Title
The Impact of Sea-Level Rise on Pinniped Haul-Out Sites Along the California Coast

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The Impacts of Sea-Level Rise on Pinniped Haul-Out Sites along the California Coast

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Abstract

Over the past century sea level has risen more than 20 cm along the California coast, and it is projected that under medium-high emissions, mean sea level will rise by 1.4 m over the coming century. The likelihood of losing current beach habitat due to sea-level rise constitutes a major threat for many wildlife species, such as pinnipeds that require terrestrial habitat for breeding, pupping, molting, and resting. This study applies GIS to analyze the impacts of sea-level rise on pinniped haul-out sites along the central and southern California coast. ArcMap was used to overlay inundation data with haul-out sites of three abundant California pinniped species: California sea lions (*Zalophus californianus californianus*), Pacific harbor seals (*Phoca vitulina richardsi)*, and Northern elephant seals (*Mirounga angustirostris*). Affected area due to sea-level rise was also quantified for Northern elephant seal haul-out sites. GIS data showed that approximately 99% of haul-out sites among all species were affected throughout central and southern California. Furthermore, over 373,000 m^2 of elephant seal habitat were found to be affected by sea-level rise. These impacts may result in loss of pinniped habitat, redistribution of haul-out sites, and controversy over land use for humans or for pinnipeds. Given the potential for conflict, policymakers should begin to assess the Marine Mammal Protection Act and Coastal Act to ensure that these legislations will be able to meet management needs. Furthermore, adaptation strategies such as structural protection may help alleviate pressure on pinniped habitat and prevent future controversy over land allocation.

Background

Climate change and sea-level rise

Climate change has been observed from increased global mean air and ocean temperatures, rising mean global sea level, decreased snow and ice extent, and the frequency and intensity of extreme weather events (IPCC 2007). Increases in global mean surface temperatures have risen by 0.8°C over the last 100 years (Hansen et al. 2006). At the same time, increases in sea level have been recorded at 1.8 mm per year over the last 42 years (IPCC 2007). The majority of sea-level rise is contributed by thermal expansion of the ocean, with another significant contribution by surface ice melting, both of which are linked to increasing temperatures (IPCC 2007). These changes have already begun to impact natural systems (IPCC 2007). While sea level has fluctuated during the last 20,000 years, current rates of sea-level rise have not been experienced for the past 5,000 years (Church et al. 2001) and may also be increasing faster than previously projected (Rahmstorf 2007).

Islands and coastal areas are extremely susceptible to rising seas. California's coastline, which includes more than 1,800 kilometers of open coast and enclosed bays, wetlands, and estuaries, is particularly vulnerable to sea-level rise resulting from climate change (Heberger et al. 2009). Sea level has risen more than 20 cm along the California coast over the past century (Figure 1), and it is projected that sea level will continue to rise at accelerating rates in the future (Cayan et al. 2009; Heberger et al. 2009).

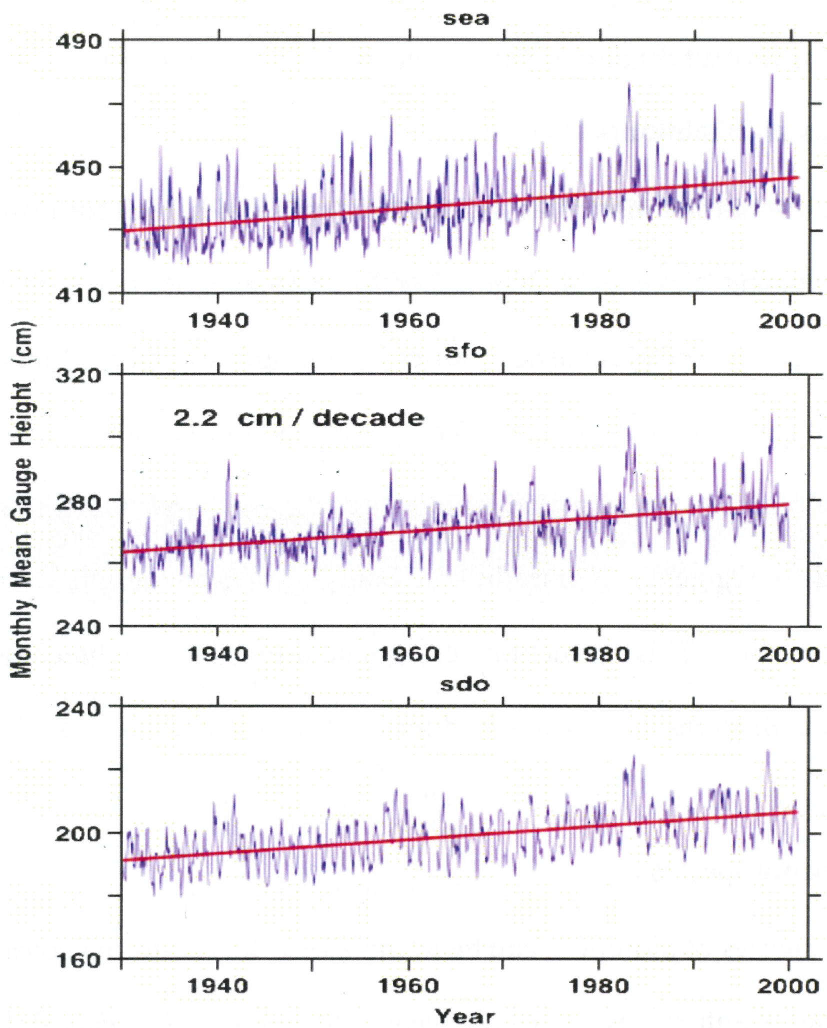

Figure 1. Sea-level rise along the West Coast over the last century. Data show observed monthly mean sea level (cm) from three tide gauges in Seattle, San Francisco, and San Diego. Cayan et al. 2008.

Potential impacts of sea-level rise include increased frequency of flooding events and coastal erosion, both of which may lead to substantial changes of the bathymetry and topography of soft coastal margins (Hunter 2010). In response to rising seas, beaches are also expected to shift landward (Fish et al. 2008). While many beaches may be able to migrate, those that cannot retreat may be lost to sea cliffs or developed coastline, including roads, buildings, parking lots, and other infrastructures. Development along the California coast is extensive, and the likelihood of losing current beach habitat within the next century constitutes a major threat for many wildlife species.

Pinnipeds as coastal inhabitants

Pinnipeds are marine mammals that require terrestrial habitat for resting, molting, parturition, and nursing (Baker et al. 2006); therefore sea-level rise may affect pinniped populations. Length of time spent ashore varies among species, but the highest densities can be observed during the molting and breeding seasons (Burns 2009, p. 538; Hindell and Perrin 2009, pp. 366-367). Areas where pinnipeds come ashore are known as haul-out sites, and annual breeding aggregations at traditional haul-out sites are designated as rookeries (Antonelis 2009, p. 986). This distinction between haul-out sites and breeding sites is significant because affecting rookeries would impact the breeding success of pinniped populations.

Abundant California species

While six species of pinnipeds can be found along the California coast, three species are most abundant: California sea lions (*Zalophus californianus californianus*), Pacific harbor seals (*Phoca vitulina richardsi*), and Northern elephant seals (*Mirounga angustirostris*). Each species shows variability in use of terrestrial habitat (Table 1). The Pacific harbor seal is a subspecies of harbor seal that ranges from Baja California to the Pribilof Islands in Alaska (Carretta et al. 2007). These pinnipeds haul-out on near-shore coastal and estuarine areas, offshore islands, intertidal sandbars, rocky shores, and beaches (Lowry et al. 2005). Harbor seals use haul-out sites throughout the year but more frequently and in greater numbers during the pupping and molting seasons. Pupping occurs from February to April, and molting occurs from mid-summer to early autumn (Burns 2009, pp. 539-540). The breeding and pupping areas of harbor seals are vastly different from those of elephant seals and sea lions. Harbor seals will haul-out in small numbers at many different sites. In California alone there are an estimated 400-600 haul-out sites (Hanan 1996; Lowry et al. 2005), and several of these are used for pupping. Harbor seals breed soon after pups are weaned, typically about 4 weeks after birth, and breeding takes place in the water (Burns 2009, p. 539).

Species/Subspecies	Habitat Preference	Number of Haul-Out Sites[1]	Number of Individuals per Site[2]
California Sea Lion (*Zalophus californianus californianus*)	Remote sandy beaches, small to medium sized rocky islands, and piers.	30	812
Pacific Harbor Seal (*Phoca vitulina richardsi*)	Near-shore coastal and estuarine areas, offshore islands, intertidal sandbars, rocky shores, beaches, and man-made structures.	423	52
Northern Elephant Seal (*Mirounga angustirostris*)	Islands, remote sandy beaches (usually with gradual slopes), and sand spits.	31	224

Table 1. Differences in habitat preference, number of haul-out sites, and haul-out size of three common pinnipeds in California: California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina richardsi*), and Northern elephant seals (*Mirounga angustirostris*).
[1]Based on number of haul-out sites surveyed in central and southern California (Mark Lowry, unpublished data).
[2]Based on average number of individuals across all central and southern California haul-out sites. (Mark Lowry, unpublished data).

Northern elephant seals range as far north as Alaska and as far south as Mexico (Carretta et al. 2007). They prefer gradually sloping sandy beaches or sand spits on remote islands and coasts (Le Boeuf and Laws 1994, Carretta et al. 2007). Unlike harbor seals, elephant seals demonstrate seasonal use of haul-out sites, and approximately 80% of their life cycle is spent at sea (Hindell and Perrin 2009, p. 366). Elephant seals will haul-out during the breeding season from December-March and return to the same breeding grounds to molt between April and August (Hindell and Perrin 2009, p. 365; Carretta et al. 2007). Since haul-out sites are used primarily for breeding they are often referred to simply as breeding sites. Currently 15 breeding colonies exist from Point Reyes to the Baja California peninsula, and most of these sites are within U.S. waters (Hindell and Perrin 2009, pp. 364-366).

The California sea lion subspecies ranges from British Columbia to the Baja California peninsula and Gulf of California (Carretta et al. 2007). Two other subspecies of California sea lion exist outside of California (Heath and Perrin 2009, p. 170), but for this report the California subspecies will be termed California sea lion. California sea lions tend to use remote sandy beaches, small to medium sized rocky islands, and even piers (NCCOS 2007). Major rookeries are located on the Channel Islands and other islands off southern California, western Baja California, and the Gulf of California (Carretta et al. 2007), and pupping occurs from May to June (Lowry and Maravilla-Chavez 2005). Noting the differences in use and characteristics of haul-out sites among these species is significant because it allows for predictions to be made regarding the impacts of sea level-rise on particular habitats.

Objective

While various characteristics influence the suitability of pinniped habitat, including presence of marine predators, currents, disturbance, undersea topography, tidal height, and proximity of the sites to regions of high ocean productivity (NCCOS 2007), this project focuses primarily on the impacts of sea-level rise on mainland coastal habitats currently used by the three abundant California pinniped species and subspecies. Specifically, this study aims to show the number of haul-out sites that may be affected and the extent of impact on selected areas. Estimating potential changes in pinniped haul-out sites and distributions may help policymakers in their evaluation of sea level-rise impacts on coastal resources. Since controversy may result over land use if space becomes more limited, this report introduces several policy implications and potential adaptation strategies that may help prevent future conflict over use of coastal land for humans or for pinnipeds.

Methods

Study area

Haul-out sites and sea-level rise data were analyzed in 15 counties of central and southern mainland California (Figure 2). Central California included Marin County through San Luis Obispo, and southern California included Santa Barbara through San Diego. Analysis of the mainland also included near-shore islands. Portions of Santa Barbara, Los Angeles, and Orange counties as well as a number of small rocks and remote offshore islands were excluded from the analysis of affected sites due to data deficiency of sea-level rise predictions for these areas. Northern California was also not included in the analysis due to deficiency of current California sea lion site and abundance data.

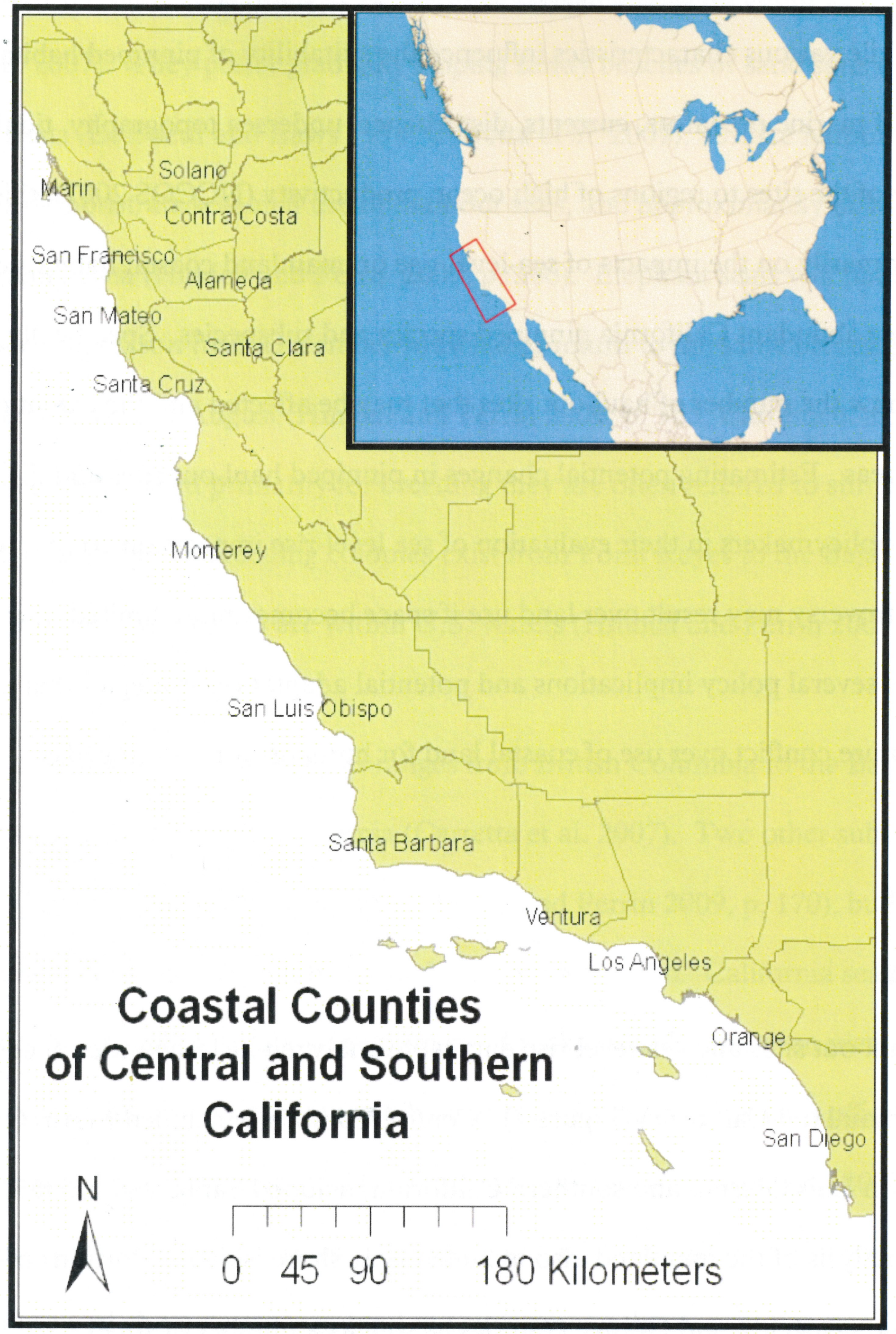

Figure 2. The central and southern California coast. Haul-out sites in 15 coastal counties were analyzed for impacts of sea-level rise

Data sources

Pinniped data

Elephant seal haul-out site and abundance data for Marin County were taken from *The Northern Elephant Seal Monitoring 2005-2007 Report* provided by Point Reyes National Seashore. These reports included ground surveys of pups, weaners, and females during the 2007 breeding season as well as estimates of total population size for each site (Adams et al. 2008). Maps of each haul-out site showed general vicinities of breeding areas. South of Marin County, raw elephant seal data was provided by Mark Lowry of Southwest Fisheries Science Center (SWFSC) (unpublished data). These data included aerial and ground survey counts for 2005 of adult males, females, juveniles, and pups at each haul-out site, which were also taken during the breeding season. Each haul-out site was assigned longitude and latitude end points that designated boundaries where sightings occurred.

Site and abundance data surveyed in 2004 for harbor seals and 2007 for California sea lions were also provided by Mark Lowry (unpublished data). Harbor seal data were collected during the molting season and included total counts on land. California sea lion data were taken at the end of the breeding season and included counts of pups, juveniles, adult females/young males, subadult males, and adult males. Both harbor seal and sea lion counts were taken from aerial surveys and included latitude and longitude points for each site.

Sea-level rise projections

The Intergovernmental Panel on Climate Change (IPCC) special report on emission scenarios (SRES 2000) includes six scenarios of emissions that explore alternative development pathways, covering a wide range of demographic, economic, and technological driving forces and resulting greenhouse gas emissions (Heberger et al. 2009). Numerous global projections of sea-level rise have been made depending on these emission scenarios and parameters of the model used to make the projections.

Projections for California that apply to this analysis assume that sea-level rise in California will be the same as the global estimates (Cayan et al. 2009). Furthermore, these estimates are based on the link between global sea surface temperature and global sea-level rise (Cayan et al. 2009). The projections also account for the impact of artificial dams and reservoirs, which have changed surface run-off into the oceans (Chao et al. 2008; Cayan et al. 2009). Taking water impoundment into account, Cayan et al. (2009) projected a 1 m rise under medium (B1) emissions, a 1.4 m rise under medium-high (A2) emissions, and a 1.5 m rise under high (A1F1) emissions for California by the year 2100 (Cayan et al. 2009)(Figure 3). The A2 scenario presents a future where economic growth is uneven, the income gap remains large between now-industrialized and developing parts of the world, and technology diffuses more slowly (IPCC 2007). The B1 emissions scenario presents a future with a high level of environmental and social consciousness resulting in more sustainable development (IPCC 2007). The A1F1 storyline is primarily characterized by high-level use of fossil fuels (Heberger et al. 2009).

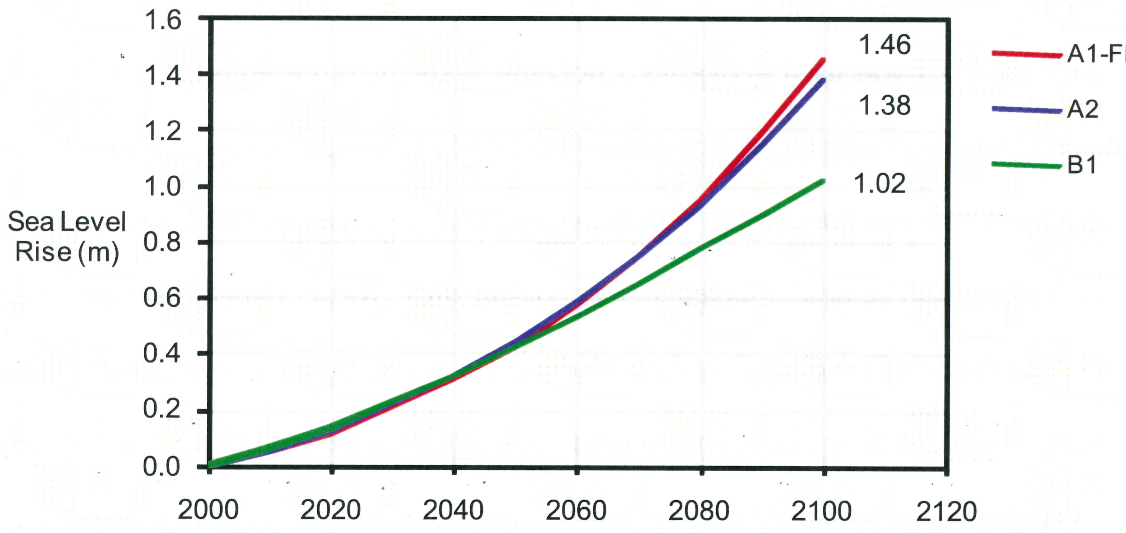

Figure 3. Sea-level rise projections for California by the year 2100 under IPCC A1F1, A2, and B1 scenarios. Cayan et al. 2009. Interpreted by Heberger et al. 2009.

GIS data for sea-level rise predictions

Shapefiles for sea-level rise predictions were obtainable from the Pacific Institute's report on *The Impacts of Sea-Level Rise on the California Coast* (Heberger et al. 2009). Two files were used for a majority of the coastline, while one file provided data for the San Francisco Bay Area. One of the coastline files represented area inundated by mean higher high water (MHHW) under baseline conditions (year 2000), and the other represented area inundated by MHHW under a 1.4-meter rise in sea level (year 2100). Both coastline predictions were represented as polygon shapefiles. A raster shapefile of areas inundated after a 1.4-meter rise in sea level was used for the San Francisco Bay Area.

Mapping and analysis

ArcMap 9.3.1 was used to overlay a polygon shapefile representing MHHW under current conditions with a polygon shapefile of MHHW under a 1.4-meter rise in sea level. The area bound between the current high water line and the predicted high water line by 2100 was estimated to be total affected area at coastal sites. Raster data of area inundated by MHHW in the San Francisco Bay Area under a 1.4 m rise in sea level was also displayed in ArcMap. Harbor seal, sea lion, and elephant seal site data were plotted in ArcCatalog and point shapefiles were created for every site of each species. These points were then overlaid with MHHW polygons and raster data using ArcMap.

Calculating number of sites per county

Since the harbor seal and sea lion data were recorded as single points that represented larger areas, these data were used as reference points rather than exact locations and size of the site area. In order to provide a better perspective of the sites, a buffer of 50 m was set around each point. To calculate number of affected sites, each buffered point was individually examined to see if it fell within the area inundated by MHHW with a 1.4-meter rise in sea level. If this buffered site overlapped an area of inundation, it was designated as "affected". For this study, "affected" indicated that sea-level rise may alter the site in some way – either the site will decrease in size, migrate landward, or be completely inundated, although this study did not distinguish between the three categories.

A buffered site on the mainland that did not overlap with inundated area was designated as "unaffected" by sea-level rise. However, buffered sites on near-shore islands that showed no overlap but were surrounded by inundation were still designated as "affected", since these sites exhibited visibly limited area. Lastly, buffered sites that did not overlap with any land or inundation data were designated as "data deficient". These sites were most likely small offshore rocks that were not recognized in the Pacific Institute's GIS analysis, which excluded remote islands less than 500 square meters in size (Heberger et al. 2009). After designating affected areas, a shapefile of California county boundaries was layered over the haul-out site data in order to calculate number of sites affected for each county. Since sea-level rise data was not available at every haul-out site, the total number of sites calculated in this analysis does not accurately reflect the total number of haul-out sites that have been counted in past pinniped surveys for central and southern California.

Elephant seal haul-out site data provided end points for every site in Año Nuevo, Piedras Blancas, and Gorda breeding colonies. This allowed for boundaries of beach length to be accurately set for each colony. Beach length was estimated for sites in Point Reyes based on maps from the elephant seal monitoring report, which showed encircled areas used by elephant seals at three different major breeding areas: South Beach, Point Reyes Headlands (a.k.a. Main Colony), and North Drakes Beach. The distance between MHHW polygons equaled inundated beach width. New polygon shapefiles were then created for each breeding site, and affected area was calculated in ArcMap. Area of habitat affected was summed for each sub-site, site, then totaled across all breeding sites. For elephant seal sites, "affected area" described the area (m^2) that would be inundated by sea-level rise. This term was used for all sites excluding Año Nuevo Island, which was described as "habitat loss", since the island showed noticeably limited area surrounded by inundation.

Population size estimates were also presented to show number of animals that may be affected at each breeding colony. The Northern elephant seal monitoring report provided these estimates for each of the breeding sites in Point Reyes. Estimates were based on a 3.5

pup count multiplier that was used with the maximum total of pup and weaner counts by colony to estimate total population size (Adams et al. 2008). For Gorda, Piedras Blancas, and Año Nuevo colonies, population estimates were calculated using the same method as Point Reyes with total live and dead pup counts, which were provided by Mark Lowry (unpublished data).

Results

Number of sites affected

Areas inundated by MHHW with a 1.4 m rise in sea level show that 193 of 195 (99%) sites from Marin county to San Diego will be affected (Table 2). Monterey County showed the highest number of affected sites with 61 of 62 sites affected. However, Monterey also contained the highest number of haul-out sites of any county analyzed in this study. San Luis Obispo followed with 49 of 50 sites affected. In both counties, harbor seal haul-out sites contributed to a large majority of affected sites (Figure 5), and among all counties, harbor seal sites contributed 69% of the total affected sites (Table 2). This was essentially due to the considerable number of harbor seal haul-out sites that have been observed in past surveys (Figure 4).

Figure 4. Distribution of Northern elephant seal (*Mirounga angustirostris*), California sea lion (*Zalophus californianus californianus*), and Pacific harbor seal (*Phoca vitulina richardsi*) haul-out sites along the central and southern California coast. County boundaries were used to calculate number of affected sites in each county. Not all sites shown above were included in this study. (Mark Lowry, unpublished data).

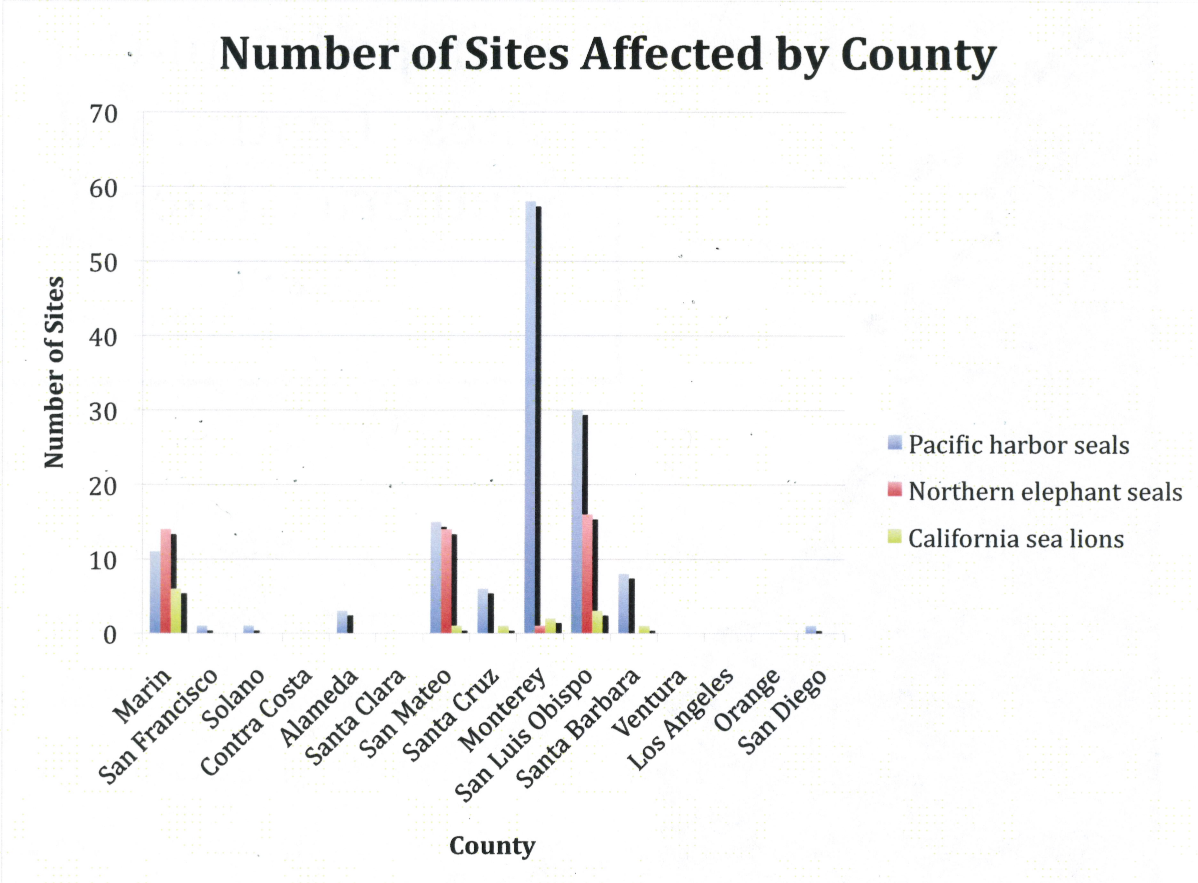

Figure 5. Number of affected haul-out sites in 15 counties along central and southern California with a 1.4 m rise in sea level. Three common California pinniped species/subspecies are shown: Pacific harbor seals in blue, Northern elephant seals in red, and California sea lions in yellow.

Overall, 99% of the harbor seal haul-out sites were affected, and 100% of both elephant seal and sea lion sites were affected. Most of the affected and total haul-out sites were also concentrated in central California, and southern California accounted for only 5% of total affected sites.

	Pacific Harbor Seals (*Phoca vitulina richardsi*)		Northern Elephant Seals (*Mirounga angustirostris*)		California Sea Lions (*Zalophus californianus californianus*)		All Species	
County	Number (%) of Sites Affected	Total Sites[1]	Number (%) of Sites Affected	Total Sites	Number (%) of Sites Affected	Total Sites	Number (%) of Sites Affected	Total Sites
Marin	11 (100)	11	14 (100)	14	6 (100)	6	31 (100)	31
San Francisco	1 (100)	1	0	0	0	0	1 (100)	1
Solano	1 (100)	1	0	0	0	0	1 (100)	1
Contra Costa	0	0	0	0	0	0	0	0
Alameda	3 (100)	3	0	0	0	0	3 (100)	3
Santa Clara	0	0	0	0	0	0	0	0
San Mateo	15 (100)	15	14 (100)	14	1 (100)	1	30 (100)	30
Santa Cruz	6 (100)	6	0	0	1 (100)	1	7 (100)	7
Monterey	58 (98)	59	1 (100)	1	2 (100)	2	61 (98)	62
San Luis Obispo	30 (97)	31	16 (100)	16	3 (100)	3	49 (98)	50
Santa Barbara	8 (100)	8	0	0	1 (100)	1	9 (100)	9
Ventura	0	0	0	0	0	0	0	0
Los Angeles	0	0	0	0	0	0	0	0
Orange	0	0	0	0	0	0	0	0
San Diego	1 (100)	1	0	0	0	0	1 (100)	1
Total	**134 (99)**	**136**	**45 (100)**	**45**	**14 (100)**	**14**	**193 (99)**	**195**

Table 2. Number of affected sites for Pacific harbor seals, Northern elephant seals, and California sea lions in 15 coastal counties of central and southern California. Percent of sites affected is shown in parentheses for comparison.
[1]Sites for which data were available.

Area of affected elephant seal habitat

A total of 373,140.16 m^2 of elephant seal habitat was affected among all breeding sites (Table 3, Appendix: pp. 30-33). Piedras Blancas showed the largest affected area with 225,370.80 m^2, followed by mainland Año Nuevo with 72,718.17 m^2. Affected area among all breeding sites at Point Reyes was totaled at 69,623.28 m^2. According to the 2005 and 2007 elephant seal counts (Mark Lowry, unpublished data), the largest estimated population of elephant seals was 12,106.5 and 8,302 at Piedras Blancas and Año Nuevo, respectively. While Point Reyes Headlands showed only 10,000 m^2 of affected area, this site provided habitat for approximately 1,319 animals. The total estimated population size across all sites analyzed in this study was 15,610.

Rookery Site	Affected Area (m^2)	Estimated Population[1]
Piedras Blancas	225,370.80	12,106.5
Año Nuevo		
Año Nuevo Island	4,997.79	1,715
Año Nuevo Mainland	72,718.17	6,587
Total Año Nuevo	77,715.96	8,302
Gorda	430.12	9,34.5
Point Reyes		
South Beach	43,368.60	84
Point Reyes Headlands	9,917.24	1,319
North Drakes Beach	12,510.41	882
NDB Subsite 1	1,898.63	N/A
NDB Subsite 2	863.83	N/A
NDB Subsite 3	1,064.57	N/A
Total North Drakes Beach	16,337.44	882
Total Point Reyes	69,623.28	2,819
Total All Sites	373,140.16	15,610

Table 3. Affected area (m^2) of 4 major elephant seal rookeries along the central and southern California coast with a 1.4 m sea-level rise. Estimated population size is also presented for each breeding site to show relative use of the sites to the overall population along the coastline.
[1]Based on pup count multiplier of 3.5

Discussion

Nearly every haul-out site along the coast was affected by a 1.4 m rise in sea level. The total number of affected sites among each species and subspecies was influenced by the scope of the study area and the biology of the animals. For example, since many of the California sea lion haul-out sites were located farther offshore, these remote islands were not included in the data and limited the analysis of affected areas observed for the subspecies. However, we could still make predictions of how sea lion sites may be affected by sea-level rise based on preferred sea lion habitat. It is important to note that these animals are more mobile on land and may haul-out on high rocks or man-made structures where sea-level rise may have less impacts.

Since harbor seals typically haul-out in small numbers and in hundreds of different locations, a majority of affected sites per county were represented by the large number of harbor seal haul-out sites that exist. However, many of the sites that exist are located on small, near-shore rocks and reefs; therefore they could not be recognized in the sea-level rise inundation data and were designated as data deficient. Again, the habitat of harbor seals is characterized by shallow slopes that are currently at extremely low elevations. Some of these already fall under MHHW and will most likely be impacted by sea-level rise in the future.

Elephant seal habitat was affected at every site analyzed, and most sites showed thousands of square meters of affected habitat. Since hundreds to thousands of elephant seals will haul-out in a few select sites, and nearly 400,000 square meters of total habitat was affected, populations at these sites may be heavily impacted in the future. Furthermore, there are only five mainland elephant seal rookeries in California (Piedras Blancas, Gorda, Año Nuevo, Point Conception, and Point Reyes), and all four breeding sites that could be analyzed in this study were affected. Since elephant seals prefer shallow sloping beaches, the remaining offshore and mainland sites may be particularly vulnerable to inundation with even small rises in sea level.

Sea-level rise and beach migration

The data presented in this report show that a majority of haul-out sites will be affected by a 1.4 m rise in sea level. A number of haul-out sites on offshore rocks or shallow islands will most likely be completely inundated. However, the impacts on larger islands and mainland beaches are more difficult to predict. Beaches backed by open land will be able to retreat, and habitat at these areas may experience few effects from sea-level rise. Natural barriers such as sea cliffs may ultimately erode to form new beach, but some may not erode fast enough to keep up with rates of sea-level rise. The rate of sea cliff erosion and overall seacliff retreat depends on the degree of wave action as well as the lithology and material strength of the cliff (Griggs et al. 2000). Artificial barriers, including parking lots, buildings, and other infrastructures also threat beach migration; however, they pose a much larger problem to coastal habitats regarding the potential for human conflict.

Policy implications

Given that thousands of square kilometers of coastal area are currently used by pinnipeds along central and southern mainland California, and much of this area will be affected in the future, an equivalent quantity of area needs to be available inland in order to avoid habitat loss at haul-out sites. If beaches cannot migrate landward to compensate for inundated haul-out area, we may see dramatic changes in the distribution of pinniped species. Animals may migrate to existing haul-out sites on offshore islands, new beaches along the coast, or simply landward with the migrating beach. However this distribution changes, there are potential conflicts that may arise over use of coastal habitat for humans or for seals. Humans will then be responsible for deciding the fate of sites backed by artificial barriers. Furthermore, the potential for redistribution of pinnipeds along the coast will need proper management. What will be the outcome if pinnipeds choose to haul-out at recreational beaches or on private property? The policy implications behind this potential conflict involve the assessment of current legislation as well as the need for climate change adaptation strategies.

The Marine Mammal Protection Act

The Marine Mammal Protection Act (MMPA) prohibits, with some exceptions, the take of marine mammals by U.S. citizens on the high seas and the take of marine mammals in U.S. waters (MMPA 1972). "Take" under the MMPA means to "harass, hunt, capture, collect, or kill, or to attempt to harass, hunt, capture collect, or kill any marine mammal" (MMPA 1972). Included in a list of "take" examples are "restraint and detention" and "the doing of any other negligent or intentional act which results in disturbing or molesting a marine mammal" (MMPA 1972). With the potential for competing space along the California coast and the movement of pinnipeds to new areas, government officials and citizens will turn to the MMPA to serve their management needs. A recent controversy over the MMPA was highlighted in La Jolla, California, over use of the Children's Pool for direct human use or for seal habitat. Many local citizens wanted to disperse the animals from the beach, but groups who argued in favor of the seals referred to the harassment aspect of the MMPA. Those in favor of returning the beach for recreation referenced exceptions to the MMPA. These exceptions allow the take of marine mammals by government officials or employees in their course of duty for the protection or welfare of the marine mammal or protection of public health or welfare (MMPA 1972). The water quality of the Children's Pool cove that had declined well below state standards after the harbor seals occupied the beach was perceived as a public health issue.

In addition, the MMPA does not require habitat protection for marine mammals. Rather the Act suggests that "efforts should be made to protect essential habitat including the rookeries, mating grounds, and areas of similar significance for each species of marine mammal from the adverse effect of man' s actions" (MMPA 1972). Therefore, if new haul-out sites begin to conflict with area that is used by humans, these sites are not guaranteed legal protection.

The controversy over use of the Children's Pool cost the City of San Diego over $1 million in court fees as well as years of heated conflict among environmental groups and local citizens. Using the Children's Pool episode as a lesson, local governments and policymakers should consider how current legislation could address future conflicts that may arise. Government officials will be forced to interpret the MMPA in favor of pinniped haul-out site protection, or they may identify circumstances as exceptions to the Act.

The California Coastal Act

Californians should consider another piece of legislation, the Coastal Act, to address climate change and sea-level rise along the California coast. The Coastal Act aims to "protect, maintain, enhance, and restore the overall quality of the coastal environmental zone and its natural and artificial resources…while also taking into account the social and economic needs of the people of the state" (California Coastal Act 1976). This legislation is a significant policy tool in the decision-making process of coastal resource allocation and will be needed to serve management of land use for both pinnipeds and humans.

The California Coastal Commission, a state agency responsible for mandating the Coastal Act, has already identified the need to consider climate change and potential sea-level rise through its planning, regulatory, and educational activities (California Coastal Commission 2009). Communicating the goals of the Coastal Act to local governments and citizens will be necessary to ensure that coastal resources are addressed in development and management plans, particularly where areas of human development currently overlap with pinniped sites or areas where new development is proposed. Regarding both the MMPA and the California Coastal Act, policymakers should begin to consider if these laws are capable of addressing future issues or if there are gaps in current legislation. If such legislation does not meet potential management needs, it should be amended for climate change and sea-level rise. Given the probability that controversy will arise, a closer analysis of the MMPA, CCA, and other of pieces of legislation concerning coastal policy would be beneficial to the State of California.

Adaption strategies for haul-out sites

In addition to legal protection of haul-out sites, physical protection may also be necessary. This may include structural protection measures at current or potential sites. Beach nourishment can restore the width of an eroding beach on a temporary basis as well as provide long-term restoration in certain types of areas (Heberger et al. 2009). However, this mode of protection requires costly offshore dredging and pumping to the desired site. Breakwaters are also an option, which reduce wave heights and littoral drift (Heberger et al. 2009). Though the breakwater at the Children's Pool in La Jolla was constructed to offer a protective recreational swimming cove, it now serves as an example of how such man-made structures can create suitable pinniped habitat.

Prohibiting development on natural lands adjacent to beaches at risk may also help alleviate potential impacts on haul-out sites. These "buffers" could be set directly landward from the beach, which would allow the beach to retreat, or at sites nearby to offer habitat for migrating animals. The decision to protect potentially affected sites should be site and species specific. For example, protecting a large elephant seal rookery would be evaluated differently than protecting smaller harbor seal haul-out sites. These decisions should also be based on the significance of the haul-out site to the species or subspecies, including frequency of use for breeding, pupping, molting and resting. In addition, a cost-benefit analysis of adaptation strategies should include recreational, tourism, educational, and property values, which would help policymakers in their evaluation of various protection measures.

Conclusions

The California coastline is heavily impacted by dense human population and extensive coastal development. At the same time, it is a valuable ecological resource that provides habitat to a variety of wildlife species. For years humans and pinnipeds have shared the coastline, but competition for space has become evident with incidents such as the Children's Pool in La Jolla. Space along the coast will become even scarcer as sea level rises and beaches move landward. Depending on the availability of beach migration, conflict may arise concerning the use of coastal land. Predicting the impacts of sea-level rise on haul-out sites is difficult due to uncertainty of sea-level rise scenarios, and additional research of local impacts should be conducted at each site. Sea-level rise may affect haul-out sites by beach erosion, sediment transport, tides, and storm surge, all of which should be further assessed. Since pinnipeds select haul-out sites based on a number of biological and physical factors (NCCOS 2007), predicting where these animals may prefer to move in conjunction with areas of unoccupied habitat also requires additional analyses. Furthermore, it is important to note that the pinnipeds analyzed in this study are common and none are listed under the Endangered Species Act (ESA); however, if the implications of this study are applied to pinnipeds of California listed on the ESA, including Steller sea lions (*Eumetopias jubatus*), Northern fur seals (*Callorhinus ursinus*), and Guadalupe fur seals (*Arctocephalus townsendi*), further management options should be discussed. Though a better understanding of sea-level rise is necessary to make specific policy recommendations, this study introduces the need to access current legislation in order to properly manage a changing California coastline and alleviate potential conflict.

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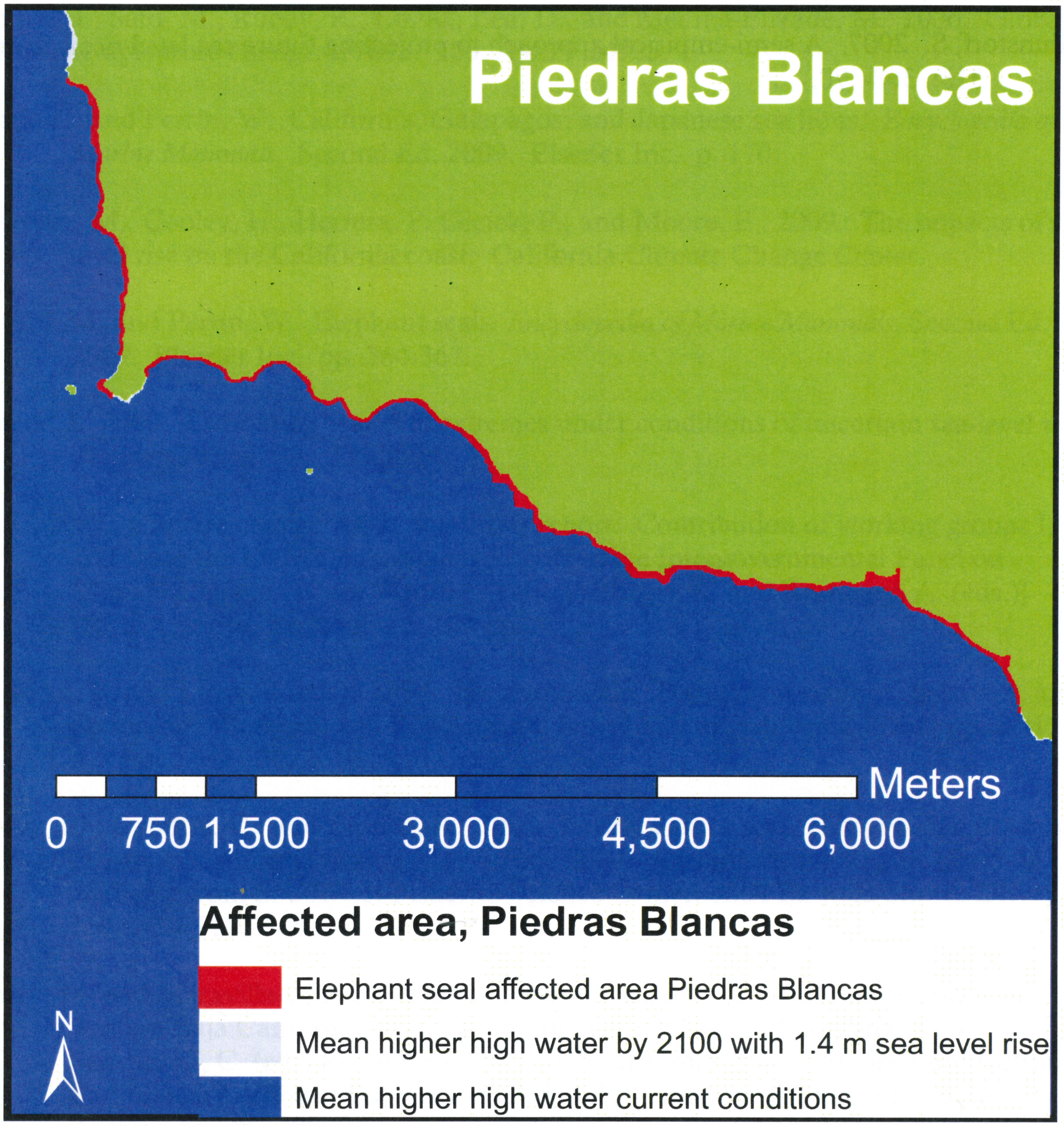
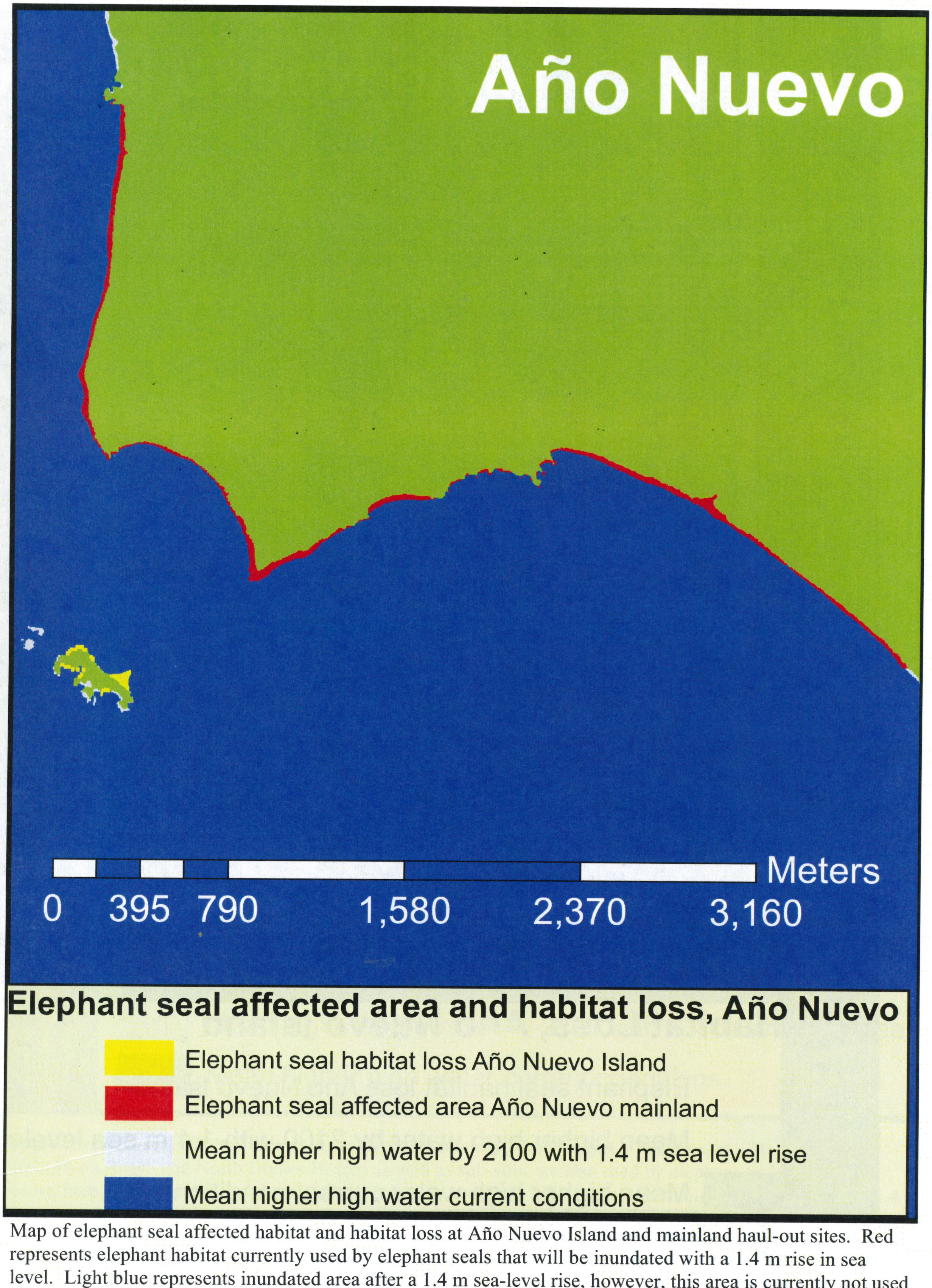
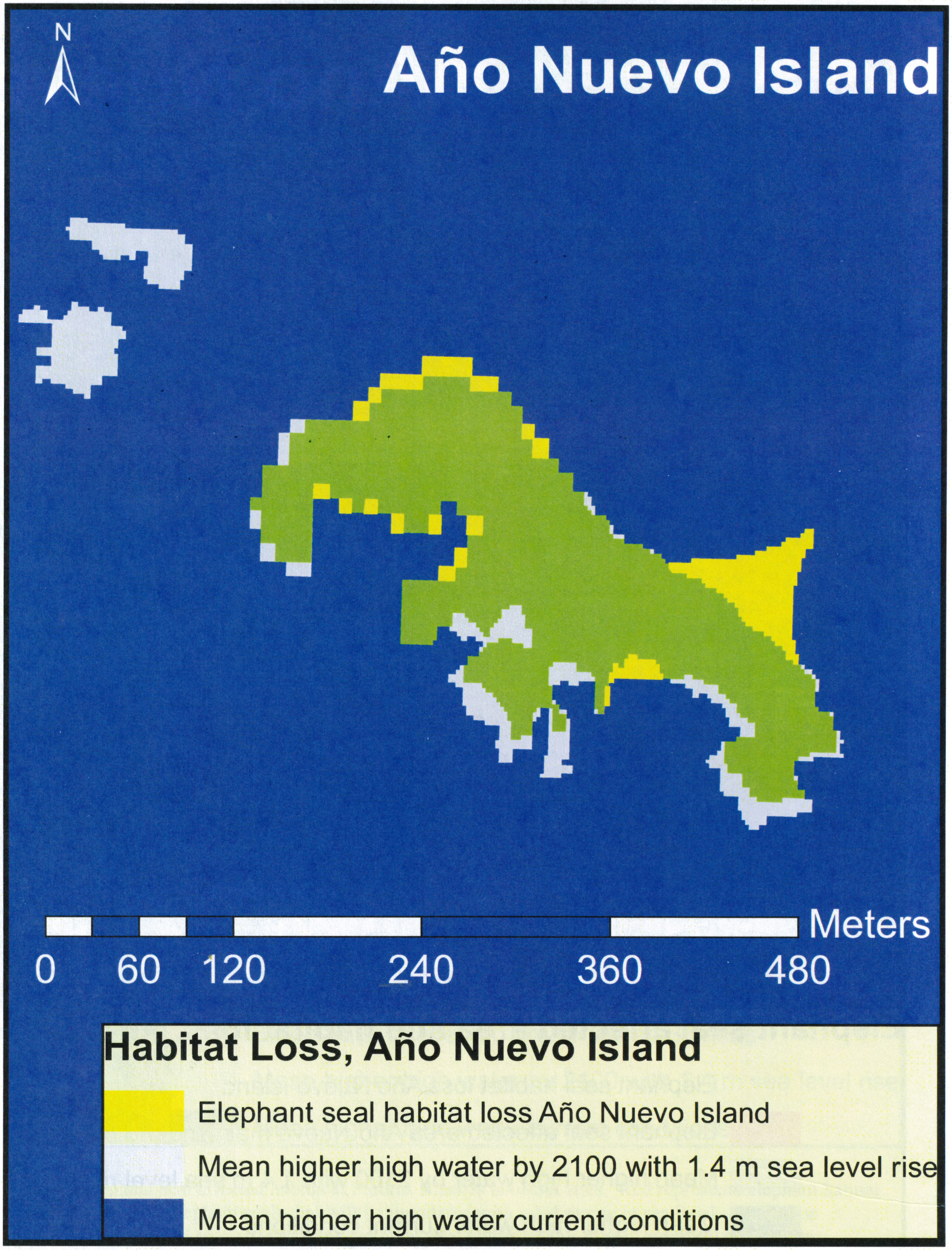
Appendix: GIS maps illustrating affected area at selected elephant seal haul-out sites



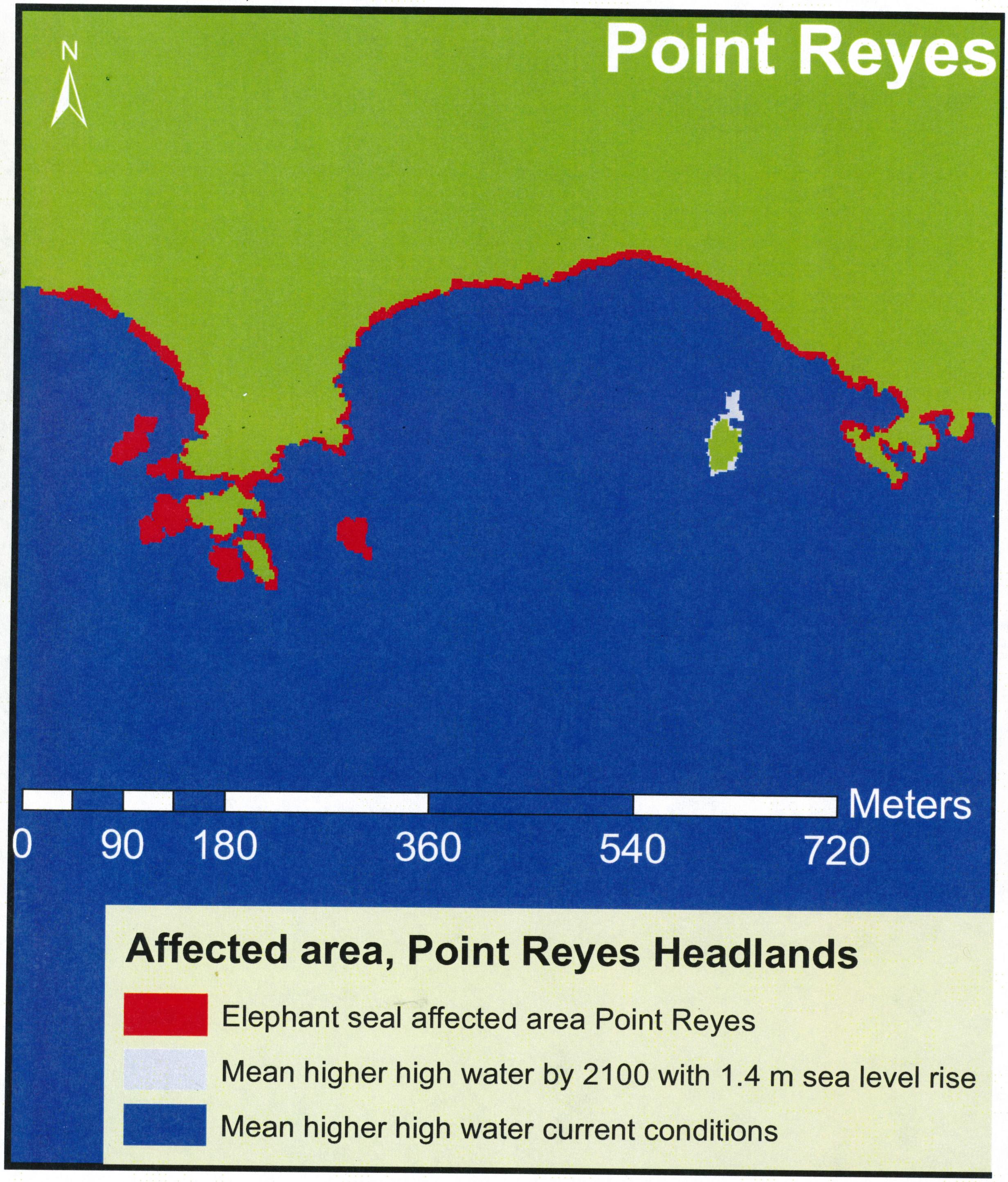
Map of elephant seal affected habitat at Piedras Blancas haul-out sites. Red represents elephant habitat currently used by elephant seals that will be inundated with a 1.4 m rise in sea level. Light blue represents inundated area after a 1.4 m sea-level rise, however, this area is currently not used by elephant seals. 225,370.80 m^2 was calculated as affected area for Piedras Blancas.



Map of elephant seal affected habitat and habitat loss at Año Nuevo Island and mainland haul-out sites. Red represents elephant habitat currently used by elephant seals that will be inundated with a 1.4 m rise in sea level. Light blue represents inundated area after a 1.4 m sea-level rise, however, this area is currently not used by elephant seals. 77,715.96 m^2 was calculated as affected area for both the mainland and island, but 72,718.17 m^2 was contributed by Año Nuevo mainland. As shown in the following figure, Año Nuevo Island is limited in space, thus inundation of area was termed "habitat loss".



Map of elephant seal habitat loss at Año Nuevo Island haul-out sites. Red represents elephant habitat currently used by elephant seals that will be inundated with a 1.4 m rise in sea level. Light blue represents inundated area after a 1.4 m sea-level rise, however, this area is currently not used by elephant seals. 4,997.79 m^2 was calculated as habitat loss for the island. Since the beach area was visibly limited, "habitat loss" was used to describe sea-level rise impacts. Currently 1,715 elephant seals use the beaches on the island to haul-out.



Map of elephant seal affected area at Point Reyes Headlands (Main Colony), Point Reyes. Two other main sites (South Beach and North Drakes Beach) as well as sub-sites are also used by elephant seals, but are not shown here. Red represents elephant habitat currently used by elephant seals that will be inundated with a 1.4 m rise in sea level. Light blue represents inundated area after a 1.4 m sea-level rise, however, this area is currently not used by elephant seals. While only 9,917.24 m^2 was calculated as affected area, this site currently provides habitat for 1,319 elephant seals.