Pelagic Water Column and Associated Benthic Habitat (Cordell Bank, Fanny Shoals, Rittenburg Bank)

The bulk of the content for this report comes from the Climate Change Impacts Report (Largier et al. 2010), a working group report of the Gulf of the Farallones Sanctuary Advisory Council and the 2009 Condition Report of Cordell Bank National Marine Sanctuary. Information has also been excerpted and summarized from the GFNMS, CBNMS and SIMoN websites.

Habitat Sensitivity

1. Direct Sensitivities to water temperature

- Coastal measurements of **sea surface temperature** from Southern California to Oregon document an increasing trend in temperature offshore and at shore stations since these data were first collected in 1955 (McGowan et al. 1998; Enfield and Mestas-Nunez 1999; Sagarin et al. 1999; Mendelssohn et al. 2003; Palacios et al. 2004).
- **Water temperature** over the north-central California continental shelf has cooled over the last 30 years (by as much as 1C in some locations) due to stronger and/or more persistent upwelling winds during spring, summer and fall (Mendelssohn and Schwing 2002; Garcia-Reyes and Largier 2010)
- Water temperatures in this region may increase due to warming or decrease due to increased upwelling, perhaps increasing temperatures offshore while decreasing temperatures in upwelling centers.

Habitat's sensitivity and response to changes in temperature

Benthic organisms that are unable to extend their geographic range as temperatures change will have to adapt or perish. If temperatures increase, then species with a center of distribution in higher latitudes may have a difficult time adapting as these species are at the southern end of their distribution and likely close to their thermal tolerance limits. In contrast, species that have their center of distribution to the south in warm temperate oceans will likely expand their distribution north as ocean temperatures warm. However, there are complex interactions between temperature and other physical parameters that will have synergistic and unpredictable effects on benthic communities.

Low seabird breeding propensity has been linked to high sea surface temperature (Lee et al. 2007). Other studies have shown correlations between low seabird reproductive success and warm, non-productive conditions (Ainley et al. 1995; Abraham and Sydeman 2004; Sydeman et

al. 2006; Jahncke et al. 2008; Roth et al. in preparation). The effect is especially dramatic during El Niño events that are likely to become more frequent in the future. El Niño events have also been linked to low adult survival (Lee et al. 2007). Low productivity that occurs frequently or over many years and low adult survival will ultimately lead to declines in breeding populations (Lee et al. 2007).

Diet studies of common seabirds breeding on Southeast Farallon Island have shown major changes in the availability of juvenile rockfish. Diet studies on common murres (Uria aalge) have shown a decrease in juvenile rockfish (Sebastes spp.) during years with warm sea surface temperatures and/or warm (positive) PDO periods (Miller and Sydeman 2004). Similar findings were found for rhinoceros auklet (Cerorhinca monocerata) where the appearance of juvenile rockfish in the diet was higher in years with low sea surface temperatures (Thayer and Sydeman 2007). Trawl data from NOAA National Marine Fisheries Service shows similar results, particularly a sharp decline in juvenile rockfish in response to the warm-water conditions observed in the central California Current region in 2005.

2. Sensitivities to other climate and climate-driven changes

A. Dissolved Oxygen

When dissolved oxygen (DO) concentrations in coastal oceans fall to hypoxic levels, there are severe consequences for offshore benthic communities. The oxygen depleted water mass suffocates everything that cannot move out of the area resulting in a massive mortality event. Areas adjacent to upwelling centers like Point Arena are particularly susceptible to low DO levels as the upwelling process naturally delivers low oxygen water onto the continental shelf from the deep ocean. Currently the source for upwelled water is shallower than the Oxygen Minimum Zone (OMZ) (Grantham et al. 2004). An extensive OMZ exists along the continental margin of the northeast Pacific Ocean (Kamykowski and Zentara 1990). Recent work indicates that in the vicinity of Point Conception, the OMZ has shoaled by up to 90 meters (Bograd et al. 2008). Shoaling of the OMZ could lead to significant and complex ecological changes in the California Current System including direct hypoxia-related effects on benthic organisms where the OMZ contacts the continental margin (Levin 2003). If the OMZ were to migrate shallow enough to provide the source water for coastal upwelling, hypoxic events may be observed in this region and there would be severe ecological impacts (Bograd et al. 2008).

B. Ocean Acidification

Ocean acidification will add cumulatively to the stress of benthic organisms. Low-pH water becomes corrosive to a wide variety of marine animals including corals, sea urchins, and mollusks (Guinotte and Fabry 2008), and calcification rates are likely to decline (Gazeau et al.

2007). Decline in the biomass of plankton will also affect the deeper benthic communities but the implications to food webs are poorly understood. Shell-building pteropods and foraminiferans are key species at the base of ocean food webs that will be adversely impacted by increasing acidity (Fabry et al. 2008; Spero et al. 1997). Ocean acidification could also impact larval and juvenile stages of benthic organisms during the developmental phase of their early life history (Kurihara et al. 2007). Many species spend this part of their life in the water column as free-floating plankton.

C. Upwelling

Strong upwelling is generally associated with high seabird reproductive success because of its positive effect on ocean productivity (Ainley et al. 1995; Abraham and Sydeman 2004; Sydeman et al. 2006; Jahncke et al. 2008; Roth et al. in preparation). However, the effect of a long-term increase in upwelling intensity is difficult to predict. Increased upwelling may mitigate the negative consequences of rising sea surface temperature to some extent by cooling surface temperature and increasing productivity in the system. Conversely, upwelling that occurs too early in the year or is too intense may disrupt the food supply that seabirds rely on. Pringle (2007) found evidence that zooplankton move into deeper waters during intense upwelling to avoid being adverted offshore. Increased time at depth could make zooplankton less available to seabirds, because they are restricted to varying degrees in how deeply they can dive for food. Increased turbulence could also lead to decreased production of forage fishes by disrupting the food supply of larval fish (Cury and Roy 1989). Disruptions in the food web ultimately could lead to decreased ocean productivity and decreased seabird reproductive success and survival. Sessile benthic organisms depend on currents to deliver food. Any significant disruption to the timing or intensity of seasonal upwelling winds resulting in reduced productivity over time would have negative impacts on long term survival of benthic animals.

In years where alongshore winds were strong and began earlier in the spring, strong and early upwelling resulted in increased abundance of important zooplankton species (e.g., euphausiids and copepods). The increased abundance of these zooplankton species (specifically krill) during the critical breeding time of the Cassin's auklet resulted in above average breeding success of this species. The opposite of the above scenario occurs in years when alongshore winds are weak and/or delayed, which was characteristic of conditions in 2005 and 2006.
Upwelling occurred later in the spring, causing reduced phytoplankton and zooplankton abundances in the region. The zooplankton community changed as well; not only did abundances of krill (adult krill, in particular) and copepods decline, but abundances of gelatinous zooplankton appeared to have increased. Due to the lack of available adult krill, Cassin's auklets abandoned nests and failed to breed in these years. The decline in adult krill in

2005 may also be related to decreased survival of Chinook salmon entering the ocean that year and low salmon returns in California in 2008. Sightings of blue whales (another krill predator) also dropped significantly from 2004 numbers (PRBO unpublished data). Drastic bottom-up effects in the ecosystem were observed and documented in a relatively short time period (July 2004 to August 2005), including low primary production, low krill abundance, a decline in at-sea seabird abundance, and late and reduced reproductive success in seabirds on the Farallon Islands (Jahncke et al. 2008).

D. Transport

Many offshore benthic organisms that live in the California Current have early life histories linked to an annual production cycle driven by coastal upwelling. Most of these animals spend the first part of their lives as free-floating plankton, which facilitates dispersal, feeding and predator avoidance. If the timing or magnitude of seasonal winds driving coastal upwelling were to change significantly, it could reduce larval survival for many resident species.

E. Species Range Shifts

In recent years, jumbo squid populations have expanded to Cordell Bank from the south and have persisted in the area; this top-level predator has the potential to have significant impacts on the biodiversity and community composition within the sanctuary (excerpted from CBNMS Condition Report 2009). Though there is little direct evidence for long-term change of zooplankton communities in the study region, the shift towards a more "southerly" planktonic fauna has been observed both north and south of the region. The California Cooperative Oceanic Fisheries Investigations (CalCOFI) dataset in southern CA demonstrated a decline in zooplankton biomass (by 80% since 1950) associated with warming waters (excerpted from Largier et al. 2010).

3. Sensitivities to non-climate stressors

Due to proximity to the coast, Cordell Bank and Davidson Seamount face a number of anthropogenic threats, including but not limited to vessel traffic, sea temperature rise, ocean acidification, commercial harvest, underwater cables, cumulative research collection, bio-prospecting, and military activity. Sanctuary regulations provide important, although not comprehensive, defenses against some of these threats. Activities that currently have the greatest potential impact on Cordell Bank are the use of bottom-tending fishing gear, the deposition of lost fishing gear and other marine debris, the introduction of invasive species, and the construction and placement of cables and pipelines on the bank. (excerpted from SIMoN website: http://sanctuarysimon.org/regional_sections/seamounts/overview.php)

A. Cables and pipelines

The construction and placement of cables on shallow offshore banks can have a highly disruptive impact on the benthic habitat.

B. Human use

Lost fishing gear can become entangled on the seafloor and lead to damage of sensitive habitats that provide food and shelter for invertebrates and fishes, including structure forming hydrocorals and sponges (Barnes and Thomas 2005). Significant amounts of derelict fishing gear have been documented in rocky areas of Cordell Bank (ONMS 2009). From 2001-2005, Cordell Bank sanctuary conducted demersal submersible surveys on and around the bank. During these surveys, fishing gear was consistently observed on the bottom (Figure 34). In 2002, derelict gear was observed entangled on the seafloor on 18 of the 20 transects (90%) conducted over rocky habitat. The most common gear types observed were long-lines and occasional gill nets. Most gear is entangled among boulders or on high relief rock. Many of the high relief areas are covered with hydrocorals and other encrusting invertebrates and derelict gear has been documented entangled on these sensitive species. As some areas in the sanctuary are now off limits to the use of bottom contact gear and bottom trawling, condition of biologically structured habitats should improve; however, there is insufficient data to determine a trend. Further, due to the slow growth of some habitat-forming organisms, such as cold water corals, recovery from past damage could be slow. Furthermore, it is not known how scouring from storm events and subsequent larval settlement affect the condition of the biologically structured habitat. It is also unclear how a long-term warming trend in the ocean and changes in pH would affect the condition of the lush invertebrate community carpeting the upper reaches of the bank (excerpted from CBNMS Condition Report 2009).

Historically, trawl intensity was concentrated in several locations of the sanctuary, specifically in the region of the shelf break as well as within deeper regions of the sanctuary on the continental slope (Final Environmental Impact Statement 2008; Fig. 3-4). Recently, a variety of fishery management measures, including Rockfish Conservation Areas and Essential Fish Habitat Conservation Areas have been implemented that limit the extent of trawling activity and use of bottom contact fishing gear in the sanctuary. Currently, 86% of the Cordell Bank sanctuary is closed to some type of bottom tending fishing gear. The net effect of these measures may be an improvement in the condition of habitats due to some recovery of seafloor habitats in the areas that were previously trawled or fished with other bottom contact gear. Nevertheless, a directed study to determine habitat differences in open and closed areas and recovery rates of benthic habitats relieved of fishing pressure has yet to be conducted (excerpted from CBNMS Condition Report 2009).

Shipping lanes run very nearby the eastern edge of Cordell Bank, and some 2,000 large commercial vessels transit through CBNMS every year. While vessel numbers transiting the sanctuary do not appear to be increasing (1999-2005, United States Coast Guard, Automatic Identification System, unpubl. data), it is unknown what the levels of discharge are from these vessels and how this has changed through time (CBNMS Condition Report 2009). Documented ship strikes of humpback, blue and fin whales have occurred throughout the coastal waters of California.

C. Pollutants/Contaminants

Because of the offshore nature of these banks, and the distance from population centers on the mainland, water quality is considered to be in fairly good condition (CBNMS Condition Report 2009). However, oil spills are a threat to the health of this ecosystem, and there have been several large spills in the region over the last decade.

D. Invasive Species

A number of non-native species are present in the marine environment near Cordell Bank sanctuary, but none are known to currently exist in the sanctuary; however, there has not been a comprehensive inventory of species within the sanctuary. For this reason, this question is rated "undetermined" for both its status and trend. There is some concern regarding an invasive tunicate, *Didemnum* sp. that has been observed in nearby coastal areas and has covered large areas of Georges' Bank on the east coast (Bullard et al. 2007). The invasive tunicate is similar to a native *Didemnum* species and sampling will be necessary to determine which species is present on Cordell Bank (CBNMS Condition Report 2009). Shifts in the size, frequency, or timing of gelatinous zooplankton blooms in response to climate change have become a concern in many coastal marine ecosystems worldwide. When abundant, gelatinous zooplankton can induce trophic cascades as well as alter energy flows to upper-level consumers (Robinson and Graham 2014). The moon jelly is an invasive species of gelatinous zooplankton found in nearshore and offshore waters of California.

E. Harmful Algal Blooms

Water samples are taken from Cordell Bank sanctuary during monthly monitoring cruises for the California Department of Health Services. The purpose of the sampling is to identify early warning signs of harmful algal blooms, focusing on the dinoflagellate *Alexandrium catenella* (which causes paralytic shellfish poisoning) and the diatom *Pseudonitzschia* spp (domoic acid carriers). To date, there have been no indications of elevated levels of either species (California Department of Health Services, monthly reports). Although these data are

insufficient to identify the effects of specific stressors, there are currently no data to suggest that water quality is compromised (CBNMS Condition Report 2009).

Habitat Adaptive Capacity (information summarized from SIMoN and CBNMS websites)

1. Extent, Integrity and Continuity

A. Geographic extent of habitat: endemic, transcontinental, etc?

Offshore rocky reefs, including banks and seamounts, are ubiquitous worldwide, though patchy in their distribution (see Figure 2 for banks and seamounts in the southern stretch of the study region). These rocky reefs and pinnacles may act as "stepping stones" for the dispersal of species. Relatively little research has been conducted on these ecosystems, compared to other habitats in the study region.

B. Structural and functional integrity in study region: is the habitat typically pristine or degraded?

Because of the offshore nature of the Cordell Bank sanctuary and the distance from major urban population centers, most water quality parameters suggest relatively good conditions. Benthic habitat quality has been impacted over the years as a result of bottom contact fishing gear on the rocky reef and soft bottom habitats of the sanctuary. Many derelict long lines and gill nets remain entangled on rocky areas of the bank. Spatial fishing gear restrictions that are currently in place in some areas will help protect sanctuary habitats and conditions are expected to improve. Living resource conditions within Cordell Bank National Marine Sanctuary are considered to be diminished, because of depleted populations of rockfish, salmon, leatherback sea turtles and some species of seabirds. It might be expected that conditions for living resources will improve due to fishery closures that are helping to rebuild depleted fish stocks, but uncertainty remains due to global changes that are currently affecting our oceans. To date, no maritime archaeological resources have been identified in the sanctuary (2009 CBNMS Condition Report).

C. Continuity of the habitat: is it continuous or occur in isolated spots?

The specific regions identified for this vulnerability assessment are discrete rocky reef banks that are isolated in space and have higher elevation and a different substrate than the surrounding seabed of the continental shelf. Details on each of the 3 features include:

Cordell Bank: In CBNMS, the bank is 27 miles NW of Farallon Light and 20 miles W of Point Reyes, is about 9.5 miles long and 4.5 miles wide; 26 square miles. The bank sits at the edge of the continental shelf and rises abruptly from the soft sediments of the shelf to within 115 feet of the ocean surface.

Rittenberg Bank: In GFNMS, the bank is 38 miles west of the mainland, and approximately 5 miles from the edge of the continental shelf. The bank is 1.8 square miles in size. Depth ranges from 85 to 115 meters.

Fanny Shoal: In GFNMS, 9.8 miles NW of Farallon Light and 14 miles SW of Point Reyes (in between Rittenberg and the Farallon Islands), is 2 miles in extent and covered 2 to 30 fathoms.

2. Habitat Diversity

A. Diversity in topographic and physical characteristics

Cordell Bank: A proportion of Cordell Bank is made up of granite reef, but much of the bank is a mixture of rock reef, boulders, cobbles, sand and mud. The bathymetry and location of Cordell Bank combine to make it a very productive marine environment. Nutrients and productivity emanating from an upwelling center near Point Arena are carried over the bank and sustain a thriving biological community. Localized upwelling may also contribute to productivity.
Rittenburg Bank and Fanny Shoal: These rocky banks are outcroppings of granitic continental crust and are homogenous and erosion-resistant. Boulders and smaller rocks are often present on flat areas of granitic outcroppings.

B. Diversity in species/functional groups

Each of the banks provides a complex and heterogeneous surface for colonization by deep-water corals, sponges, other invertebrates and many species of fish. Their vertical structure, habitat complexity and rocky substrate support a very different biological assemblage than the soft bottom that typically surrounds them. Because these rocky features extend up into the water column, they provide ideal habitat for attached sessile invertebrates that depend on currents to deliver their food. The hard substrate is also favorable for settlement of larvae from the water column. 246 species of fish, 26 species of marine mammal, 59 species of bird and countless benthic algae and invertebrates use the water surrounding Cordell Bank and the bank itself. 23 taxa of managed fish species (including the Widow Rockfish, a focal species, and numerous unidentified juvenile rockfish), 113 coral colonies, 322 seapens and seawhips and 2,628 sponges were observed on Rittenberg Bank during a 2012 research cruise (GFNMS EFH proposal). These banks serve as critical habitat for young of the year, juvenile and adult rockfish.

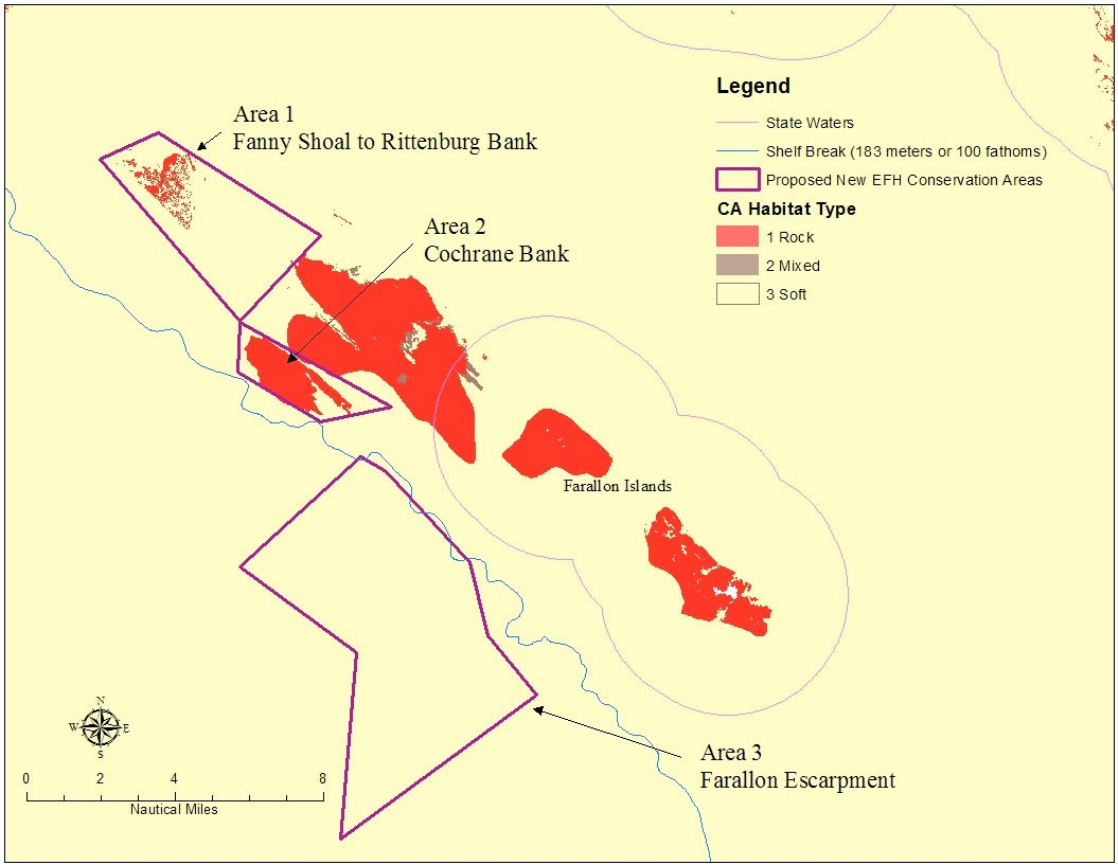
C. Dependence on a single keystone species? (excerpted from CBNMS Condition Report 2009)

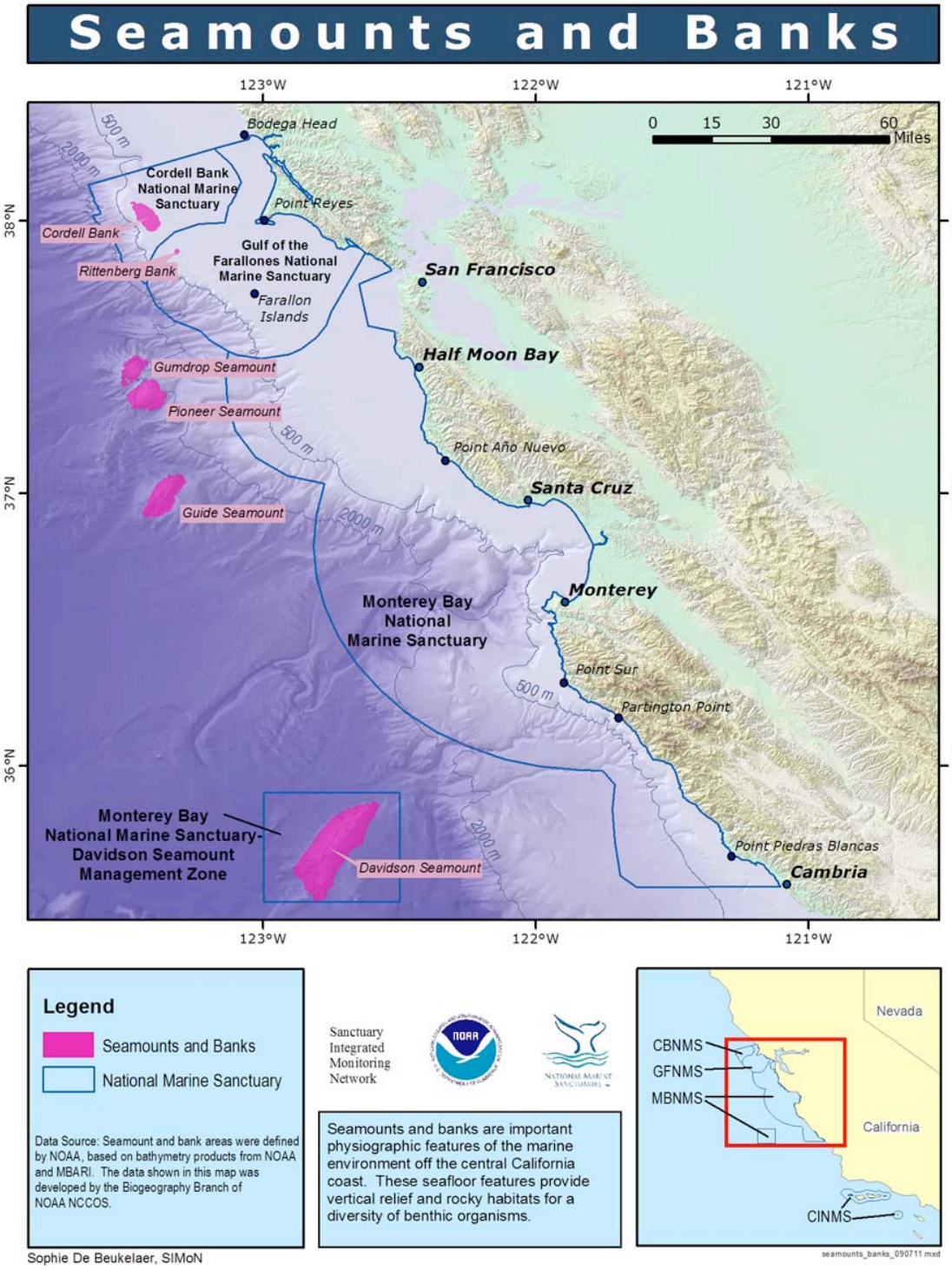
Hydrocorals and sponges are important habitat-forming species for benthic communities of offshore banks. The upper reef areas of Cordell Bank shallower than 60 meters are covered with a rich and diverse assemblage of benthic invertebrates. Sponges, strawberry anemones, hydrocorals, and tunicates encrust rock surfaces, while more mobile sea stars, sea urchins and crabs move over the surface of this reef.

Krill are keystone species and large changes in population size are related to changing oceanic conditions. Reduced primary productivity in 2005 (Jahncke et al. 2008), which was associated

with anomalous atmospheric conditions that delayed upwelling, limited krill population growth and impacted the condition of higher trophic levels dependent on krill (Sydeman et al. 2006, Jahncke et al. 2008). Blue whales (focal species for this study) are dependent on the presence and abundance of this keystone species.

Figure 1. Proposed EFH areas in GFNMS EFH proposal. The hard rock (in red) encompassed by "Area 1" is Rittenburg Bank. Fanny Shoal is the large rocky reef in between Area 1 and the Farallon Islands. Cordell Bank is not pictured.




Seamounts and Banks
123°W
122°W
121°W
38°N
37°N
36°N
0 15 30 60 Miles
Bodega Head
Cordell Bank National Marine Sanctuary
Point Reyes
Cordell Bank
Gulf of the Farallones National Marine Sanctuary
Rittenberg Bank
Farallon Islands
San Francisco
Half Moon Bay
Gumdrop Seamount
Pioneer Seamount
Point Año Nuevo
Santa Cruz
Guide Seamount
Monterey
Monterey Bay National Marine Sanctuary
Point Sur
Partington Point
Monterey Bay National Marine Sanctuary-Davidson Seamount Management Zone
Davidson Seamount
Point Piedras Blancas
Cambria
500 m
2000 m
Legend
Seamounts and Banks
National Marine Sanctuary
Data Source: Seamount and bank areas were defined by NOAA, based on bathymetry products from NOAA and MBARI. The data shown in this map was developed by the Biogeography Branch of NOAA NCCOS.
Sanctuary Integrated Monitoring Network
Seamounts and banks are important physiographic features of the marine environment off the central California coast. These seafloor features provide vertical relief and rocky habitats for a diversity of benthic organisms.
Nevada
California
CBNMS
GFNMS
MBNMS
CINMS
Sophie De Beukelaer, SIMoN
seamounts_banks_090711.mxd

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Office of National Marine Sanctuaries 2009. Cordell Bank National Marine Sanctuary Condition Report 2009. US Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 58 pp.

Reyna, Karen. 2013. A Proposal to Consider Options for New EFH HAPC(s) and Conservation Areas Submitted by Gulf of the Farallones National Marine Sanctuary.

Robinson KL, Graham WM. 2014. Warming of subtropical coastal waters accelerates *Mnemiopsis leidyi* growth and alters timing of spring ctenophore blooms. *Mar Ecol Prog Ser* 502:105-115.

Sanctuary Integrated Monitoring Network (SIMoN) website:
http://sanctuarysimon.org/cordell/sections/seamounts/overview.php
http://sanctuarysimon.org/monterey/sections/seamounts/overview.php

Cordell Bank National Marine Sanctuary website:
http://cordellbank.noaa.gov/science/characterization.html