Science Foundation Chapter 5 Appendix 5.1 – Case Study Harbor Seal (*Phoca vitulina*)

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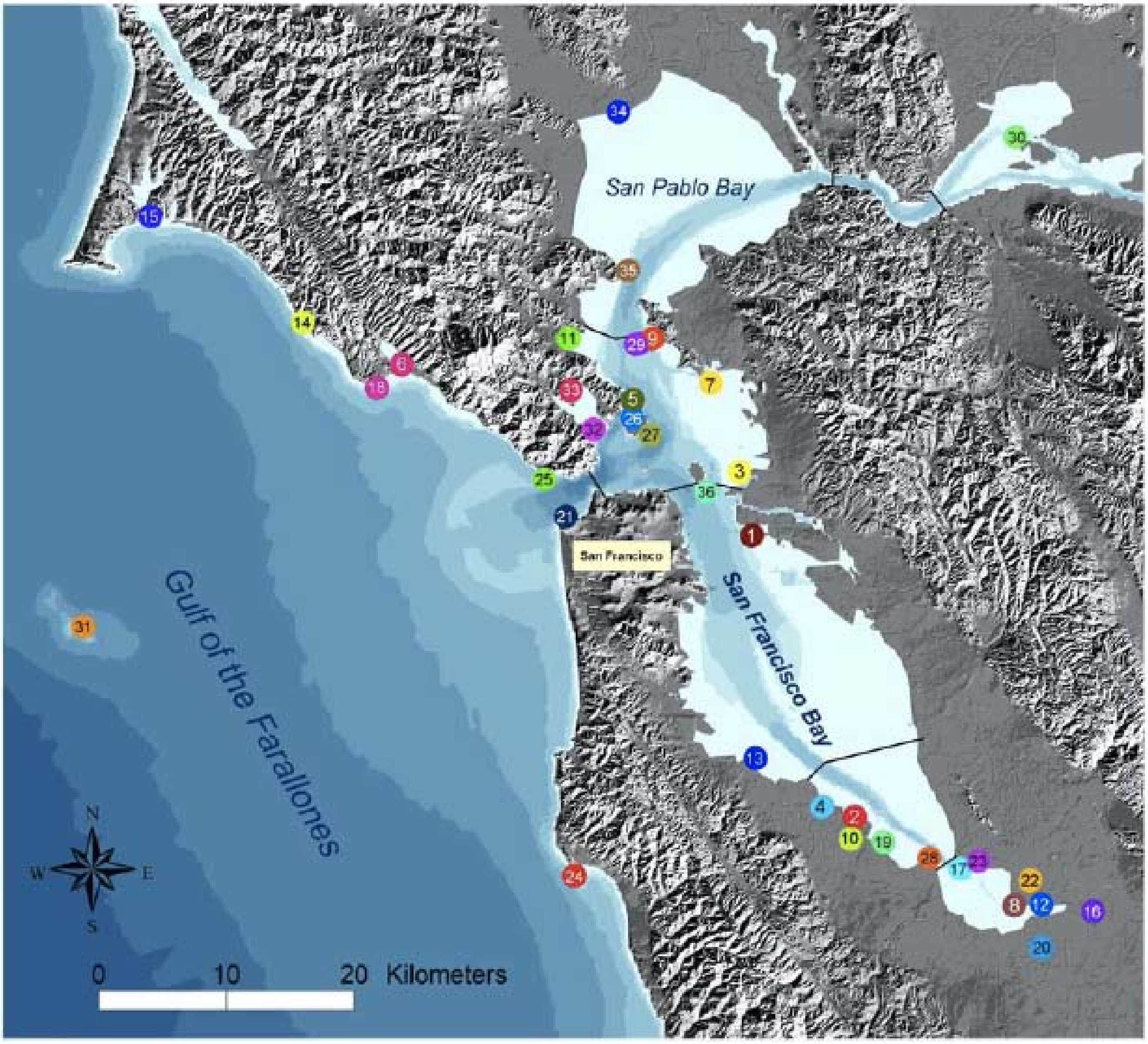
DESCRIPTION OF THE SPECIES

Harbor seals (*Phoca vitulina*) are the only marine mammal present in San Francisco Bay year round where they rest ashore on islands, tidal rocks, mudflats, and sand bars. Other marine mammals may visit the Bay seasonally to forage (California sea lions, *Zalophus californianus*) or occur at the mouth of the bay while migrating or foraging (gray whales, *Eschrichtius robustus*; harbor porpoise, *Phocoena phocoena*; bottlenose dophins (*Tursiops truncatus*), but harbor seals are year round residents. They use terrestrial areas (called haulouts) daily to rest between foraging trips and annually during breeding season (March-June) and molt (June-July). While substrate may vary, haulouts are generally characterized by gentle slopes, easy access to deep water and proximity to food (Allen 1991). The seals use the same haulouts year round and year after year, and generally seals have been using the same sites in the Bay for decades and in some cases for more than 60 years. Individual seals may frequent multiple haulouts within the Bay, and also move outside of the bay to coastal sites to the north and south. In the past, seals hauled out on a greater number of sites within the Bay, but researchers have concluded that seals abandoned some of these, likely because of human development and disturbance (Bartholomew 1949, Grigg et al. 2002).

During the breeding season, seals are more abundant onshore while nursing pups. Harbor seal pups are unusual for a pinniped because they are precocious and can swim at birth. Mating occurs in the water and male seals have "maritories" which are underwater territories near female haulouts that they defend from other males. Although their vocalizations are not elaborate, underwater vocalizations are apparently important to seal breeding (Hayes 2004a, Hayes 2004b).

Within a day, seals are generally more abundant onshore during the day time than at night, but may be present at haulout sites any time of the day or night when tide levels expose the substrate (rocks or tidal sandbars). Seals rest onshore for an average of 7 hours per day, and when seals are with pups or molting, average time onshore increases to 10-12 hours per day depending on availability of haulout space (Allen 1988).

There are nearly 30 haulout sites within San Francisco Bay, but the number of seals at most of the sites is small. There are 3 major sites, with more than 100 seals, located in the north, central and south bays (see Grigg et al. 2004). The number of seals in the Bay varies by site and by season. More seals are present overall in the Bay during the winter foraging period than during the spring breeding season. This pattern in the Bay is different from that reported at remote, nearby coastal sites where a higher abundance of seals occurs during the breeding and molt seasons (Codde and Allen 2013). Large concentrations of spawning Pacific herring (*Clupea pallasii*) and salmonids likely attract seals into the Bay during the winter months.



Map of current and historical haulout locations in San Francisco Bay and along the adjacent coastline from Green et al (2006).

1. Alameda Breakwater; 2. Bair Island; 3. Bay Bridge Sandspit; 4. Belmont Slough; 5. Bluff Point, Tiburon; 6. Bolinas Lagoon; 7. Brook's Island; 8. Calaveras Point; 9. Castro Rocks; 10. Corkscrew Slough; 11. Corte Madera; 12. Coyote Creek; 13. Coyote Point; 14. Double Point (PRNS); 15. Drakes Estero (PRNS); 16. Drawbridge; 17. Dumbarton Point; 18. Duxbury Reef; 19. Greco Island; 20. Guadalupe Slough; 21. Land's End; 22. Mowry Slough; 23. Newark Slough; 24. Pillar Point; 25. Pt Bonita; 26. Pt. Ione, Angel Island; 27. Pt Blunt, Angel Island; 28. Ravenswood Point; 29. Red Rock; 30. Ryer Island (Suisun Bay); 31. SE Farallon Island; 32. Sausalito Boatworks; 33. Strawberry Spit; 34. Tubb's Island; 35. Two Sisters; 36. Yerba Buena Island.

Harbor seals forage within and outside of the Bay and individual seals have been documented foraging in the Sacramento River as far north as Sacramento. Most seals, though, forage within the three primary bays with the largest haulout sites (Grigg et al. 2012). They are opportunistic eaters whose diet varies seasonally and even regionally within the bay (Gibble and Harvey 2015, Harvey and Torok 1994). Fish are the primary prey item but seals also forage on invertebrates such as shrimp (*Crangon* spp) and market squid (*Loligo opalesens*). More detailed information about harbor seal food habits and historical distribution within the bay can be found in the Goals Project 2000.

CRITERIA FOR SELECTION OF THE SPECIES

Harbor seals have been studied extensively over the past 50 years in SF Bay (Bartholomew 1949, Grigg et al. 2004). Globally, they are vulnerable to perturbations such as human disturbance, prey shifts, pollutants and disease outbreaks, and these same perturbations have affected seals in SF Bay (Paulbitski 1975, Riseborough et al. 1980, Harvey and Torok 1994, Allen 1991, Greig et al. 2011, Grigg et al. 2012).

Harbor seals are native to San Francisco Bay and are protected under the Marine Mammal Protection Act (MMPA) which was passed in 1972. In the 1970s and 1980s after passage of the MMPA, the harbor seal population in CA increased along the central CA coast with the growth slowing in the 1990s (Sydeman and Allen 1999). Within the bay, the population has been relatively stable or slowly increasing depending exactly where and when you count (Grigg et al. 2004). The current population estimate for the state of CA, based on a 2009 aerial count, is 30,196 seals (95% CI = 22,745–37,647; Harvey and Goley 2011) and within the bay, numbers are estimated at 500 – 600 seals (Grigg 2004, Lowry 2008). Seal numbers are monitored during the breeding and molt seasons in the Bay and along the coast by a network of biologists, and the data are summarized annually in a report (see website: http://www.sfnps.org/harbor_Seals/).

Harbor seals are of conservation concern and considered vulnerable to climate change due to 1) anticipated impacts on their habitat (intertidal zone) and lack of alternative habitats, and 2) indirect effects on food availability, haul out space, increased exposure to diseases and increased interactions with humans.

OTHER INFORMATION ABOUT THE SPECIES

A high number of SF Bay seals (~40%) exhibit a red coloration compared to other locations along the CA coast or even globally (Allen et al. 1993). This coloration is a result of iron oxide precipitation on the hair. Each summer when the harbor seals molt, the red hair is shed and replaced with silver hair; however, within a couple of weeks the rusty color returns again. While red seals often have brittle fur and short whiskers, there is no evidence of ill health (McHuron 2012) or differences in heavy metal accumulation in muscle or liver (Moser 1996). Nevertheless, one study suggested there was a correlation between red seals and pollutant loads (Kopec and Harvey 1995).

Harbor seals are easily disturbed by human activities adjacent to their haulout sites. Harbor seals are able to adapt to human presence which has enabled them to continue to breed in highly industrialized areas such as the San Francisco Bay; however, there is a threshold at which seals no longer tolerate human activities and will alter their haul out patterns or abandon a site if disturbances are chronic or if habitat is altered. In one study, seals hauled out more at night than during the day at one site in the Bay, likely because of disturbance (Grigg et al. 2002). Abandonment of haulout sites has also been documented within the Bay (Allen 1991). Alternatively, seals have also been documented using new haulout sites within the Bay where there are fewer disturbances (Lowry et al. 2008).

Pollutants in the Bay have been a concern since the 1970's when aborted fetuses were reported at multiple locations within the bay (Risebrough et al. 1980) and organochlorine concentrations have been detected in harbor seal tissues at levels known to cause reproductive and health effects in European harbor seals (Kopec and Harvey 1995, Neale et al. 2005). Mercury contamination is also an ongoing concern for harbor seals in the bay area (Brookens et al. 2007, Brookens et al. 2008, McHuron et al. 2014).

REVIEW OF CLIMATE CHANGE EFFECTS ON THE SPECIES

1. Loss of habitat with sea level rise or during extreme storm events.

Sea level rise, large storm events and erosion along the shoreline are predicted to increase and alter shorelines within the Bay. Loss of habitat is predicted to have a large effect on the intertidal haulout habitat of harbor seals (Largier et al. 2010). These sites are used for breeding and resting. The existing numbers of haulout sites where seals give birth are limited and there are few alternative sites available now or likely under the various sea level rise scenarios. Loss of this habitat will severely reduce the number of seals breeding in the bay, although seals may travel from elsewhere into the bay to forage.

2. Prey shifts with warming sea water temperature.

Pinniped populations are sensitive to environmental perturbations such as El Niño events, which cause shifts in their prey. During ENSO events, harbor seals produce fewer pups (Allen et al. 1989 Sydeman and Allen 1999, Becker et al. 2011). Since seals prey on what is locally abundant, changes in prey availability due to ENSO events likely reduce food for seals, possibly resulting in their inability to maintain a pregnancy. Intense ENSOs such as in 1998, may affect foraging and survival of adults as was documented in elephant seals (LeBoeuf et al. 2000). Reductions in prey availability could decrease body condition which could affect reproduction (decreased pregnancy rate) and health (decreased immunity, increased susceptibility to disease).

3. Pathogen range shifts with warming sea water temperature.

Harbor seals are susceptible to infection from a number of disease causing pathogens. As waters warm, many of these pathogens have the opportunity to expand into new geographic areas. As an example, morbilliviruses such as phocine distemper (PDV) have had devastating consequences on harbor seals in Europe (Härkönen et al 2006). To date, there have been no morbillivirus outbreaks in the Pacific and PDV has not been detected in SF Bay harbor seals (Greig et al. 2014). Recently, however, the strain of PDV that caused >30,000 deaths in harbor seals in Europe was detected in sea otters in Alaska (Goldstein et al. 2009). It is hypothesized that decreasing ice conditions in the arctic may have altered seal haulout and migration patterns and allowed contact between Atlantic, Arctic, and Pacific sub-species of harbor seals and other pinniped species that had not occurred previously. This highly infectious virus has the potential to infect the immunologically naïve harbor seals of the Pacific.

OTHER STRESSORS

1. Disturbance (hikers, kayakers, clammers, cars, motor boats, aircraft) and other interactions with humans (pollution, boat strike).

Even when disturbance does not result in direct mortality or haulout site abandonment it can have more subtle effects. For example, more pups are born at sites with lower disturbance rates (Codde et al. 2013). First year mortality among harbor seal pups also appears to be reduced in San Francisco Bay compared with nearby locations although the reasons for that are not clear (Greig 2011).

2. Disease (algal toxins, bacteria, viruses, protozoal, pollution).

Pollution has been a concern of harbor seals for decades because of the elevated levels of PCBs and DDEs in the seals of the Bay (Risebrough et al. 1980, Kopec and Harvey 1995). Lower reproduction and aborted fetuses were speculated to be associated with these elevated pollutant loads. More recently, pollutant concentrations in harbor seal tissue have been associated with immune systems effects, congenital defects, and first year survival (Neale et al. 2002, Neale et al. 2005, Harris et al. 2011, Greig 2011).

Combinations of stressors have been implicated in major population declines of harbor seals in other locations. Declines in harbor seals in Scotland since 2000 have been attributed to a combination of factors including human caused trauma, biotoxins, and possibly competition for food with other seal species (Thompson et al. 2001, Bexton et al. 2012, Hall and Frame 2010). During the 1988 PDV outbreak in the North Sea, contaminant concentrations in the blubber of seals that died from PDV were greater than in seals that survived the outbreak (Hall 1992). Synergistic effects are also possible among these additional stressors; embryonic exposure of zebrafish (*Danio rerio*) to DDT enhanced their susceptibility to seizures induced by domoic acid suggesting that in utero contaminant exposure could have the same effect on marine mammals (Tiedeken and Ramsdell 2009).

3. Human land use will also continue to affect the bay in terms of chemical pollutants, and increased nutrients entering the bay. For example, as use of new flame retardant chemicals increases, these emerging chemical may enter the Bay food chain (Klosterhaus et al. 2012).

LIFE CYCLE CONSIDERATIONS

One pup is born per year per female (March – May), females are reproductive at 3 to 5 years of age. Females are presumed to pup every year thereafter with no data on senescence. Females can live to 15 or 20 years old. After birthing, females nurse pups for 30 days and then wean them. After weaning, pups forage alone, and first year survival is highly variable depending on year and location (Lander et al. 2002, Oates 2005, Greig 2011). Females skip pupping during ENSO years. Males do not contribute to rearing pups. Mortality can be as high as 80% during the first year of life making this is a critical life stage for the species.

FACTORS THAT MAY AFFECT SPECIES RESILIENCE

Harbor seals are very resilient to the occasional bad year (El Niño for example), but not to sustained, chronic change/disturbance which can result in abandonment of habitat areas (Bartholomew 1949, others). If alternate suitable habitat is available near disturbed haul out sites, seals may shift to new haul out sites (Allen et al. 1985).

Harbor seals within the bay have exhibited resilience to sustained predictable disturbance by **s**witching from a diurnal to nocturnal haulout pattern as a result of activity on the Richmond Bridge (Grigg et al. 2002). Seasonal closure of haulout sites has resulted in an increase in seal numbers and pupping (for example, Point Bonita in SF Bay, Codde et al. 2013).

Harbor seals also have exhibited an ability to switch prey within the Bay, eating non-native yellow gobies when they became more abundant (Gibble and Harvey 2015, Harvey and Torok 1994).

LIKELY CLIMATE CHANGE IMPACTS AND RISKS

1. Loss of resting and nursery habitat with sea level rise or during extreme storm events

2. Prey shifts with warming sea water temperature, ocean acidification

3. Changes in disease ecology/risk – pathogens may undergo range shifts with warming water and changes in salinity.

MANAGEMENT ACTIONS TO BE CONSIDERED

Short-term v. long-term recommendations – focus on thresholds

1. Maintain current mudflat/rocky habitat and buffer from human population (ie. maintain or decrease level of disturbance).

North Bay: Castro Rocks, Ryer Island, Corte Madera mudflats, East Brother Island

Central Bay: Yerba Buena Island, Angel Island

South Bay: Mowry/Newark/Alviso Sloughs; Bair Island/Corkscrew Slough

This includes restoration or other environmental management efforts which have the possibility to reduce disturbance of seals. If sea level rises, this will result in the inundation and loss of current habitat, but more will form if human development is maintained far enough away from the shoreline. For example, the restoration of south bay salt ponds to wetland habitat is a great opportunity for creating seal habitat including potential haul out sites for harbor seals. They currently haul out in several sloughs on the edge of the old salt ponds. Additionally, there is potential alternative shoreline habitat on Red Rock Island (private land) and Angel Island (California State Park) if disturbances are reduced.

2. Monitor seals within the bay for changes in behavior, numbers, and habitat use and develop a seal monitoring program in the bay to address some of the data gaps highlighted below.

For seal populations along the coast, the National Park Service recommended the following (Allen 2011):

1. Monitor the population and links to environmental conditions

2. Reduce disturbance and fisheries interactions

3. Restore pinniped habitats

4. Communicate with the public

UNCERTAINTY AND KNOWLEDGE GAPS

There is uncertainty about the harbor seal response to climate change stemming in part from the data gaps in knowledge of harbor seal population dynamics within SF Bay (detailed below), and also from the unpredictability of these animals. Additionally there is uncertainty regarding the effects of climate change on prey availability and disease ecology. This uncertainty does not change the importance of maintaining haulout areas to increase seal flexibility and resilience.

Important Data Gaps

We are missing the data needed to monitor and model the population of seals within San Francisco Bay:

1. Basic information on number of seals and habitat use within the bay. Are there potential new haulout locations within the bay where numbers are increasing already (for example, Ryer's Island in the north bay), or locations that have the potential to absorb seals (Red Rock Island and Angel Island)?

2. Demographic data - Pregnancy rate, mortality and survival rates

3. Movements and habitat use

4. Synergistic effects of disease, pollutants, and disturbance on health and survival

5. Diet. Although there have been periodic studies on the diet of seals in the bay, there have been no long term studies to document seasonal and inter-annual changes in diet. For example, how does diet change during ENSO events?

All of these gaps would be optimally addressed by a comprehensive, ongoing monitoring program.

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