White Paper

Recommendations and Outcomes from the Sanctuary Advisory Council Symposium on Connections between the San Francisco Bay and Greater Farallones National Marine Sanctuary

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Presented to Maria Brown, Superintendent, Greater Farallones National Marine Sanctuary

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I. Purpose of the White Paper

The purpose of this white paper is to:

1. Provide written documentation of the outcomes and recommendations emerging from the Symposium on Connections between the San Francisco Bay and Greater Farallones National Marine Sanctuary (the symposium) held on October 16, 2019, for the benefit of the Greater Farallones National Marine Sanctuary (GFNMS) Advisory Council (SAC).
2. Identify opportunities for California Sea Grant and the National Oceanographic and Atmospheric Administration (NOAA) to provide capacity to actions related to symposium recommendations for the sanctuary.

II. Background

The SAC advises the sanctuary superintendent on priority issues, connects the public with the sanctuary, and provides opportunities for information exchange on issues affecting the health of the sanctuary ecosystem. It holds four public meetings and one SAC retreat per year. Each year, the SAC retreat focuses on a timely sanctuary topic that the SAC seeks to learn more about.

In 2019, the SAC retreat focused on connections between the sanctuary and outer coast of California, and the San Francisco Bay (SFB), including oceanographic, anthropogenic, and wildlife-related conditions at the intersection of the two bodies of water. The SAC identified this topic with the goal of learning more to further discussions and develop potential recommendations on management of the sanctuary waters near the sanctuary-SFB intersection. On October 16, 2019, the SAC co-hosted the Symposium on Connections between the San Francisco Bay with San Francisco State University's Estuary and Ocean Science Center (EOS Center) and National Oceanographic and Atmospheric Administration's San Francisco Bay and Outer Coast Sentinel Site Cooperative (the cooperative)[1] (symposium program, Appendix A). The symposium, held at the EOS Center, was attended by SAC members, San Francisco State University students and faculty, Bay Area colleagues, and members of the public.

This white paper summarizes the presentations and recommendations[2] emerging from the symposium.

III. Symposium Goals and Outcomes

The overall goal of the symposium was to bring together experts in their fields related to the intersection of the sanctuary and SFB and to bring attention to issues of resource protection, research, and human use of that area.

The symposium consisted of three panels of experts covering topics including wildlife traveling between and living at the intersection of the sanctuary and SFB (habitat, behaviors, threats); oceanographic connections and influences between the sanctuary and SFB (ocean acidification, hypoxia, nutrients, and water movements); and some of the commercial and recreational activities taking place at the intersection of the sanctuary and SFB (industries, impacts, and communities).

[1]The goal of the Cooperative (https://oceanservice.noaa.gov/sentinelsites/welcome.html) is to connect NOAA and NOAA partners' data, tools, projects, and activities locally with NOAA resources nationally and with regional California partners, government agencies, and organizations, to improve understanding of and ability to respond to sea level rise. The Cooperative is made up of the NOAA Office of Coastal Management, the San Francisco Bay National Estuarine Research Reserve, the Bay Conservation and Development Commission, the Greater Farallones National Marine Sanctuary, and California Sea Grant. There are currently five Cooperatives in the NOAA Sentinel Site Cooperative Program: Chesapeake Bay, Hawaii Islands, North Carolina, Northern Gulf of Mexico, and San Francisco Bay.

[2]Recommendations summarized in this paper do not necessarily reflect the opinions of the symposium speakers individually or as a group.

Opening and closing remarks were provided by Maria Brown, Sanctuary Superintendent; and Karina Nielsen, EOS Executive Director & Professor of Biology. (Symposium program, Appendix A; symposium video recording, Appendix C).

Below, we have identified the key points that emerged from presentations and discussions at the symposium. While not comprehensive, these outcomes can be used to inform management of the sanctuary and SFB with consideration for influences each has on the other and for the threats present at their intersection.

A. Climate Change Impacts

Climate change impacts were a thread that emerged throughout the symposium, including issues related to sea level rise, changing ocean temperatures, presence of domoic acid, ocean acidification, and prey availability.

Wildlife panelists identified prey availability as a major concern for many marine species, noting that prey availability has been linked to changing ocean temperatures related to climate change. Two specific examples were discussed at the symposium: seabirds, many of which use the area at the sanctuary-SFB intersection for foraging; and pinnipeds that live in and travel between the sanctuary and SFB. Surf Scoters, for example, are one of the most abundant seabirds in SFB during winter months, but their population has declined over the last few decades. It's unclear why that's happening but speakers pointed to possible causes including breeding habitat decline and/or impacts to prey availability. For pinnipeds, prey availability can have significant impacts on populations. It was pointed out in the symposium that California sea lions have reportedly experienced dramatic shifts in reproductive success and distribution during El Niño years when fish prey populations are impacted.

Issues of climate-related disease were also identified as a threat for pinnipeds. When asked whether there have been correlations between domoic acid in pinnipeds and the increase in strandings, panelists stated that during El Niño years or other warm water events, typically an increase in the numbers of California sea lion strandings from domoic acid toxicosis is seen, mostly due to toxic algal blooms. Loss of coastal habitat due to sea level rise may also be a threat to pinnipeds.

Panelists noted that climate-related ocean acidification lowers the pH of the water and makes the conditions for calcifying organisms unfavorable. The sources of acidified waters that lead to ocean acidification exposure in this area are coastal upwelling and increased atmospheric CO_2 from the combustion of fossil fuels. Alongshore winds drive upwelling, bringing cold nutrient-rich, and oxygen-poor waters up from the deep ocean, displacing warmer nutrient depleted coastal waters offshore. This upwelled ocean water is also lower in pH (more acidic) from a combination of natural sources and an additional amount of CO_2 taken up from the atmosphere decades earlier. The additional CO_2 taken up and lower than expected pH of the deep waters has been attributed to human activities that are increasing atmospheric CO_2. As a result, exposure to ocean acidification in the coastal zone is increased when there is an increase in the alongshore winds that drive upwelling. Another source of acidification is diffusion of contemporary atmospheric CO_2 that dissolves into the ocean causing the pH to lower. The additional CO_2 in ocean waters from human activities reduces the pH and leads to a reduction in the concentration of carbonate ions, and subsequently, aragonite saturation. Most calcifying organisms form aragonite when they build their shells and other calcified structures from the essential building blocks of carbonate and calcium ions. When aragonite saturation is low, it gets harder for organisms to build and maintain calcified structures, including shells. The acidified waters from the ocean travel into the SFB, typically at depth, and combine with freshwater inflow from the upper estuary in dynamic zones of mixing and biogeochemical activity where nutrients, pH and oxygen levels may be further modified, sometimes resulting in additional acidification and oxygen drawdown.

According to the symposium speakers, salinity, pH, oxygen, and temperature are changing in SFB. SFB outflow also influences the properties of waters in the sanctuary. The speakers indicated there is a need to improve long-term monitoring of carbonate chemistry and oxygen dynamics in general, and to study these dynamics at the intersection of the sanctuary and SFB.

B. Other Anthropogenic Threats to Wildlife

Symposium presenters spoke about many types of animals that travel through or use the marine ecosystem at the intersection of the sanctuary and SFB, and identified threats these animals might face including pollution, entanglement, ship strikes, oil spills, and habitat loss.

During the Oceanography Panel, speakers noted that river plumes leave SFB and enter the coastal waters of the sanctuary. These river plumes, also known as "microplastic highways to the ocean," transport freshwater, nutrients, sediments, plankton, and pollutants. These plumes likely influence marine mammals and other marine life. A focus of current research on these plumes is to determine the effects of winds, river discharge, topography, and seasonal variability, as well as influences of long term oceanic processes.

Several dozen seabird species use various sanctuary and SFB habitats throughout the year. Symposium speakers focused on the Common Murre, Brandt's Cormorant, Western Gull, and Surf Scoter, and identified threats these seabirds may face. There was a large decline in Common Murres, for example, in the 1980s due to a rise in the gillnet fishery. Panelists noted that it is estimated that tens of thousands of Common Murres were killed in gillnets each year at that time. The population is now in recovery after a decline in gillnet use, however oil spills remain a continued and major threat to Common Murres and other seabirds.

Panelists noted that ship strikes to whales are a major threat as large container ships travel to and from major California ports like the one in the SFB. The panel indicated that for the population of humpback whales found in California, the number of whales taken from illegal fishing activities, entanglement, and from ship strikes, is about as many as the population can stand. While whale populations are currently increasing, if these threats also increase, there could be a negative impact to the population.

In the sanctuary, there is a voluntary 10-knot speed limit for commercial ships during peak whale migration season to reduce risk of vessel strikes. At the time of this symposium in October 2019, compliance with the 10-knot speed is around 50%. Panelists noted that there is concern that some large whales are coming closer to shore looking for food, putting them at higher risk for encounters with ships; that ship traffic in the outer coast is still moving over high traffic migration zones for whales; and that cargo ships, ferries, and recreational boats are known to travel faster than 10-knots in SFB where there also may be whales present. Recommendations to mitigate risk include reducing the co-location of ships and whales, continued efforts to achieve 100% participation of voluntary speed reduction in GFNMS, and lower speed limits into SFB.

California sea lions that breed on the Farallon Islands, and travel and forage within the sanctuary and SFB, are at risk from a number of threats. Panelists noted that each year, The Marine Mammal Center treats California sea lions for domoic acid toxicosis, malnutrition, entanglements, and other wounds. Chemicals in the water may also be a threat. When asked whether accumulation of harmful chemicals like PBDE (polybrominated diphenyl ethers) is an issue for pinnipeds in this area, panelists said scientists don't have a good understanding of contaminant levels in pinnipeds, and that more data is needed.

Commercial fisheries in SFB include California Halibut and Pacific Herring, which spawn in SFB. Recreational fisheries in SFB include California Halibut, Striped Bass, White Sea Bass, and Leopard

Shark. The SFB influences fisheries through changes in tides, freshwater flow, and rainfall. The SFB in turn influences fish populations on the outer coast (e.g., tidal and rainfall influence). It was noted that 75-80% of the Salmon caught in the outer coast comes through the SFB, coming out and back to the Sacramento River system. Salmon are dependent on freshwater outflows from rivers, coming out to the ocean as smolts and going back as adults. Panelists indicated that 40% of the Salmon caught in Oregon are from the Sacramento River system.

Vessel traffic and plastic pollution (particularly around Fisherman's Wharf) in the SFB were noted as threats to fish.

C. Data Gaps and Research Needs

The Gulf of the Farallones (GoF), located within the sanctuary, is a hotspot for productivity. The two sources for nutrients in the GoF are coastal upwelling, which supplies nitrate; and outflow from the SFB river plume (low salinity surface buoyant plume), which supplies silicate and anthropogenic ammonium (NH_4; mainly from runoff that can cause acidification). Wastewater treatment plants are sources of ammonium that is exported out of the SFB, along with some nitrate. It was indicated that more information is needed on how these ammonium sources impact the oceanography of this area, and wildlife. Additionally, the Oceanography Panel noted that more research needs to be done to understand the impact of wastewater from SFB on the outer coast water, particularly the acidity and carbon content of the wastwater. The carbon dioxide in the atmosphere around urban areas is a local cause of increased acidification. Panelists stated that there are multiple layers to the story and that some of them are only beginning to be addressed.

Phytoplankton is key to the marine food web. After absorbing nutrients, phytoplankton are then eaten by zooplankton, which are then eaten by fish and so forth. Symposium speakers stated that higher levels of ammonium can result in low levels of phytoplankton as it can repress use of nitrate by the cells. Little phytoplankton productivity or nutrient data is available for the GoF or SFB, especially regarding SFB river plume. The impacts on organisms from these oceanographic stressors is a main consideration. The Oceanography Panel indicated that we have a long way to go in addressing those impacts and stressors, and more data is needed. They also noted that in general, connections between the central SFB and GoF are relatively understudied, and that more funding is needed to study oceanographic conditions in central SFB and GoF.

Panelists stated that while there is not a lot of data on seabirds using the San Francisco-Pacifica Exclusion Area (SFPEA)[3] near the intersection of the sanctuary and SFB, they noted that it is used regularly by around 15 species including Common Murres, Cormorants, Surf Scoters, and Western Gulls.

When asked about accumulation of harmful chemicals in pinnipeds, panelists noted that we do not have a good understanding of contaminant levels in pinnipeds and that more data is needed.

Lastly, when discussing concerns around invasive species transport by ship, panelists indicated there have been major advancements in reducing the spread of non-native species by ballast water, including better technology, regulations limiting discharge, and permitting requirements; but biofouling is understudied and more research is needed on ways to limit biofouling that can lead to transportation of harmful invasive species (e.g., coating strategies).

[3]The San Francisco-Pacifica Exclusion Area (SFPEA) is a 101-square mile area of ocean along the San Francisco-Pacifica coast that was deliberately omitted from Monterey Bay National Marine Sanctuary (MBNMS) when it was designated in 1992 because several activities occurring within the SFPEA were deemed incompatible with sanctuary status at the time.

IV. Recommendations to the Sanctuary Advisory Council

During the November 13, 2019 SAC meeting, the council heard a presentation from Alyssa Ells, EOS graduate student and GFNMS/Cooperative intern at the time, summarizing the symposium outcomes and synthesizing the following recommendations:

1. Extend the sanctuary's voluntary vessel speed reduction program into the SFB to eliminate ship strikes. Whales are at risk from ship strikes in the outer coast and SFB. Therefore ships should be encouraged to slow in both areas to protect whales.
2. Additional research is needed on the connections between the sanctuary and SFB. Specifically, more funding is needed to support research on the biological and oceanographic interactions of these two bodies of water.
3. Managers should pursue coating strategies for ships to reduce biofouling that can lead to transportation of harmful invasive species.
4. The sanctuary should consider amending its boundaries to close the SFPEA near the intersection of the sanctuary and SFB. This area was identified as an important habitat for several marine species, including endangered humpback whales; as well as an area that should be studied more closely for oceanographic changes and climate impacts.

(Full presentation, Appendix D; November 13, 2019 SAC meeting notes, Appendix E)

Appendix

A. Symposium Program

Symposium on Connections between the San Francisco Bay and Greater Farallones National Marine Sanctuary (GFNMS)

Wednesday, October 16, 2019, 1:30 – 5:00p
Estuary & Ocean Science Center (EOS)
San Francisco Bay Hall
3150 Paradise Dr, Tiburon, CA 94920

1:30 – 1:40p Welcome
Maria Brown, GFNMS Superintendent and Karina Nielsen, EOS Executive Director & Professor of Biology

1:45 – 2:35 Session 1: Wildlife Panel
Discussion of wildlife traveling between, and living at the intersection, of the bay and sanctuary: habitat, behaviors, and threats.
Moderator: Ellen Hines, Estuary and Ocean Science Center
Bill Keener, The Marine Mammal Center
Elizabeth McHuron, University of Washington
Gerry McChesney, U.S. Fish & Wildlife Service

2:35 – 2:45 Break

2:45 – 3:45 Session 2: Oceanography Panel
Discussion of oceanographic connections and influences between the bay and sanctuary with topics including ocean acidification, hypoxia, nutrients, and water movements.
Moderator: John Largier, U.C. Davis, Bodega Marine Lab
Ryan Anderson, Applied Technology and Science
Karina Nielsen, Estuary and Ocean Science Center
Frances Wilkerson, Estuary and Ocean Science Center
Piero Mazzini, Estuary and Ocean Science Center

3:45 – 4:45 Session 3: Human Activities Panel
Discussion of some of the commercial and recreational activities taking place at the intersection of the bay & sanctuary: industries, impacts, and communities.
Moderator: Abby Mohan, Silvestrum Climate Associates
Sam Cope, Estuary and Ocean Science Center
John Berge, Pacific Shipping Merchant Association
Chrissy Edmiston, Estuary and Ocean Science Center
Sarah Bates, F/V Bounty, Commercial Fishing

4:50 – 5:00 Closing Remarks
Maria Brown, GFNMS Superintendent and Karina Nielsen, EOS Executive Director & Professor of Biology

NATIONAL MARINE SANCTUARIES
GREATER FARALLONES

EOS center

SENTINEL SITE COOPERATIVES

B. Symposium Notes

Greater Farallones National Marine Sanctuary (GFNMS) is 3,295-square miles of federally-protected ocean and coastal waters, bays, and estuaries along the northern and central California coasts, and 1,400 square miles in the northern region of the Monterey Bay National Marine Sanctuary from Rocky Point in Marin County to Santa Cruz County.

San Francisco Bay is a shallow estuary of approximately 550 square miles of freshwater that flows west from the Sacramento and San Joaquin Rivers, which stretch from the Sierra Nevada. The SFB meets the ocean at the mouth of the bay near the Golden Gate Bridge. The SFB is the largest estuary on the West Coast of the US, is home to over 1,000 species of animals, and is a stop on the Pacific Flyway for migrating birds. Sitting among a major urban center, it serves ports, airports, and a multitude of recreational and commercial purposes for residents and tourists alike.

Wildlife:

Whales
GFNMS and SFB have a diverse wildlife community, including cetaceans, pinnipeds and sea birds. There are four species of cetaceans most commonly found in SFB: harbor porpoise, bottlenose dolphin, grey whales, and humpback whales. These species can also be found in GFNMS and travel between the two. The Marine Mammal Center (TMMC) in Sausalito has a photo identification system with 70 humpback whales and 101 adult bottlenose dolphin individuals identified. Bottlenose dolphins first came into SFB in ~1982, during a strong El Niño that brought warm waters to California's coast and with it, Southern California dolphins. Bottlenose dolphins can be seen in SFB around Alameda as well as outside of the bay along the coast at Ocean Beach, where they eat fish, squid and crustaceans. Humpback whales that can be seen in the SFB and in GFNMS between April and November during their annual migration, are among the North Pacific population segment. These whales breed in Mexico and migrate north to Alaska feeding on small crustaceans and small fish.

Pinnipeds
There are six pinniped species that can be found in GFNMS and SFB. The symposium focused on Harbor seals and California sea lions. There is little research on harbor seals and California sea lions in the SFB. California sea lions breed on offshore islands, such as the Farallon Islands; and forage within the SFB for squid, rockfish, herring and even small sharks. TMMC rescues multiple California sea lions each year, for reasons including: domoic acid toxicosis, malnutrition, entanglements, and other wounds. Harbor seals prefer to stay near shore, on beaches and rocky islands, where they spend about 50% of their time. They forage about 20-40 km from their habitat, and eat squid, cod, herring, squid and flounder.

Seabirds
Several dozen seabird species use GFNMS habitats throughout various times of the year. Around a half of a million of them (around 13 species) are breeding seabirds. Another subset of a few dozen species use the SFB as well. The four seabird species focused on during the symposium include the common murre, Brandt's cormorant, western gull, and surf scoter. These species are examples of seabirds that use both GFNMS and SFB habitats, and that have begun to move into the bay more around the late 1980s.

Around half of a million common murres are estimated to inhabit the sanctuary and nest on the Farallon Islands, spending winter in the area. Alcatraz Island in SFB is an important foraging zone for the common murres in the winter months. USFWS tagging research shows that common murres during incubation periods travel from the Farallon Islands out into the sanctuary from the shelf to the shoreline, and each one that was tagged traveled into the SFB as well. The area at the intersection

of GFNMS and the SFB up until around Alcatraz is a very important feeding area for these murres during the incubation and post-fledging period.

Common murres face various threats. The population saw a large decline in the 1980s due to a rise in the gillnet fishery. It's estimated that tens of thousands of birds were killed in gillnets each year. They are now recovering from that. Oil spills are still a major threat for them.

The Farallon Islands host the world's largest breeding colony of Brandt's cormorants. Brandt's cormorants also nest on Alcatraz in the winter months. There are around 20,000 that breed in the Gulf of the Farallones. They tend to do well and see population increases during cold water regimes when fish like anchovies are plentiful for food. They tend to experience fairly rapid population declines during periods of warm water, when they lose their prey base. Data shows that there has been a shift from the Farallon Islands to nesting more on the mainland, and coming into SFB. They forage inside the SFB, particularly near the Golden Gate Bridge (GGB). The SFB-GFNMS connection for these birds has strengthened over the past few decades.

Western ulls have been tracked from the South Farallon Island (SFI) to the SFB; some have been observed traveling to SFI even when their eggs are still on SFI. Their largest colony is on SFI, but they nest along the coast and into the SFB. Alcatraz also has a large colony. Tracking studies show significant traveling between GFNMS and SFB from 2013-2018 even during breeding season when they have eggs on the island, they are traveling into SFB (source indicated: Dr. Scott Shaffer). They use the SFB more in the winter months when they are not breeding on the Farallon Islands.

Surf scoters breed in Canada and Alaska and migrate south in winter months, foraging along the coast and in estuaries, including in SFB. They are one of the most abundant seabirds in SFB during winter months. Surf scoters have declined quite a bit over the last few decades. It's unclear why that's happening (potentially breeding habitat decline and/or impacts to prey availability).

Threats/issues related to seabirds at the intersections of GFNMS and SFB:

- Boat disturbance
- Aircraft disturbance
- Oil Pollution
- Other contaminants (mercury, selenium)
- Habitat alteration
- Changing prey populations:
    - Invasive species
    - Reduced herring spawn in SF Bay
    - Anchovy decline
- Fishery interactions
    - Gill-net fishery (past, large scale)
    - Entanglements (smaller scale but chronic)
- Climate change

Panel Q&A:

- We have seen whale strikes on humpback whales causing fatalities, but also gray whales in the SFB. Whales coming into the SFB are traveling through a narrow space under the GGB where large ships come through. For the population of humpback whales found in California, the number of whales taken from illegal fishing activities, entanglement, and from ship strikes, is about as many as the population can stand. If it gets any worse, there will be an impact to the population. The trend is still upward for the population.

- Losing a single individual from a whale population in some cases can have a big impact (e.g., western population of gray whales, that travels to Baja for breeding grounds, may be only 200 animals and losing one reproductive female could have an impact).
- Regarding anchovy populations, Point Blue Conservation Science studying annual population trends, reproduction and diet on seabirds from the Farallon Islands reported that around 2008 and 2009, anchovies had become a very important food source for murres, cormorants, auklets, and other species. Then the anchovies vanished and the timing of that was concurrent with a major reproductive failure event (e.g., Brandt's cormorant die off). Some people wanted the National Marine Fisheries Service to take action regarding the anchovy decline.
- Anchovy availability impacts humpback whales as well. That was part of the consideration for the NOAA critical habitat designation for humpbacks.
- There is not a lot of data on seabirds using the San Francisco-Pacifica Exclusion Area. We know it's used by common murres, cormorants, surf scoters, and Western gulls. Around 15 species regularly use the area.
- Is accumulation of harmful chemicals like PBDE (polybrominated diphenyl ethers) an issue for pinnipeds in this area? We don't have a good understanding of contaminant levels in pinnipeds. There are not a lot of ongoing monitoring efforts for harbor seals.
- Do you have additional recommendations for whales apart from the sanctuaries' vessel speed reduction program? It is hard to say how many whales are not hit because of the speed reduction. But the program does seem to be working in that around 50% of ships are slowing.
- Have there been correlations between domoic acid in pinnipeds and the increase in strandings? Yes, during the 2014-15 warm water "Blob" event over 300 California sea lions were rescued. So definitely during El Niño years or any warm water events, we see increased numbers of strandings from domoic acid, mostly because of the toxic algal blooms.
- What is the biggest threat to marine animals in this area?
    - Most immediate threat is oil spills because seabirds are so extensively impacted by each spill that happens. Oil spills kill a lot of birds and impact their habitat.
    - Climate change: multiple impacts. When it comes to food availability, there are big impacts. For California sea lions, we see dramatic shifts in reproductive success and distribution in El Niño years. There are also issues of climate-related diseases for pinnipeds.
    - For humpback whales, the population has grown from ~2,000 to ~20,000 since the 1970s, and that was because we stopped hunting them. Now, there are more of them and as they look for food, they may be coming closer to shore and are at risk for ship strikes. GFNMS has the vessel speed reduction program to slow ships to 10 knots, and that helps protect whales not only in the sanctuary but areas that are not protected like the San Francisco-Pacifica Exclusion Area.
    - Changing prey populations have driven population declines and increases for seabirds. There have been more seabirds die-offs along the coast in the past few years than the past few decades. Some are specifically linked to climate impacts like the warm water "Blob" of 2014-15, which led to large scale starvation events.

<u>Oceanography</u>

The Oceanography Panel discussed ocean acidification, the meeting of freshwater and saltwater in the SFB, phytoplankton and climate change, and the impact of the SFB river plume in the coastal ocean. In SFB, salinity, pH, oxygen and temperature are changing. SFB contains brackish water that is influenced by the ocean, where it enters through the mouth of the estuary and freshwater input from rivers. About 40% of the water from California enters SFB. There is a high freshwater outflow at the surface and a high salinity inflow at depth. The fresher water on top is less dense than the saltier water from the ocean. Colder, saltier water at depth is lower in oxygen and pH.

Ocean acidification lowers the pH of the water and makes the conditions for calcifying organisms unfavorable. The two sources of ocean acidification are 1) upwelling: along-shore winds push the coastal waters offshore and cold nutrient dense water from the deep ocean is brought up to replace the coastal water, this water is lower in pH so there is an increase in ocean acidification when there is increased alongshore winds; and 2) atmospheric: atmospheric CO2 from the burning of fossil fuels dissolves into the ocean causing the pH to lower. This reduces the concentration of carbonate (CO3-2), which lowers the aragonite saturation. Aragonite is an essential building block for calcifying organisms. The acidified waters from the ocean travel into SFB. There are dynamic zones of biogeochemical activity where waters meet

In general, ocean acidification is hard to measure. There is a need to improve long-term monitoring of carbonate chemistry and oxygen dynamics.

River plumes are leaving SFB and entering the coastal waters of GFNMS. These river plumes, also known as “microplastic highways to the ocean,” transports freshwater, nutrients, sediments, plankton, and pollutants. The research behind these plumes is still in progress but the scientists seek to determine the effects of winds, river discharge, topography, and seasonal variability as well as influences of long term oceanic processes. These plumes are likely influencing marine mammals and other marine life.

The Gulf of the Farallones (GoF), located within GFNMS, is a hotspot for productivity. The two sources for nutrients in the GoF are coastal upwelling, which supplies nitrate; and outflow from the SFB river plume (low salinity surface buoyant plume), which supplies silicate and anthropogenic ammonium (NH4; mainly from runoff that can cause acidification). Wastewater treatment plants are a source of ammonium that is exported out of the SFB, along with some nitrate.

Phytoplankton is key to the food web. After absorbing the nutrients, phytoplankton are then eaten by zooplankton, which is then eaten by fish and so forth. Ammonium can result in low levels of phytoplankton as it can repress use of nitrate by the cells. Chlorophyll (phytoplankton) occurs where both NO3 and NH4 are low. Little phytoplankton productivity or nutrient data is available for the GoF or SFB, especially SFB river plume.

Panel Q&A:

- Regarding ammonium coming from sewage plants within the SFB, there are two treatment plants—one flows out near the San Francisco Zoo and one from the Pacifica treatment plant—have you looked at the parameters of those plants? We have not looked into that.
- Regarding the acidity and carbon content of wastewater and how it impacts outer coast water, we’re seeing acidic surface water so there’s more to be investigated. The carbon dioxide in the atmosphere around urban areas is a local cause of increased acidification. There are multiple layers to the story and we’re just starting to address some of them.
- Are there efforts to look at these components as a whole? There is some preliminary work looking at nutrients, CO2, and ocean acidification together. A lot of these topics are interconnected. Plumes that bring surface water that might be a source of buffering against ocean acidification in some cases. The nutrients might have a reaction with acidification. There are interesting questions about regulating these things. You can locally control wastewater and reduce to some extent the acidification. We’re just starting to engage with some of these regulatory solutions.
- The impacts on organisms is the bigger consideration, and thinking about the parameters of stressors that impact the ecosystem. We have a long way to go in addressing those impacts and stressors.

- Point Arena is the upwelling center where the deep water flows up and then south. Some water goes into the SFB. There's definitely a connection between the outer coast water and the SFB.
- The harmful algal bloom that impacted the abalone population went up around Point Reyes when there was relaxation. That area around Point Reyes and Bodega gets water from both the north and coming out of the SFB.
- What are the unknowns? The connections between the central SFB and GoF are relatively understudied. There's a lot of interest and funding for studying species in the Delta. While there are dedicated people interested in studying the GoF, it's actually less understood and there is less dedicated funding for it. We need a lot more investment in studying the GoF and the interactions between the GoF and SFB.

Human Activities

The speakers discussed vessel traffic coming through GFNMS in and out of the San Francisco Bay, including ways of monitoring and tracking vessels, risks to whales from ship strikes, and transport of invasive species. Marine Monitor (M2) developed by Protected Seas has been created to monitor nearshore areas, integrate data from multiple sensors, and view live and recorded vessel traffic. After a year of data collection the results showed the six most common vessel types: Cargo ships, tankers, tugboats, ferries, recreational vessels, and sail boats.

In GFNMS there is a voluntary 10-knot speed limit during peak whale migration to reduce risk of vessel strikes. Cargo ships, ferries, and recreational boats are known to travel faster than 10-knots in SFB where there also may be whales present.

Discussion around large commercial shipping vessels in GFNMS and SFB included issues of ship strikes to whales and invasive species. Ship traffic is still moving over high traffic migration zones for whales. Recommendations to mitigate risk include: reduce the co-location of ships and whales, vessel speed reduction (voluntary VSR for SF TSS; 10 knot speed limit), and possible expansion of the voluntary speed limit into SFB. There is about 45% participation of voluntary speed reduction in GFNMS now. The goal is full participation.

Invasive species are also a concern with ships traveling into GFNMS and SFB. Invasive species are transported through ballast water and biofouling. Ballast water provides stability and maneuverability for the ship. Ships may discharge ballast water when coming into shallow areas like a bay. It's the better known/researched method of how species are introduced. There have been major advancements in reducing the spread of non-native species by ballast water, including better technology, regulations limiting discharge, and permitting requirements.

Invasive species are also transported through biofouling, when species attach to surfaces of a ship and are transported with the ship. Biofouling can also reduce fuel efficiency by creating drag on the ship, leading to higher emissions. Regulations were put into place in 2017. Biofouling is understudied.

Commercial fisheries in SFB include California halibut and Pacific herring, which spawn in SFB. Recreational fisheries in SFB include California halibut, striped bass, white sea bass, and leopard shark. The SFB influences fisheries (changes in tides, freshwater flow, rainfall).

The SFB influences fish populations on the outer coast (i.e., tidal and rainfall influence) 75-80% of the salmon caught in the outer coast comes through the SFB, coming out and back to the Sacramento River system. Salmon are dependent on freshwater outflows from rivers, coming out to the ocean as smolts and go back as adults. 40% of the salmon caught in Oregon are from the Sacramento River system.

Vessel traffic and plastic pollution (particularly around Fisherman's Wharf) in the SFB are threats to fish.

Panel Q&A:

- What do ships do to remove biofouling? Ships go into dry dock every five years. They completely clean their holds and add a new coat that is intended to keep biofouling off. In between, they clean loose biofouling off with a soft brush. The catch-22 is that everyone wants the ships to be clean when they come into port, but no one wants to have the ships cleaned at the port.
- How is ballast water cleaned and what are the regulations/standards for this cleaning? This is complicated and there are a few different methods that can include UV rays or chemicals. California has strict standards of what needs to be done but the current methods aren't good enough to meet these standards, so expect advancement of technology in the coming years. Stand Lands Commission inspects ballast water to meet Coast Guard regulations. For the bottom of the hull, the State Land Commission can use ROVs to do inspections and determine if a ship is keeping good care of the hull.
- Is there a history of ship strike by passenger ferries in San Francisco Bay? No, not that we are aware of but it's hard to tell what the cause of injury is. Also, there could be disturbance by passenger ferries, not just an actual strike.
- How is whale behavior affected by ship movement and noise? We aren't sure, we know more about what happens after a whale is struck by a ship. We recommend more information be provided to crews and the Coast Guard to report whales and other marine mammals for other ships. And, while it's important for ships to move slowly they need to maintain enough speed to have control over the ship itself.
- For ballast water management, what are the standards for clean water? Yes, there are standards for living cells of certain sizes and this can be tested and inspected.

C. Symposium Video Recording
https://nmsfarallones.blob.core.windows.net/farallones-prod/media/videos/20191016-sac-retreat-and-symposium.mp4

D. Alyssa Ells' presentation to the Greater Farallones National Marine Sanctuary Advisory Council, November 13, 2019
https://nmsfarallones.blob.core.windows.net/farallones-prod/media/docs/20191107-connections-on-the-san-francisco-bay-and-the-greater-farallones-national-marine-sanctuary.pdf

E. GFNMS SAC Meeting Minutes: November 13, 2019
https://nmsfarallones.blob.core.windows.net/farallones-prod/media/docs/20191113-meeting-highlights.pdf