Nearshore Water Column
Soft-bottom Subtidal

The nearshore zone extends from the surf out to waters that are approximately 30 meters (100 feet) deep. This habitat lacks hard substrate and is greatly impacted by waves and currents.

Habitat Sensitivity

1. Direct Sensitivities to water temperature and precipitation

A. 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 (excerpted from Largier et al. 2010)

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 seabird breeding populations (Lee et al. 2007).

Low productivity and low survival for pinnipeds are also associated with El Niño events. Low productivity may occur frequently or over many years, and low adult survival may lead to low populations (Sydeman and Allen 1999).

2. Sensitivities to other climate and climate-driven changes

A. Upwelling (excerpted from Largier et al. 2010)

The direction of change in upwelling for the study region is uncertain, but either scenario (increases or decreases in intensity) will affect nutrient delivery to the nearshore subtidal. Increased nutrient availability in the nearshore may therefore benefit benthic macroalgae as well as phytoplankton. However, intensification of upwelling could also alter the strength of offshore transport, increasing the dispersion of larvae and spores released in the nearshore subtidal, as well as enhance turbulent mixing, thus disturbing food particle concentrations critical to larval survival (Bakun 1999).

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.

B. Stratification (excerpted from Largier et al. 2010)

In nearshore regions sheltered from the direct effects of upwelling, an increase in stratification would reduce nutrient delivery to surface waters and thus to subtidal habitats, as well as decrease offshore transport of larvae and spores. Changes in horizontal mixing and transport is expected to occur with changes in upwelling and the associated mesoscale (10s-100s km) circulation, such as recirculation cells in the lee of headlands. Mesoscale features are important corridors between offshore and nearshore habitats. Climate moderates mesoscale circulation in the California Current System, thereby affecting nearshore-offshore connections (Keister and Strub 2008).

An increase in stratification may also be seen in sheltered waters in bays. Increased water column stratification may lead to a major shift in phytoplankton communities in the region, as was observed in Monterey Bay between 2002 and 2004. Diatom abundance declined and dinoflagellate abundance increased concomitant with increased stratification (Pennington et al. 2007). Diatoms are generally associated with strong upwelling in the spring and summer, while dinoflagellates become more abundant during the "oceanic period" in the fall and early winter. Reduced atmospheric forcing during 2002-2004 and the presence of elevated nutrient levels in Monterey Bay (possible related to the enhanced upwelling observed along the open coast in the same years), led to a massive dinoflagellate bloom in areas with warm sea surface temperatures, highly stratified water column and shallow thermoclines. In the Bering Sea, elevated numbers of gelatinous zooplankton have been linked to warmer and more stratified waters (Brodeur and Terazaki 1999). Increased water temperatures lead to higher reproductive rates and extended growing seasons. These gelatinous organisms may become the dominant predators in altered ecosystems

C. Ocean Acidification (excerpted from Largier et al. 2010)
The northern and central California coast is especially vulnerable to acidification because of upwelling, which transports acidified waters (under-saturated with respect to aragonite) from offshore onto the continental shelf, potentially reaching the coastal shallow subtidal (Feely et al. 2008). The acidified upwelled water may affect calcifying organisms utilizing the nearshore subtidal habitat although, unlike the rocky intertidal, few nearshore subtidal habitats in this region are dominated by calcifying organisms.

D. Storm Activity (excerpted from Largier et al. 2010)
The most important source of natural disturbance to the soft-bottom subtidal habitat is wave action. Extreme storm waves can remove as much as a meter of surface sediments at water depths greater than 10 meters (Hodgson and Nybakken 1973). Increasing significant wave heights will affect sediment redistribution and may change the coastal topography of the area. Increased storm activity may increase precipitation in this area, leading to greater freshwater input to the nearshore subtidal, including inputs from the San Francisco Bay outflow. An increase in terrestrial inputs as well as storm activity will lead to higher resuspension of sediment resulting in increased turbidity and light attenuation.

E. Species Range Shifts
A fundamental prediction that can be made regarding biotic responses to climate change is that species will shift their range to maintain optimal environmental conditions. Therefore, in response to warming temperatures, both northern and southern species may shift their range

towards the poles (Parmesan 1996). However, poleward range expansion may not always be the case. Nonetheless, the paleontological record indicates that during past warming events, species have generally responded this way (van Devender and Spaulding 1979; Fields et al. 1993; Roy et al. 1996). Contemporary studies have documented this phenomenon in a variety of marine habitats, including rocky intertidal, kelp forest, and pelagic environments. 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). Bottle nosed dolphins have shifted north into San Francisco Bay, which may be due in part to changes in sea temperature in nearshore habitats (Largier et al. 2010).

3. Sensitivities to non-climate stressors

Human-induced disturbances, such as dredging, disposal of dredge material and bottom-tending fishing gear, have been shown to affect the physical structure of the sandy seafloor and subsequently alter the associated biological communities. However, the long-term impacts of many human activities on the sandy seafloor habitat and community are not well understood (excerpted from MBNMS SIMoN website). The release of pollutants during dredging of soft bottom habitats has been documented, and may potentially expose species to additional pollutants (pers. comm. Sarah Allen, NPS).

A. Shoreline armoring

Shoreline armoring can impact the supply of sediment, which is critical to the stability and persistence of soft-bottom subtidal habitat.

B. Human use/Disturbance

The long-term impacts of fishery trawling on benthic communities (generally beyond scuba depths) are unknown, but likely to be extensive. There are significant reductions in benthic fish and large invertebrates in trawling grounds that are active today (SIMoN).

C. Pollutants/Contaminants (excerpted from Largier et al. 2010)

Although point sources of sewage input often modify nearby bottom communities (Oakden et al. 1984), local sewer outfalls have no measurable impact on biological communities or sediment chemistry, except that the pipes act like reefs in sand bottoms (Kim 1989). However, climate predictions indicate that the timing and intensity of terrestrial runoff will be modified, both as a function of precipitation patterns and indirectly by changing the snowpack in

California (Barnett et al. 2008)), with consequences for the occurrence of harmful algal blooms. Recent evidence points to the importance of anthropogenic nutrients on the development and proliferation of harmful algae in California (Anderson et al. 2008; Kudela et al. 2008). Changes in the hydrological cycle, as well as long-term trends in coastal (human) populations and nutrient discharge, could result in dramatic shifts in the timing, intensity, and duration of HAB events, resulting in both positive and negative changes.

D. Invasive Species

A small handful of invasive species have been reported in nearshore coastal waters in California, including the moon jelly and striped bass. There has not yet been a systematic survey of nearshore coastal waters to evaluate the level of invasive species present (MBNMS). 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). Striped bass have been documented to negatively affect endangered salmon through predation (CDFW has estimated take as high as 25-50% of both the endangered Sacramento River winter-run and the threatened Central Valley spring-run Chinook salmon).

E. Harmful Algal Blooms (excerpted from Largier et al. 2010)

Harmful Algal Blooms (HABs) are now generally recognized as occurring over a wide range of oligotrophic to hyper-nutrified habitats, and appear to be expanding globally (Anderson et al. 2005; Glibert et al. 2005; Kudela et al. 2005). An example of the response of harmful algae to climate change near the study region may be seen in the observed increase in dinoflagellates in Monterey Bay over the last decade. Using data from the Santa Cruz Wharf in Monterey Bay, California, Jester et al. (2009) documented a dramatic shift in phytoplankton community structure starting in 2004, resulting in an increasing dominance of dinoflagellates and a corresponding decrease in diatoms. With this shift, Jester et al. (2009) reported a concomitant increase in HAB problems associated with dinoflagellates (paralytic shellfish poisoning, diarrhetic shellfish poisoning, red tides, including fish and shellfish killing red tides). Jessup et al. (2009) also documented, for the first time, a harmful event linked to what was previously assumed to be a harmless red tide organism. While it is only suggested that these events may be linked to climate change (as opposed to other oscillations in the oceanic environment), they provide a glimpse at what a warmer California Current may look like in terms of harmful algae.

F. Disease (excerpted from Largier et al. 2010)

The prevalence of disease in marine ecosystems has been projected to increase in response to a warming climate (Harvell et al. 2002). These increases have been documented in corals, seagrasses, oysters, sea urchins, and sea stars, and may act in concert with climate change to reduce the abundance of marine organisms (Harvell et al. 1999). This is because warming can result in increased pathogen development and survival rates, as well as favoring transmission and host susceptibility. Sea star wasting syndrome may be associated with warmer temperatures (http://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting/).

Habitat Adaptive Capacity

1. Extent, Integrity and Continuity

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

Soft-bottom substrate dominates the world's continental shelves.

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

Long-term impacts of human activities (fishing, dredging) on the soft-bottom seafloor habitat are not well understood. Water quality in the nearshore environment is degraded for the most part, due in part to impacts of outflow from San Francisco Bay and agricultural runoff from surrounding rural areas, though on-going monitoring studies in Monterey Bay National Marine Sanctuary indicate that large, structural sessile habitat-forming invertebrates (e.g., sponges, anemones, tube worms) appear to be healthy and no major perturbations have been observed.

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

Sandy bottom subtidal habitat is ubiquitous throughout the study region and fairly continuous. For example, in the very southern reach of the study region (and extending further south), the nearshore zone in Monterey Bay National Marine Sanctuary is composed of 80% soft bottom habitat. In a 2003 study of the dispersal potential of macroinvertebrates throughout the Pacific coast of North America, soft-bottom subtidal larvae had the greatest potential for extensive dispersal. These communities had the highest proportion of taxa with planktonic feeding development and larvae with planktonic lifespans greater than 30 days (Grantham et al. 2003).

2. Habitat Diversity

A. Diversity in topographic and physical characteristics

This habitat exhibits little diversity in topography and physical characteristics – the soft bottom is characterized by soft sediments such as sand and mud, and wave currents form sand waves and ripples that organize sediments into different particle sizes (SIMoN). At the mouth of the San Francisco Bay are the largest sand waves on the west coast (6 m in height, 80 m from crest to crest) that offer a very distinct and unique habitat (Gibbons and Barnard, 2007).

B. Diversity in species/functional groups (excerpted from MBNMS SIMoN website)

Many organisms make their homes either on (i.e., epifaunal) or in (i.e., infaunal) the sediments. In particular, two communities are organized along a gradient of wave-induced substrate motion that are observed from San Diego to Washington:

- The crustacean zone: this shallower zone, characterized by strong water motion and sandy sediments, is occupied by small, mobile, deposit-feeding crustaceans, including the sand-burrowing amphipods and surface-active cumaceans and ostracods. All burrow into superficial sediments, and flourish in wave-disturbed sand bottoms (Oakden 1981, Slattery 1980, Slattery 1985).
- The polychaete zone: characterized by more stable, fine sand with a significant amount of mud, this deeper zone is dominated by polychaete worms living in relatively permanent tubes and burrows. Many other relatively sessile and suspension-feeding groups are also common here.

The width and depth limits of these two zones vary, depending on the strength of wave activity. Benthic fishes are less abundant in the crustacean zone than the polychaete zone. Fish diversity on the sandy seafloor is relatively low compared to adjacent reefs, but some of the most abundant species are important forage for large predatory fishes, seabirds and marine mammals.

C. Dependence on a single keystone species?

Gray whales may be considered a keystone species because they are recognized as ecological engineers for their foraging behavior. They have a dramatic effect on bottom sediments, as one whale can plow 100 acres in one summer while foraging in the soft bottom sediments of Alaska. Resident whales that over-summer in central California are becoming more frequent (pers. comm. Sarah Allen, NPS).

Literature:

Gibbons, H. and P.L. Barnard. 2007. Sand Waves at the Mouth of San Francisco Bay, California [Postcard]: U.S. Geological Survey General Information Product 54 [http://pubs.usgs.gov/gip/2007/54/].

Grantham, B.A., G.L. Eckert, and A.L. Shanks. 2003. Dispersal potential of marine invertebrates in diverse habitats. *Ecological Applications* 13:S108-S116.

Hodgson, A. T. and J. W. Nybakken. 1973. A quantitative summary of the benthic infauna of northern Monterey Bay, California. Moss Landing Marine Labs Tech. Rep. 73-8, 241 p.

Largier, J.L., B.S. Cheng, and K.D. Higgason, editors. 2010. Climate Change Impacts: Gulf of the Farallones and Cordell Bank National Marine Sanctuaries. Report of a Joint Working Group of the Gulf of the Farallones and Cordell Bank National Marine Sanctuaries Advisory Councils. 121pp.

Monterey Bay National Marine Sanctuary: Invasive Species. Retrieved May 22, 2014 from http://montereybay.noaa.gov/resourcepro/resmanissues/invasive.html

Sanctuary Integrated Monitoring Network (SIMoN). Retrieved May 14, 2014, from http://montereybay.noaa.gov/sitechar/shallow.html

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.

Sydeman, W.M. and S.G. Allen. 1999. Pinnipeds in the Gulf of the Farallones; 25 years of monitoring. *Marine Mammal Science.* 15:446-461.