of reducing the impacts of climate change.

Current restrictions in assessing or conducting research on the resource category: Regulations, permits, funding.

- It is best practice to leave maritime heritage resources in place. While this assists managers in retaining integrity of place and setting, it creates limitations in the preservation of archaeological remnants. *In-situ* preservation is the preferred treatment for archaeological resources; however, it remains time, energy, and resource intensive for effective management.
- Regulations for the sanctuaries prohibit possessing, moving, removing, or injuring, or attempting to possess, move, remove or injure, a sanctuary historical resource (15CFR922.82(a)(9); 15CFR922.112(a)(7); and 15CFR922.132(a)(3)).
- National Marine Sanctuary permits may be issued for activities that would otherwise be prohibited, without a permit, by sanctuary regulations (15CFR922.30 - 922.35). Activities that are not prohibited by the regulations do not require a National Marine Sanctuary permit, though they may require permits or other approvals by other agencies.
- As these resources are more difficult to access due to geographic location and water depth, funding is a severe restriction due to technological requirements.
- Safe access to some sites is a restriction due to ocean conditions. Some sites may not ever be able to be assessed due to the physical conditions at the site.

Likelihood of managing data loss due to climate impacts: Low

- Confidence of workshop participants: High

The likelihood of managing data loss is even lower than that of the nearshore shipwrecks. But with funding, staffing, partners, and management priority, there could be increased management potential. This is a critical priority because these are non-renewable resources.

Likelihood of managing or alleviating climate impacts: Low

- Confidence of workshop participants: High

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## Appendix A: Assessment Revision Experts, Reviewers, and Workshop Attendees

<b>Resource</b>	<b>Subject-matter expert</b>	<b>Reviewers</b>
Black Oystercatcher	Kirsten Lindquist, GFA	n/a, not revised
Black Rail	Julian Wood, Point Blue	n/a, not revised
Blue Rockfish	Mark Carr, UCSC	Scott Hamilton, MLML; Tom Laidig, NOAA
Blue Whale	Meredith Elliott, Point Blue	Jaime Jahncke, Point Blue
California Mussel	Melissa Miner, UCSC	Eric Sanford, BML; Corey Garza, CSUMB; Kathy Ann Miller, UCB; Laura Rogers-Bennett, CDFW
Cassin's Auklet	Kirsten Lindquist, GFA	Pete Warzybok, Point Blue
Cavity Nesters (Ashy Storm Petrel, Tufted Puffin, PIGU)	Pete Warzybok, Point Blue	n/a, not revised
Copepod	Jaime Jahncke and Meredith Elliott, Point Blue	n/a, not revised
Coralline Algae	Melissa Miner, UCSC	Eric Sanford, BML; Kathy Ann Miller, UCB; Laura Rogers-Bennett, CDFW
Hydrocoral/Sponge	Dani Lipski, GF/CBNMS	Kaitlin Graiff, ONMS; Tom Laidig, NOAA
Krill	Meredith Elliott, Point Blue	Jaime Jahncke, Point Blue
Mole Crab	Kirsten Lindquist and Jaclyn Schneider, GFA	n/a, not revised
Northern Anchovy/Pacific Sardine	John Field, NOAA	Andrew Thompson, NMFS
Ochre Sea Star	Melissa Miner, UCSC	Eric Sanford, BML; Laura Rogers-Bennett, CDFW
Olympia Oyster	Edwin D. Grosholz, UCD	Kerstin Wasson, Elkhorn Slough NERR
Pacific Herring	Andrew Weltz, CDFW	

<b>Resource</b>	<b>Subject-matter expert</b>	<b>Reviewers</b>
Pteropod	Meredith Elliott, Point Blue	Jaime Jahncke, Point Blue; Nina Bednarsek, SCCWRP
Red Abalone	Laura Rogers-Bennett, CDFW	Mike Kenner, USGS; Mark Carr, UCSC
Sea Otter	Lilian Carswell, USFWS	Colleen Young, CDFW; Mike Kenner, USGS
Sea Palm	Melissa Miner, UCSC	Eric Sanford, BML; Kathy Ann Miller, UCB; Rebecca Flores-Miller, CDFW
Sea Urchins	Mark Carr, UCSC	Rietta Hohman, GFA; Mike Kenner, USGS; Laura Rogers-Bennett, CDFW
Snowy Plover	Kirsten Lindquist, GFA	Matt Lau, NPS; Edwin D. Grosholz, UCD
Surface Nesters (Brandt's Cormorant, Common Murre)	Kirsten Lindquist, GFA	n/a, not revised
Tidewater Goby	Darren Fong, NPS	n/a, not revised
Widow Rockfish	Tom Laidig, NMFS	n/a, not revised
Beaches and Dunes	Kirsten Lindquist, GFA	n/a, not revised
Cliffs	Pete Warzybok, Point Blue	n/a, not revised
Estuaries	Edwin D. Grosholz, UCD	Kerstin Wasson, Elkhorn Slough NERR
Kelp Forest	Rietta Hohman, GFA	Mike Kenner, USGS; Kristen Elsmore, CDFW
Nearshore soft bottom	Steve Lonhart, MBNMS	Scott Hamilton, MLML; Tom Laidig, NOAA
Offshore rocky reefs	Dani Lipski, GF/CBNMS	Kaitlin Graiff, ONMS; Tom Laidig, NOAA
Pelagic	Meredith Elliott, Point Blue	Jaime Jahncke, Point Blue; Nina Bednarsek, SCCWRP
Rocky Intertidal	Kirsten Lindquist and Jaclyn Schneider, GFA	Melissa Miner, UCSC; Eric Sanford, BML; Corey Garza, CSUMB
Carbon Storage and Sequestration	Sara Hutto, GFA	Doug George, NOAA; Wendy Kordesch, GFA
Flood and Erosion Protection	Wendy Kordesch, GFA	Doug George, NOAA; Sara Hutto, GFA



**Workshop attendees:** Sara Hutto (GFA), Monisha Sugla (GF/CBNMS), Dani Lipski (GF/CBNMS), Kaitlin Graiff, Jan Roletto (GF/CBNMS), Maria Brown (GF/CBNMS), Kirsten Lindquist (GFA), Steve Lonhart (MBNMS), Zac Cannizzo (ONMS), Jaime Jahncke (Point Blue), Melissa Miner (UCSC), Corey Garza (CSUMB), Meredith Elliot (Point Blue), Douglas George (NOAA OCM), John Field (NOAA), Rebecca Flores Miller (CDFW), Edwin Grosholz (BML), Colleen Young (CDFW), Tom Laidig (NOAA), Keighley Lane (CINMS), Jordan Gorostiza (GFA), Gina Contolini (GFA), Angela Zepp (GFA), Brian Johnson (GF/CBNMS), Carol Preston (GF/CBNMS).

**Maritime Heritage Resource assessments**

Resource experts: Madilyn Roth (ONMS), Hans Van Tilburg (ONMS), Robert Schwemmer (ONMS West Coast Region), Lilli Ferguson (GF/ CBNMS), Erica Burton (MBNMS).

Note-taker: Grace Kumaishi (ONMS West Coast Region)

Facilitator: Sara Hutto (GF/CBNMS)

## Appendix B. Updated Climate Projections for the North-central California Coast and Ocean

The [Greater Farallones 2010 Climate Change Impacts Report](#) (Largier et al., 2010) informed the 2015 climate vulnerability assessment and identified 11 major climate impacts and trends. In the intervening decade, our understanding of climate change has advanced and predictions have been refined. While some trends identified in the 2010 report remain the same, many are accelerating faster than initially expected. The below table summarizes each of the major climate trends from the 2010 report, in addition to ocean deoxygenation, and provides information on how our understanding of those trends has changed since that report.

<b>Climate Hazard</b>	<b>Trend from 2010 report</b>	<b>Change in projected trend since 2010</b>	<b>Explanation of change in projection</b>	<b>Supporting Literature</b>
Sea Level Rise	Up to 75 inches by 2100	No meaningful change in projection	The most recent (2022) NOAA sea level rise projections predict up to 57 (intermediate high) to 78 inches (high scenario) of sea level rise by 2100.	<a href="#">Sweet et al. 2022 NOAA SLR viewer</a>
Coastal Erosion	Increase due to rising sea levels and increased wave and storm intensity	Likely to be greater change than previously projected	A number of recent studies suggest a higher incidence of extreme precipitation and flood events than previously predicted as well as an increase in storm strength (see below). While no studies project erosion, it is likely that these effects will accelerate coastal erosion beyond previous estimates.	See precipitation and extreme events below
Spring Runoff	Decreases due to decreased Sierra snowpack	Greater projected change than previous projections	Studies suggest a more rapid shift in Sierra precipitation towards rainfall, leading to decreased snowpack and spring runoff by 2100. Spring runoff is projected to decrease and occur earlier.	<a href="#">Schwartz et al. 2017</a> <a href="#">Sun et al. 2019</a>

<b>Climate Hazard</b>	<b>Trend from 2010 report</b>	<b>Change in projected trend since 2010</b>	<b>Explanation of change in projection</b>	<b>Supporting Literature</b>
Precipitation	Increased variability with drier dry years and wetter wet years	Previously projected change already being observed. Greater projected change than previous projections.	Wetter wet years and drier dry years are already being observed. Projected increases in the frequency and intensity of both extreme wet and extreme dry events. Projected 25-100% increase in extreme dry-to-wet precipitation events. Projected increase in rapid transitions from very wet to very dry years and vice-versa.	<a href="#">Warner et al. 2015</a> <a href="#">Wehner et al. 2017</a> <a href="#">Swain et al. 2018</a>
Water Temperature	Increase offshore and over continental shelf	Greater projected change than previous projections	Sea surface temperatures in the sanctuary could increase between 1.5 and 3 °C by 2100. Bottom water temperatures in the sanctuary could increase between 1 and 2 °C by 2100. These changes may be partially mitigated by increasing upwelling intensity.	<a href="#">Howard et al. 2020</a> <a href="#">Siedlecki et al. 2021</a> <a href="#">Pozo-Buil et al. 2021</a>
Upwelling	Enhanced upwelling due to increasing alongshore winds	Greater uncertainty than previous projections	Upwelling timing and intensity are projected to change across the region over the next century. Projected increase in spring upwelling intensity, some decrease in summer upwelling. Overall, a likely increase in upwelling intensity in Greater Farallones and Cordell Bank, with greater uncertainty in trend towards the southern end of the Sanctuaries.	<a href="#">Howard et al. 2020</a> <a href="#">Pozo-Buil et al. 2021</a>



<b>Climate Hazard</b>	<b>Trend from 2010 report</b>	<b>Change in projected trend since 2010</b>	<b>Explanation of change in projection</b>	<b>Supporting Literature</b>
Extreme Events	Increase in frequency and intensity	Greater projected change than previous projections	MHWs are expected to increase in frequency and intensity. Total number of non-atmospheric river storms may decrease. Storms, including atmospheric river events, are expected to increase in intensity with greater likelihood for extreme precipitation events.	<a href="#">Wang et al. 2017</a> <a href="#">Frölicher et al. 2018</a> <a href="#">Knutson et al. 2019</a> <a href="#">Huang et al. 2020</a> <a href="#">Corringham et al. 2022</a> <a href="#">Huang and Swain 2022</a>
Ocean Acidification	Decrease in pH, increase in pCO <sub>2</sub>	Greater projected change than previous projections	The acidity of California waters has increased by 60% (decrease of 0.21 pH) since 1895, a faster rate than previously thought. pH of California waters could decrease an additional 40% below 1995 levels by 2050.	<a href="#">Gruber et al. 2012</a> <a href="#">Osborne et al. 2020</a>
Species Range Shifts	Expected northward shift of key species	Previously projected change already being observed. Greater projected change than previous projections.	Species have been observed moving generally northward and deeper, more quickly than previously anticipated. MHWs led to unprecedented rapid and extreme shifts.	<a href="#">Poloczanska et al. 2013</a> <a href="#">Sandford et al. 2019</a> <a href="#">Lonhart et al. 2019</a> <a href="#">Pinsky et al. 2020</a>
Phytoplankton Community	Shift in dominant taxa from larger species to smaller species	Previously projected change already being observed. Greater projected change than previous projections.	A shift in the phytoplankton community towards smaller species was observed during the 2013-2016 heatwave and is seen as a possible glimpse into future conditions. Shifts towards domination of the zooplankton community by smaller species has also been observed and is expected under future conditions.	<a href="#">Fisher et al. 2015</a> <a href="#">Cavole et al. 2016</a> <a href="#">Sandford et al. 2019</a>

Climate Hazard	Trend from 2010 report	Change in projected trend since 2010	Explanation of change in projection	Supporting Literature
Human impacts	Climate impacts will be compounded by human impacts	Previously projected change already being observed. Likely to be greater change than previously projected.	Expected to continue and likely to increase. Sharp example is the record whale entanglement within Monterey Bay in 2016 resulting from an intersection of heatwave-driven impacts on upwelling, a HAB triggered by the heatwave, and the Dungeness crab fishery.	<a href="#">Santora et al. 2020</a>
Deoxygenation	Not included in 2010 report as this was not a widely-known climate impact at the time		Oxygen concentrations in deep waters off California have dropped by 20% since 1980. Oxygen levels in deep waters could drop below the range of natural variability between 2030 and 2060. Expected to be exacerbated by upwelled water that is progressively lower in oxygen due to climate-driven changes in oxygen supplies to deep waters globally.	<a href="#">Bograd et al. 2015</a> <a href="#">Long et al. 2016</a> <a href="#">Ito et al. 2017</a> <a href="#">Breitbart et al. 2018</a> <a href="#">Howard et al. 2020</a> <a href="#">Pozo-Buli et al. 2021</a>

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## Appendix C. Climate Vulnerability Revision Survey

Q1: Using your expert opinion, the 2022 climate science update, and any other supporting literature, have climate projections and projected impacts to your resource changed significantly enough in the past 15 years to warrant a revision of the 2015 assessment?

Q2: Using your expert opinion, the summarized Status and Trend information from the Sanctuary Condition Reports and any other supporting literature, has the condition of the resource changed sufficiently enough since 2010 to warrant a revision of the 2015 assessment?

Q3: In your expert opinion, and in light of your responses to Q1 and Q2, do the overall rankings of vulnerability (available at the top of your resource's 2015 vulnerability assessment) need to be revised to reflect the current available knowledge? (i.e. has new research been conducted or information come to light that changes our perception of the resource's vulnerability?)

Q4: How confident are you in your responses to this survey on a scale from 1-5?

## Appendix D. Vulnerability scores for all resources

<b>Species</b>	<b>2014 Score</b>	<b>2014 Adjusted<sup>24</sup></b>	<b>2023 Score</b>	<b>Change</b>
American Dune Grass	3.77	6.27	N/A	N/A
Ashy Storm Petrel	2.86	4.13	4.13	0.00
Black Rail	3.05	4.30	4.30	0.00
Blue Rockfish	0.65	1.99	2.11	0.13
Blue Whale	2.56	5.06	5.28	0.23
Brandt's Cormorant and Common Murre	1.81	3.12	3.12	0.00
California Mussel	1.71	3.76	3.87	0.12
Cassin's Auklet	1.83	3.10	4.00	0.90
Copepod	1.60	4.10	4.10	0.00
Coralline Algae	1.41	2.91	3.31	0.40
Gaper Clam	2.25	4.31	N/A	N/A
Hydrocoral/Sponge	1.56	3.13	3.07	-0.06
Krill	0.14	2.64	2.79	0.15
Mole Crab	1.02	3.41	3.41	0.00
Northern Anchovy	1.10	2.74	3.04	0.30
Ochre Seastar	1.50	3.55	3.75	0.20
Olympia Oyster	2.39	4.52	4.52	0.00
Oyster Catcher	4.02	6.32	6.32	0.00
Pacific Herring	1.48	3.32	3.91	0.59
Pacific Sardine	1.20	2.87	3.59	0.72
Pigeon Guillemot, Tufted Puffin	1.51	2.78	2.78	0.00
Pteropod	3.43	5.93	6.40	0.48
Purple Urchin	1.24	2.41	3.25	0.84
Red Abalone	2.26	3.76	5.16	1.40
Red Urchin	1.24	2.41	3.34	0.93

<sup>24</sup> The 2014 scores were adjusted by removing the 0.5 weighting for exposure, in order to compare with the newly revised 2023 scores.

<b>Species</b>	<b>2014 Score</b>	<b>2014 Adjusted<sup>24</sup></b>	<b>2023 Score</b>	<b>Change</b>
Sea Palm	2.62	4.62	4.98	0.36
Southern Sea Otter	1.87	3.62	4.08	0.45
Tidewater Goby	2.50	4.00	4.00	0.00
Western Snowy Plover	2.98	4.98	5.48	0.50
Widow Rockfish	1.13	2.73	2.73	0.00

<b>Habitats</b>	<b>2014 Score</b>	<b>2014 Adjusted<sup>25</sup></b>	<b>2023 Score</b>	<b>Change</b>
Beaches/Dunes	3.08	5.33	5.33	0.00
Coastal Cliffs	1.50	2.64	2.64	0.00
Estuaries	2.62	4.78	5.04	0.26
Kelp Forest	0.28	1.55	4.69	3.14
Nearshore soft bottom	1.50	3.50	3.72	0.22
Offshore rocky reefs	0.46	1.58	2.86	1.28
Pelagic	1.05	3.11	3.18	0.06
Rocky Intertidal	2.02	4.06	4.73	0.67

<b>Ecosystem services</b>	<b>2014 Score</b>	<b>2014 Adjusted<sup>26</sup></b>	<b>2023 Score</b>	<b>Change</b>
Carbon Storage	3.17	5.67	5.50	-0.17
Flood and Erosion Protection	3.97	6.47	5.55	-0.92
Food Production	2.05	4.05	N/A	N/A
Recreation and Tourism	1.20	3.20	N/A	N/A
Water Quality	2.55	4.55	N/A	N/A

<sup>25</sup> The 2014 scores were adjusted by removing the 0.5 weighting for exposure, in order to compare with the newly revised 2023 scores.

<sup>26</sup> The 2014 scores were adjusted by removing the 0.5 weighting for exposure, in order to compare with the newly revised 2023 scores.





NATIONAL MARINE  
**SANCTUARIES**

AMERICA'S UNDERWATER TREASURES

Informational Item

# San Francisco-Pacifica Exclusion Zone Summary of the Bren School Report

Research and Conservation Seats

August 2<sup>nd</sup>, 2024

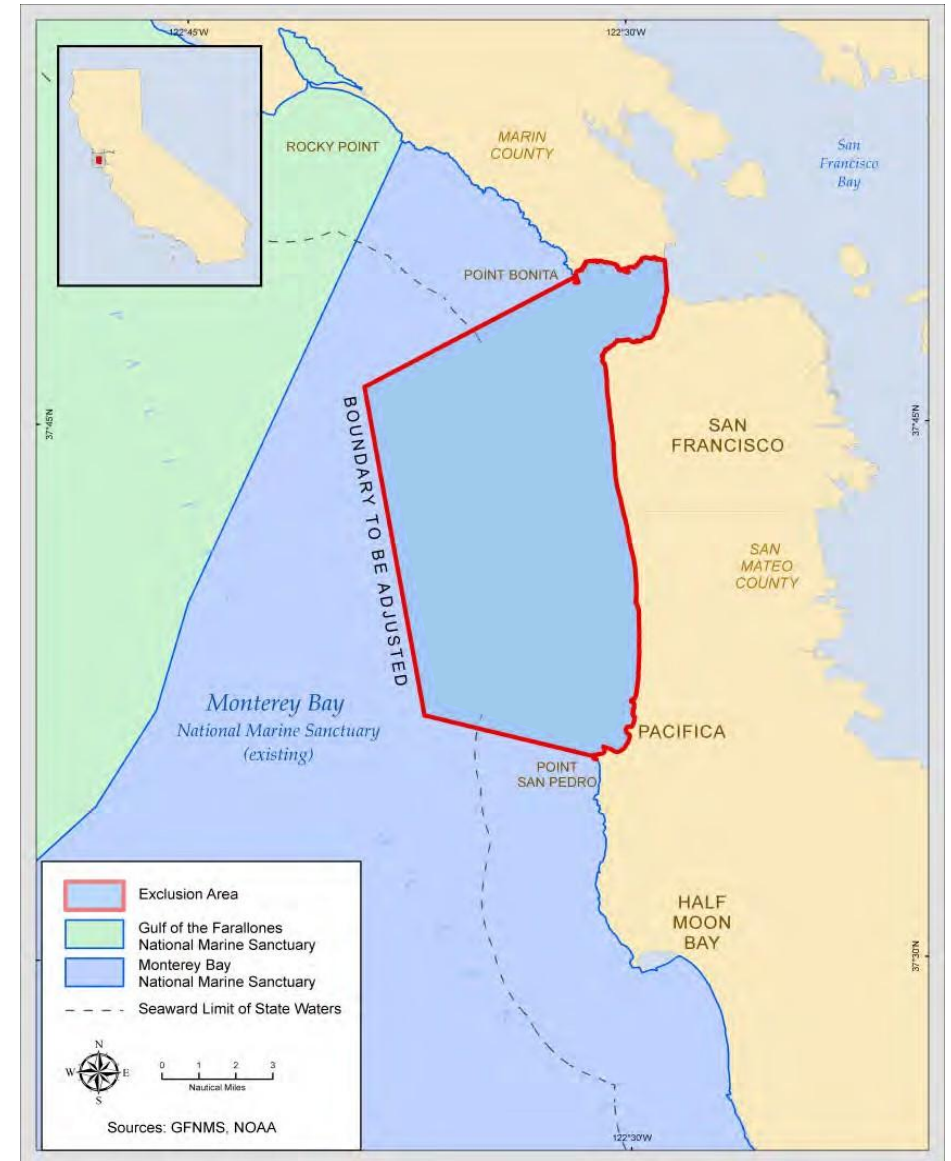


# History of the SF-Pacifica Exclusion Area

- The San Francisco-Pacifica Exclusion Area was omitted from MBNMS in 1992 due to issues with sewer overflows, dredged material disposal, and high vessel traffic.
- Renewed Interest: Improved conditions in the Exclusion Area, required analysis from the 2008 mgmt. plan, and stakeholder support driving reconsideration.
- Stakeholder Support: Stakeholders support the incorporation, recognizing the ecological value of the area and ongoing improvements in management practices.
- Potential Management: If incorporated, the Exclusion Area would likely be managed by GFNMS, which currently oversees the northern region of MBNMS.

# The report addressed the following:

1. Do the three factors that resulted in the San Francisco-Pacifica Exclusion Area's omission from MBNMS still present barriers to a proposed Sanctuary expansion?
2. Does the San Francisco-Pacifica Exclusion Area fulfill the sanctuary designation criteria in the National Marine Sanctuaries Act?



# Combined water/sewer discharge

## **The issue:**

- Concerns about sewer overflows from San Francisco led to the Exclusion Area's omission from MBNMS.
- San Francisco's sewer system (CSS) treats storm water runoff, domestic sanitary flow, and industrial wastewater together.

## **Infrastructure updates:**

- Water Pollution Control Plant upgraded: primary treatment up to 65 MGD and secondary treatment up to 43 MGD.
- Westside Wet Weather Facilities improved for larger volumes to reduce the number of Combined Sewer Discharges (CSDs).

# Combined water/sewer discharge

## Coastal Analysis:

- Post-1993 updates reduced the average annual number of CSD events from 50 to 7.
- Fecal indicator bacteria (FIB) levels, such as Total Coliform and E.coli, decreased significantly post-update, *while Enterococcus levels showed a significant increase.*

## Offshore Analysis:

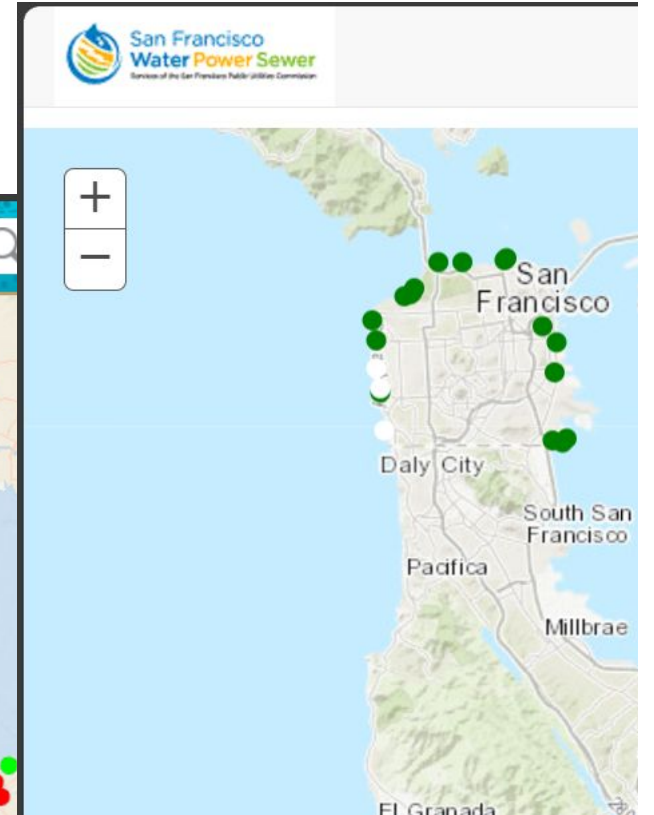
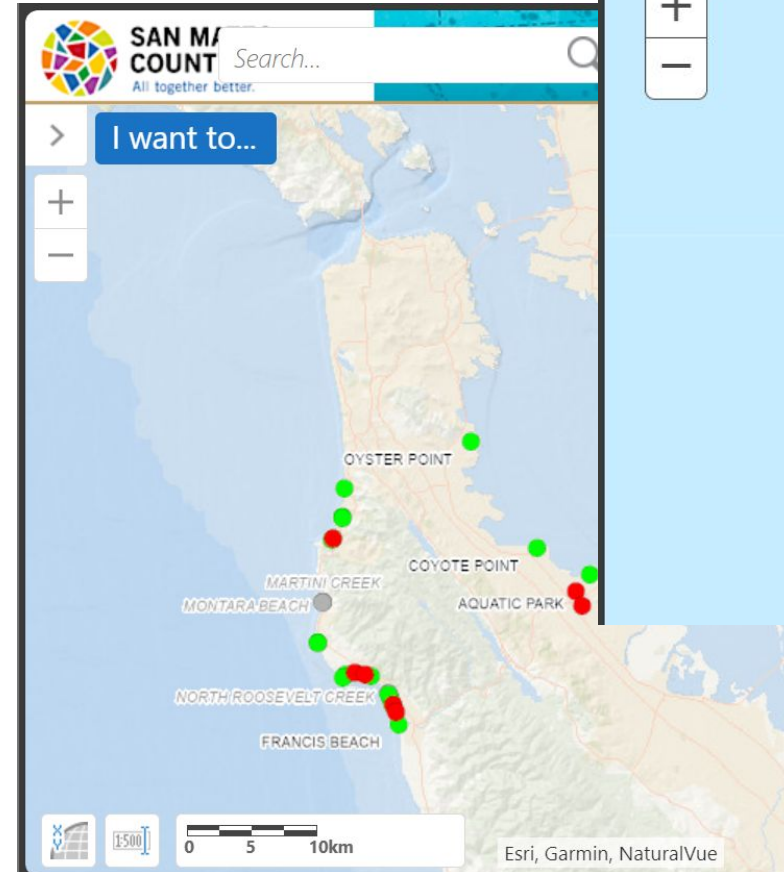
- SFPUC's monitoring from 1997 to 2008 found no significant negative impacts on sediment quality, benthic infauna community structure, epibenthic and demersal fish community structure, or bioaccumulation of contaminants.
- Secondary treatment at the Oceanside WPCP reduced the likelihood of eutrophication and other adverse impacts.

# Combined water/sewer discharge

SEE OUR REAL-TIME MAP OF SAN FRANCISCO BEACH WATER QUALITY

## Recommendations:

- Due to the lack of identified impacts from current discharges and the high cost of further reducing wet weather discharges, GFNMS should consider exempting the west side's Water Pollution Control System from discharge prohibitions.
- Collaboration between SFPUC and GFNMS is recommended to balance marine resource protection and wastewater control services.



# Dredged material

## The issue:

- Placement of dredged material was a reason for excluding SF-Pacifica from MBNMS.
- *This reason should have been invalid since dredging occurs in other sanctuaries (Monterey Bay and Stellwagen Bank).*

## Barrier Analysis:

- Dredging must continue to maintain safe vessel transit to San Francisco and Oakland.
- There is enhanced oversight, better practices, and reduced impacts since 1996.
- Placement sites have similar sediment characteristics, minimizing impact.
- Dredged material from MSC is largely non-toxic (98% sand, minimal organic carbon).

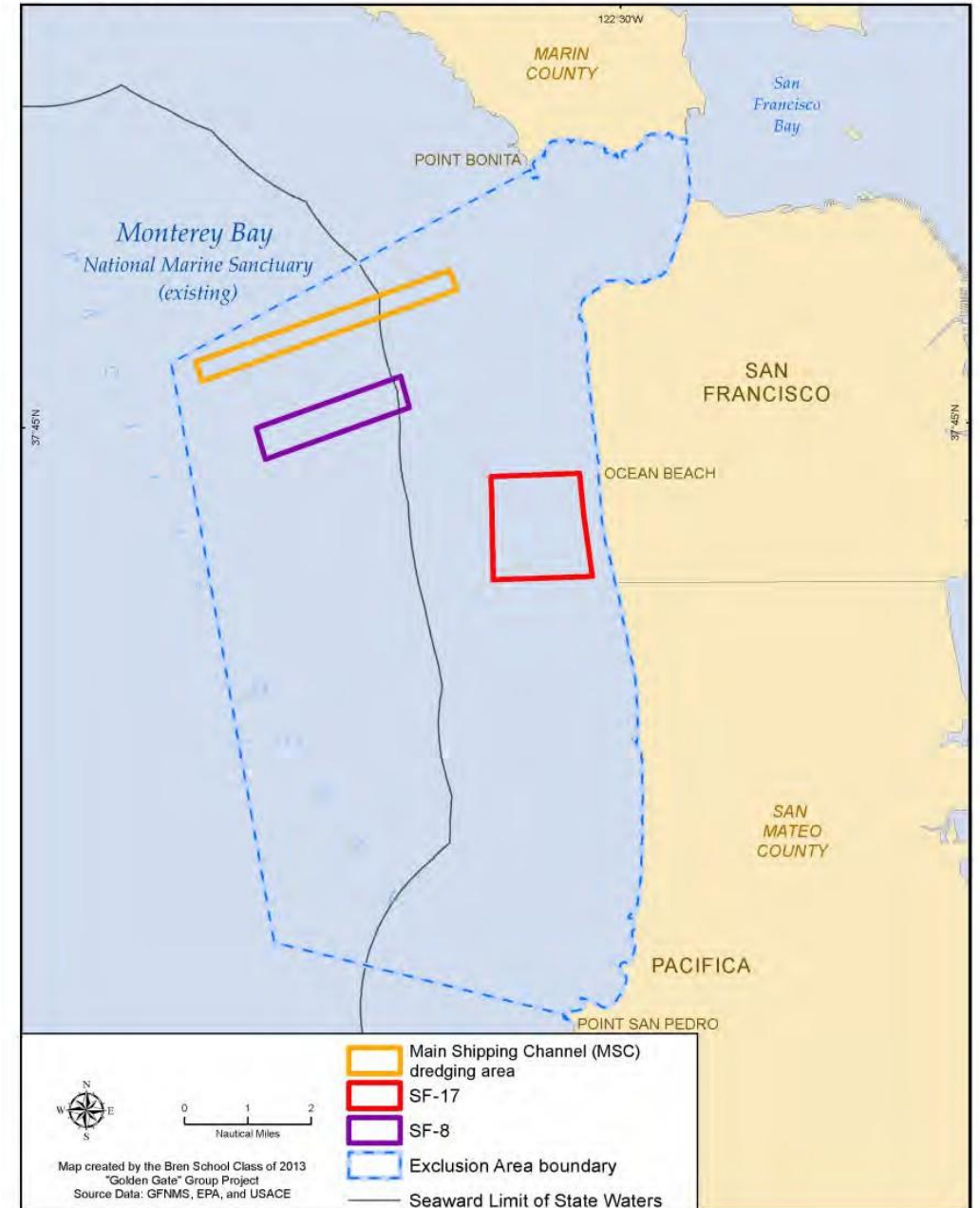


# Dredged material

## Recommendations:

- Consider exemptions for current and future sediment management projects to ensure minimal environmental impact.
- Align NOAA's and ONMS's policies to support beneficial reuse of dredged material.
- Maintain communication with stakeholders to anticipate and manage coastal erosion and sediment management needs.

## Dredging Activities in the San Francisco-Pacifica Exclusion Area



# High vessel traffic

## The issue:

- High vessel traffic in the Main Shipping Channel (MSC) was another reasons to exclude the SF-Pacifica area from MBNMS.
- *Vessel traffic in the MSC is not a barrier since traffic lanes are present in multiple sanctuaries (SW, CI, CB, GF, MB).*
- *The MSC's fan-out point in MBNMS sees comparable vessel traffic, showing that traffic volumes do not preclude designation.*

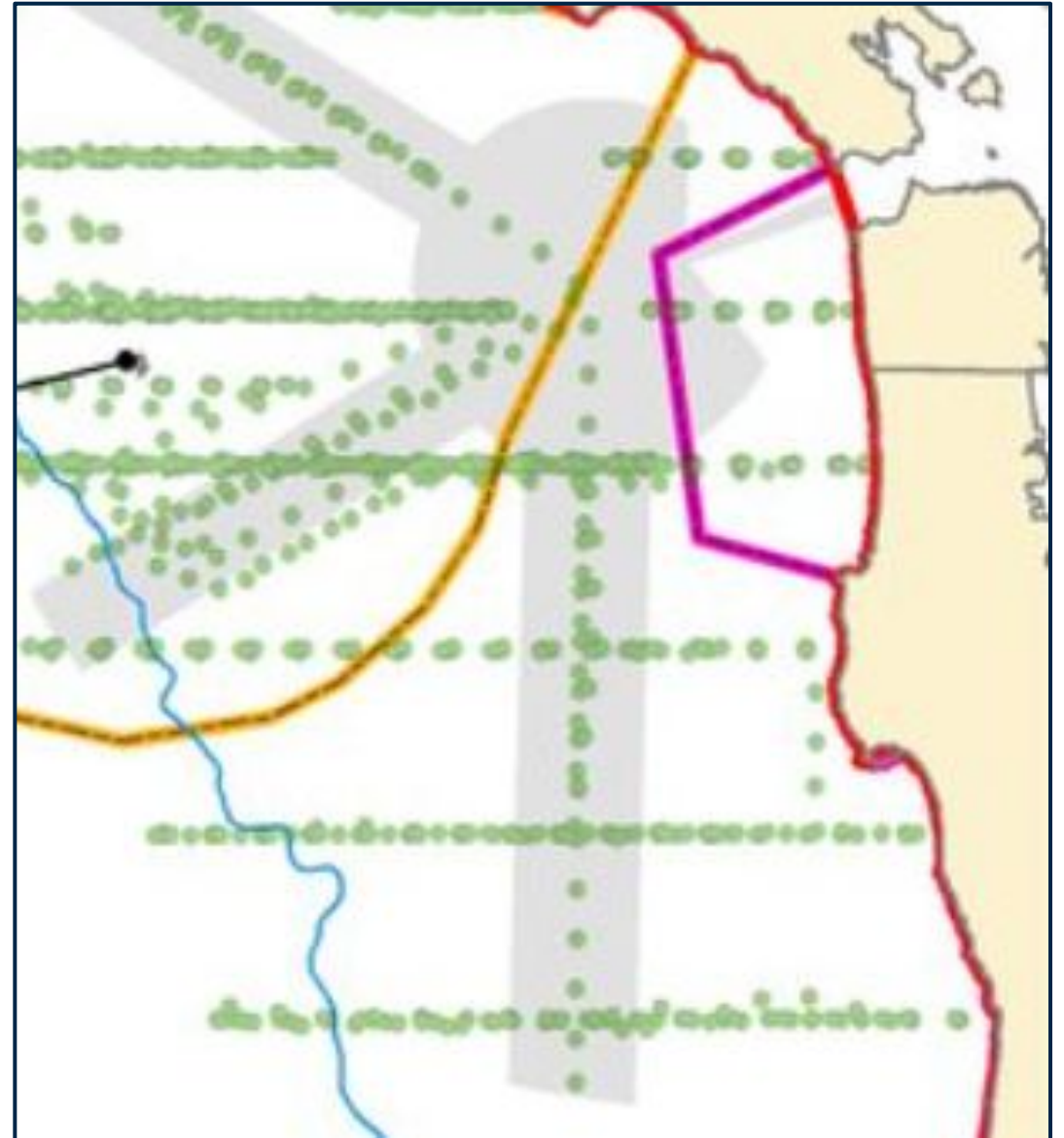
## Potential challenge

- Existing regulations on vessel discharges may conflict with the 2012 California No Discharge Zone (NDZ) regulations.
- Incorporating the Exclusion Area into MBNMS could eliminate the last unregulated discharge area near the coast.

# High vessel traffic

## Recommendations

- The MSC does not pose a barrier to the proposed sanctuary expansion. Other sanctuaries with show similar traffic.
- Potential conflicts with NDZ regulations need coordinated management between the Sanctuary and EPA to mitigate adverse effects.



# Ecological Significance

The Exclusion Area meets emergent criteria for sanctuary designation:

- High productivity due to seasonal upwelling.
- Important feeding and breeding habitat for marine mammals and seabirds.
- Presence of endangered species and high diversity of fish.

The area's ecological qualities meet the National Marine Sanctuaries Act (NMSA) standards for significance, contributing to biological productivity, maintaining ecosystem structure, and supporting critical habitats and species. This warrants its designation as a sanctuary.

# Scientific Significance

The Exclusion Area fulfills emergent criteria for scientific value under the NMSA:

- Due to existing research projects and the area's natural resources.
- While no major facilities are within the Exclusion Area, numerous institutions conduct significant research nearby (5+ universities, 3+ NGOs, State).
- Exclusion Area's scientific qualities align with the NMSA standards, emphasizing its importance for ongoing and future research initiatives

Overall, the Exclusion Area's scientific qualities align with the NMSA standards, emphasizing its importance for ongoing and future research initiatives

# Recreational Significance

San Francisco contributed 20% to state-wide ocean tourism and recreation (2005-2010). The Exclusion Area is located within SF and directly influences this economic contribution.

The GG Bridge and GG National Recreation Area (GGNRA), over 14 million visitors annually. Ocean Beach, within the Exclusion Area, most visited beach 300,000 visitors annually.

Recreational activities in the Exclusion Area include Beach Activities, Hiking and Scenic Viewing, Surfing, Wildlife Viewing, Fishing, Boating and Kayaking, Aviation

The Exclusion Area qualifies for sanctuary designation due to its recreational significance.

# Human Use Significance

The Exclusion Area meets emergent criteria for human use significance:

- Growing human activity intensity.
- Increasing accessibility to an urban population.
- Presence of various recreational activities.

While the Exclusion Area's commercial fishing does not represent the most significant human use, it does have regional importance, particularly for California halibut.

The increasing intensity of human activity and diverse recreational uses support the area's eligibility for sanctuary designation based on human use significance.

# Historical, Cultural and Archaeological Sig.

The Exclusion Area shares commonalities with other historically significant sanctuaries:

- Historical resources may be present due to rich cultural history tied to Paleo-Indians, Native Americans (Coast Miwok and Ohlone tribes), and European explorers.
- Historically Focused Sanctuaries (e.g., Monitor and Thunder Bay) and contains >60 shipwrecks from 1849 to 1950 that contribute to NOAA's Maritime Heritage Program.

The Exclusion Area's historical resources, including shipwrecks and potential Native American artifacts, align with the criteria for sanctuary designation, indicating its historical significance. Sanctuary designation would offer federal protection, facilitate research and the discovery of new cultural artifacts.



# Educational Significance

The Exclusion Area shares commonalities with other sanctuaries regarding educational value:

- West Coast Sanctuaries: Existing hands-on marine science activities for school-age children, beach monitoring, public lectures, field trips, and citizen science programs can be expanded to increase public awareness of sanctuary waters for residents and visitors of San Francisco and Marin counties
- Historically Focused Sanctuaries (Monitor, Thunder Bay): The Exclusion Area's shipwrecks could enhance historical education components.

The Exclusion Area's would significantly enhance educational opportunities, making it eligible for sanctuary designation based on educational significance.

# Adequacy of Existing Management

Multiple federal, state, and local agencies have jurisdiction over portions of the Exclusion Area. These agencies include Federal Agencies, State Agencies, Local Agencies.

## Benefits of Sanctuary Management

- Comprehensive and Coordinated Management: Facilitating better communication and collaboration across jurisdictional boundaries.
- Enhanced Resource Protection: Ensuring consistent protection of ecological, recreational, and historical resources.

The area already has recognition from at least two existing designations (CCNM and GGNRA), supporting its eligibility for sanctuary status.

# Ease of Management

The National Marine Sanctuaries Act (NMSA) requires that a sanctuary be of a “size and nature that permits comprehensive and coordinated conservation and management

- The Exclusion Area’s size, coastal proximity, and adjacency to other sanctuaries make it manageable (77 nm<sup>2</sup>, 20 miles of coastline, adjacent to SF).
- The current involvement of GFNMS and established management plans support ease of management and coordination with other agencies.
- GFNMS currently manages aspects of the Exclusion Area through programs like Beach Watch and oil spill surveys.

Expansion aligns with previous expansions’ criteria, indicating that it meets NMSA requirements for comprehensive and coordinated conservation and management.

# Summary

The Exclusion Area should be added to the National Marine Sanctuary System.

- 1. Ecological Significance:** The area supports diverse marine life, including threatened and endangered species, and features important habitats and high productivity.
- 2. Educational and Scientific Value:** The presence of ongoing research projects and educational programs demonstrates significant potential for further scientific and educational activities.
- 3. Recreational Importance:** The area offers numerous recreational opportunities, with increasing human activity and accessibility to urban populations.
- 4. Historical and Cultural Significance:** There are numerous historical and cultural resources, including shipwrecks and potential archaeological artifacts.
- 5. Management Feasibility:** The area is manageable in size, adjacent to existing sanctuaries, and would benefit from coordinated and comprehensive management. ***The existing challenges related to dredging, wastewater discharge, and vessel traffic do not present insurmountable barriers and can be addressed through collaborative management strategies.***

# Thank you to:

## **ANALYZING THE SUITABILITY OF THE SAN FRANCISCO-PACIFICA EXCLUSION AREA FOR INCORPORATION INTO THE NATIONAL MARINE SANCTUARY SYSTEM**

CAREY BATHA, JENNA DRISCOLL, EMMA FREEMAN,  
CAMERON GRAY, HUGO HOFFMAN, SARAH PIERCE





Point Blue  
Conservation  
Science

# Thank You

**COVER LETTER**

**Support Inclusion of the San Francisco-Pacific Exclusion Area  
into the National Marine Sanctuary System**

August 2, 2024

Maria Brown,  
Sanctuary Superintendent

Dear Superintendent Brown,

By this letter, the Sanctuary Advisory Councils for Greater Farallones and Cordell Bank National Marine Sanctuaries are recommending that the Greater Farallones and Cordell National Marine Sanctuaries (GF-CBNMS) share the attached resolution with the West Coast Regional Office and the National Office of the National Marine Sanctuaries for consideration.

Sincerely,

---

Jaime Jahncke, Chair  
GFNMS Advisory Council

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Jeff Dorman, Chair  
CBNMS Advisory Council

*The councils are an advisory body to the sanctuary superintendent. The opinions and findings of this letter/publication do not necessarily reflect the position of the sanctuaries and the National Oceanic and Atmospheric Administration*

## **PROPOSED RESOLUTION**

### **Support Inclusion of the San Francisco-Pacifica Exclusion Area into the National Marine Sanctuary System**

Whereas, the protection and sustainable management of significant marine areas are priority issues for the National Oceanic and Atmospheric Administration (NOAA) and the Office of National Marine Sanctuaries (ONMS).

Whereas, the San Francisco-Pacifica Exclusion Area, located adjacent to the Monterey Bay National Marine Sanctuary (MBNMS), possesses nationally significant ecological, historical, cultural, recreational, and educational qualities that align with the criteria for sanctuary designation under the National Marine Sanctuaries Act (NMSA).

Whereas, the Exclusion Area's oceanographic characteristics and high biological productivity contribute to the health and diversity of marine life, including important species such as seabirds, marine mammals, fish, and invertebrates, supporting the broader ecosystem of MBNMS and surrounding sanctuaries.

Whereas, the Exclusion Area has a rich historical and cultural heritage, including numerous shipwrecks and significant archaeological sites, which provide valuable educational and research opportunities.

Whereas, the Exclusion Area supports diverse recreational activities such as beach-going, surfing, hiking, wildlife viewing, fishing, and boating, contributing to the local economy and enhancing public engagement with marine conservation.

Whereas, existing management of the Exclusion Area is fragmented and lacks comprehensive coordination, highlighting the need for integrated and coordinated management to effectively protect its resources and address emerging threats.

Whereas, improvements in infrastructure and management practices have addressed previous concerns related to dredged material placement, combined sewer discharges, and vessel traffic, which were reasons for excluding the area from MBNMS in 1992.

Whereas, the incorporation of the Exclusion Area, as a contiguous or non-contiguous part of GFNMS to be decided the Sanctuary managers or the public, will facilitate a comprehensive and



coordinated conservation efforts, leveraging existing relationships and management plans to enhance the protection of its significant resources.

Whereas, incorporating the Exclusion Area into GFNMS will help achieve the 50% reduction in whale ship strike mortality set by the GFNMS in response to shifting whale distributions, climate change, and marine heat waves.

Therefore be it resolved, that the Sanctuary Advisory Councils for Greater Farallones and Cordell Bank National Marine Sanctuaries hereby jointly recommends that:

1. NOAA and ONMS should proceed with the process of incorporating the San Francisco-Pacific Exclusion Area into GFNMS
2. GFNMS collaborates with MBNMS and other relevant federal, state, and local agencies to ensure comprehensive and coordinated management of the Exclusion Area, addressing existing management gaps and leveraging existing programs and initiatives.
3. NOAA should allocate resources and support for the development of a management plan for the Exclusion Area as part of the ongoing process to update the GFNMS management plan, incorporating regulations and guidelines to protect its ecological, historical, cultural, recreational, and educational resources.

By taking these steps, we can ensure the protection and sustainable management of the San Francisco-Pacific Exclusion Area, contributing to the health and resilience of the greater Gulf of the Farallones marine ecosystem.

*The councils are an advisory body to the sanctuary superintendent. The opinions and findings of this letter/publication do not necessarily reflect the position of the sanctuaries and the National Oceanic and Atmospheric Administration*