Chapter 3. Physical Environment

3.1 Climate

The Oregon Coast National Wildlife Refuge Complex comprises six National Wildlife Refuges that span nearly 320 miles along the rugged Oregon coastline. We discuss three of the six NWR's associated with the Complex: Oregon Islands, Three Arch Rocks, and Cape Meares. Oregon Islands NWR spans nearly the entire length of the Oregon coastline and consists of two headlands and all coastal rocks, reefs, and islands that are exposed at mean high tide and not connected to the mainland, except Chief's Island. Three Arch Rocks NWR includes three large rocks and six smaller rocks located one half mile offshore from the town of Oceanside on Oregon's north coast. Cape Meares NWR is a coastal headland also located on the north coast approximately 12 miles southwest of Tillamook.

The region's climate is greatly influenced by the Pacific Ocean on the west and the Coast Range to the east. The Coast Range rises between 2,000 and 3,000 feet (610-914 m) above sea level in the north and between 3,000 and 4,000 feet (914–1,219 m) in the southwestern portion of the state with occasional mountain peaks rising an additional 1,000 to 1,500 feet (305–457 m). The coastal zone is characterized by wet winters, relatively dry summers, and mild temperatures throughout the year. Because of the moderating influence of the Pacific Ocean, extremely high or low temperatures are rare and annual temperature range is lower than any other Oregon climate zone. The area's heavy precipitation during winter results from moist air masses moving from the Pacific Ocean onto land. The lower elevations along the coast receive annual precipitation of 65 to 90 inches (165–229 cm), which can cause flood events if abundant rainfall is consistent for several days. The west slope of the Coast Range can receive 200 inches (508 cm) of annual precipitation, some of that in the form of snow. Occasional strong winds occur along the coast, usually in advance of winter storms. Wind speeds can exceed hurricane force and have caused substantial damage to structures and vegetation in exposed coastal locations. Skies are usually cloudy in the winter and partly cloudy during summer due to localized fog. As a result of persistent cloudiness, total solar radiation is lower along the north and central coast than in any other part of the state.

The Oregon coast in general has a temperate marine climate but is subject to strong winds and tides especially during the winter. Temperatures occasionally fall to freezing and rarely exceed 75°F (24°C) although temperatures exceeding 90-100°F (38°F) have been recorded. Precipitation is heavier and more persistent during the winter but regular moisture occurs from rain and fog throughout the year.

The National Climatic Data Center established the Oregon Coast, from Astoria to Brookings, as Climate Division 1. Meteorological measurements have been taken at 22 NOAA Climate Stations throughout Climate Division 1 (NCDC website) and are representative of the general climatic conditions of the refuge complex. We used NOAA's weather data to discuss weather patterns on the refuges.

3.1.1 Temperature

Based on data collected from 1948 through 2008 at Climate Division 1, the average monthly temperatures for the coast range from a low of 43.2°F (6.2°C) in January to a high of 61.2°F

(16.2°C) in August. The highest winter monthly average temperature recorded was 51.4°F (10.8°C) in February 1963, and the lowest average monthly temperature was 33.9°F (1.1°C) in January 1949. The highest summer monthly average temperature recorded was 64.1°F (17.8°C) in August 2004, and the lowest monthly average temperature was 54.9°F (12.7°C) in June 1954 (National Climatic Data Center (NCDC) website).

Based on data collected from 1971 to 2000, daily maximum temperatures at Newport, Oregon, located near the center of the Oregon coast, vary from an average of 51.2°F (10.7°C) in January to 65.7°F (18.7°C) in August. There are, on average, 0.5 days annually with maximum temperatures exceeding 90°F (32.2°C). The record maximum daily temperature was 100°F (37.8°C), recorded on July 11, 1961. The average daily minimum temperature at Newport is 38.6°F (3.7°C) during January and 50.7°F (10.4°C) during August. On average, the daily minimum temperature drops to or below 32°F (0°C) 20.3 days per year. The record minimum temperature of 1°F (-17.2°C) was recorded December 8, 1972 (NOAA Western Regional Climate Center website). The all-time maximum high temperature recorded on the Oregon coast is 108°F (42°F) and occurred in Brookings on July 8, 2008.

3.1.2 Precipitation

Average annual precipitation for the Oregon coast is 77.0 inches (195.6 cm). In 1996, the wettest year on record the precipitation measured was 108.4 inches (375.3 cm); in 1976, the driest year, only 49.0 inches (124.5 cm) were measured. The wettest season on record was the winter of 1956–57, with 18.8 inches (47.8 cm) of precipitation; the driest season was the summer of 2003, with only 0.2 inches (0.5 cm) of precipitation (NCDC website). Winter is defined as December, January, and February and summer as June, July, and August. More than half of the total annual amount of precipitation occurs from November through February.

Average snowfall in Newport ranges from a maximum of 0.6 inches (1.5 cm) in January, to 0.1 inch (0.2 cm) in February, to 0.3 inches (0.8 cm) in December. The record monthly snowfall of 11.0 inches (27.9 cm) occurred in January 1943 and December 1972. The annual record snowfall of 15.5 inches (39.4 cm) occurred in 1972. Snowfall accounts for less than 1% of all precipitation from December through February (NOAA Western Regional Climate Center website).

Fog (water vapor condensing into tiny liquid water droplets in the air) is a common phenomenon along the Oregon coast because of contrasting differences between air, land, and ocean temperatures and humidity. The average number of days per year with dense fog (visibility of 0.25 mile or less) in Astoria is 41. Fog records for central and south coastal locations were unavailable. June averaged the fewest days (1) with dense fog and October with the most days (7) (NOAA Western Regional Climate Center website).

3.1.3 Wind

Average wind speeds have been calculated on hourly data collected from 1996 to 2006 from automated stations at reporting airports in Oregon. The average annual wind speed for Newport is 8.8 mph (14.2 km/h). The highest average wind speed occurred during December and January at 11.2 (18) and 11.0 mph (17.7 km/h) respectively. The calmest month, September, recorded an average wind speed of 6.5 mph (10.5 km/h). Astoria airport recorded an average annual wind speed of 7.7 mph (12.4 km/h) with highest speeds during December at 8.7 mph (14 km/h) and lowest during September and October at 6.7 mph (10.8 km/h) (NOAA Western Regional Climate Center website).

Prevailing wind direction, defined as the direction with the highest percent of frequency, was calculated from hourly data during 1992 to 2002. The average annual prevailing wind direction in Newport (on the central coast) blows from the east and south respectively. In Newport, winds from the east occur in December through February, from the south during fall and spring, and NNW during the summer months (NOAA Western Regional Climate Center website).

As a rule, Oregon does not experience hurricanes, and tornadoes are infrequent and generally small in the northwestern part of the United States. However, the National Weather Service issued a hurricane warning for the first time for the Oregon coast during an extremely powerful storm which slammed into the Pacific Northwest during December 2-4, 2007, during which winds topped out at 130 mph (209 km/hr) along coastal Oregon (NOAA Western Regional Climate Center website). The NCDC maintains a database that provides information on the incidence of tornados reported in each county in the United States. This database reports that 94 tornados were reported in Oregon since 1950. The 7 counties closest to the refuges (Clatsop, Tillamook, Lincoln, Lane, Douglas, Coos, and Curry), only 19 tornados have been recorded since 1950. Of these, 11 tornadoes had maximum wind speeds estimated in the range of 40 to 72 mph (F0), and 8 had maximum wind speeds in the range of 73 to 112 mph (F1).

3.2 Hydrology

A description of a hydrological system usually includes parameters such as stream/river flow, runoff, ground water, and snow pack. However, the hydrology of the Oregon Islands and Three Arch Rocks NWR would be better described by Pacific Ocean processes. This immense water body surrounds, impacts, and influences the refuge headlands, rocks, islands, and reef habitats continually.

The Pacific Ocean processes can be explained by investigating features and dynamics of the California Current, also known as the Eastern Boundary Current. The California Current System extends up to 1,000 km offshore from southern British Columbia to Baja California and encompasses a southward meandering surface current, a poleward undercurrent, and surface countercurrents. This system exhibits high biological productivity, diverse regional characteristics, and intricate eddy motions. The California current system is driven by prevailing northerly winds and is associated with upwelling areas off Oregon and California (Miller et al. 1999). Wind-induced upwelling is the dominant mechanism for bringing nutrients to the surface.

The Oregon coast experiences large seasonal changes in the strength of upwelling, clearly related to seasonal differences in wind strength and direction. There are four or five periods of strong upwelling separated by periods of little or no upwelling (Mann and Lazier 2006). Each of these events precipitates a burst of productivity equivalent to a spring bloom (Barber and Smith 1981). In addition, coastal upwellings tend to be centered on topographical features such as capes and canyons. The bathymetric features along the Oregon coast are very irregular which is indicative of fracture zones, basins, ridges, and canyons. Seabirds, pinnipeds and marine fish benefit from the high productivity associated with coastal upwelling. In fall and winter a weaker counter current, known as the Davidson Current, flows north occasionally moving somewhat warmer water northward along the California and Oregon coast.

The stream and riparian habitat within Cape Meares NWR and RNA is located in the northeast corner of the northern unit, in an active glacial slide area. Several spring-fed and surface runoff streams with medium to steep gradient, step-pool morphologies, and basalt parent geology flow across this area from the top of the adjacent privately-owned headland. The streams cross under an early-successional red alder canopy and end in a 12-foot drop to the beach on a continually eroding bank. A fork of the Oregon Coast Trail passes through this portion of the refuge and parallels the main stream before dropping to the beach at the extreme northeast corner of the cape while the main trail continues north across county lands to the community of Cape Meares.

3.3 Topography and Bathymetry

To be within Oregon Islands and Three Arch Rocks NWRs, a rock, reef, or island must be separated from the mainland and above the surface of the sea at mean high tide. Reefs are low elevation, essentially bare rocks that are awash during storms at higher tides. Rocks are taller, essentially bare rocks that may or may not be inundated, and usually have rather precipitous sides. Grassy islands are generally the highest land mass. They usually have precipitous sides, vegetated tops with varying amounts of soil, and are never immersed in water. Many rocks and islands are close to shore and accessible by foot at low tides.

In areas along the southern Oregon coast, headlands often show varying stages of deposition, deflation, and extended periods of surficial stability. The Crook Point and Coquille Point headlands, consisting of Holocene dunes and floodplains, are subjected to high-energy geomorphic processes that contribute to their alteration or destruction. These processes are marine transgression and erosion by tides, winds and storm waters, as well as past human altercation (Davis 2006). The Crook Point headland is dominated by a generally barren, windblown landscape of flat to gentle slopes approximately 100 to 200 feet above sea level. The Coquille Point headland is relatively flat, and the bluffs below the headland are classified as steep coastal erosion bluff habitat.

Cape Meares NWR consists of vertical coastal cliffs, rock outcroppings and rolling headlands with old-growth forest dominated by Sitka spruce and western hemlock. Cape Meares is located on a prominent coastal headland that rises more than 640 feet above sea level. The western border of the headland ends dramatically at sheer cliffs above the Pacific Ocean, while north aspects of the headland descend gradually to sandy beaches that occur beyond the refuge boundaries. Topography is generally steep with a prominent gully formed from landslides of unstable soils being a landmark in the southern end of the refuge. The central portion of the Cape Meares headland, largely on OPRD lands, is less steep than the north or south portions and is bisected by the roadway to the State Scenic Viewpoint and lighthouse. Two small drainages contain the spring-fed and surface run-off streams mentioned previously.

Ocean bathymetry along the Oregon coast features a series of seamounts, small valleys, channels, and ridges on a multilevel plain. Bathymetric characteristics can be an important indicator of marine bird-habitat associations because they are fixed in space and can produce hydrological processes (Yen et al. 2005). Seamounts are known for their productivity and concentrations of birds (Yen et al. 2004) possibly because of upwellings that can concentrate prey. Upwelling often occurs at sills and ocean floor ridges which can increase prey abundance and availability for seabirds (Hunt and Schneider 1987). Results of another study conducted in Prince William Sound, Alaska concluded marbled and Kittlitz's murrelets (*Brachyramphus brevirostris)* were clearly associated with bathymetric features that promote upwelling and currents (Kuletz 2005, Stephensen *In review*). These hydrographic features may create accessible concentrations of invertebrates and fish that are lifted into the upper water column (Hunt et al. 1990, 1999; Coyle et al. 1992) and produce "hot spots" where birds aggregate.

3.4 Geology

The refuge landscape has been shaped by water, wind, plate tectonics and millions of years of volcanic activity. A volcanic island chain collided with North America about 50 million years ago and formed many of the scenic headlands, rocks, reefs, and islands along the coast. The Cape Meares headland is composed of solid basalt which was uplifted in the Tertiary Period approximately 65 to 1.8 million years ago. In addition, sediments that have accumulated in the coastal zone contain marine fossils that help explain the formation and origin of the unique geology of the area.

Approximately 66 million years ago, during the Cretaceous period, volcanic (Roseburg Volcanics) activity created offshore islands in the southern portion of the current Coast range. The northern portion of the range was created by Siletz River Volcanics. Lastly, a series of basalt flows from the Columbia River basalts also added to these formations with some smaller flows in-between. Pillow basalt formations were created when a hot basalt flow rapidly cooled upon meeting the salt water of the ocean. These offshore deposits were then pushed into the continental plate as a forearc basin rotating slowly over millions of years. This tectonic collision forced the basalt and newer sedimentary rock formations (including marine terrace deposits) upward and created the coastal range. Additional basalt flows originated from Eastern Oregon and added to the layers that were uplifted, as the newer Cascade Mountains had not yet been formed. By the early Oligocene period 36 million years ago, the current coastline was in place and erosion has continued to shape the range primarily through rivers cutting deep valleys through the igneous and sedimentary rocks (Orr et al. 1992).

The geologic boundaries of the coast range formation extend from southwest Washington to the Coquille River, where the older and taller Klamath Mountains begin. In the east, the mountains begin as foothills forming the western edge of the Willamette Valley and continue west to the coastline and beyond where the basalt formation tapers off into the continental shelf and ends at the continental slope with several banks and basins offshore (Orr et al. 1992). Physiographically they are a section of the larger Pacific Border province, which in turn are part of the larger Pacific Mountain System physiographic division.

3.5 Soils

Cape Meares and the coastal headland soils range from shallow to moderate in depth, are well drained, and are derived from sedimentary sandstones and or siltstones. The majority of the rocks and reefs are generally devoid of soil and vegetation. The islands have varying accumulations of soils on top which often support permanent coverings of low-growing coastal-type vegetation, ranging from extremely sparse to quite dense. Soil data are limited since reconnaissance studies have not been conducted on the refuge to determine soil type and distribution. The Crook Point headland is dominated by a generally barren, windblown landscape of flat to gentle slopes approximately 100 to 200 feet above sea level. The Coquille Point headland is relatively flat and when acquired by the Service this headland was devoid of topsoil due to past construction disturbance. It has since been restored with imported topsoil and some native plantings. The bluffs below the headland are classified as steep coastal erosion bluff habitat.

3.6 Environmental Contaminants

Few contaminant studies have been conducted on the refuges and the majority of collected data were obtained during the 1970s and 1980s. Pollutants in Oregon seabirds have not been systematically studied; however, one study was conducted in 1979 (Henny et al. 1982). The purpose of this study was to determine organochlorine burdens in seabird eggs, measure eggshell thickness, evaluate the importance of the residues and eggshell thickness detected, and compare results to the same species at other locations. A single egg was collected at 62 nests of 10 seabird species and analyzed for organochlorine contaminants (PCB and DDE). Eggshell thickness was measured for each egg. Six of the ten seabird species had less than 1 ppm (part per million) geometric mean concentration of DDE and seven species showed geometric means of PCBs less than 1 ppm. One shorebird (snowy plover, C*haradrius alexandrinus)* also had a geometric mean of less than 1 ppm concentration of DDE and PCBs. Double-crested cormorant, Leach's storm-petrel, and fork-tailed storm-petrel were the most contaminated, with concentrations greater than 1 ppm. The fork-tailed storm-petrel samples had the largest residue concentrations of 12 ppm DDE and 5.1 ppm PCBs. In all species except the fork-tailed storm-petrel, the residues were generally low, and concentrations are below estimated thresholds that may affect the species examined. The single fork-tailed storm-petrel egg was in the critical range and indicates further research is needed for that species. Eggshell thickness data can provide important supplementary information when DDE is of concern. Keith and Gruchy (1972) and Lincer (1975) reported that 18-20% shell thinning may result in reduced reproductive success. Eggshell thinning of the 1979 samples did not approach the 18-20% range and all samples had greater thickness compared to data collected in the 1950s (Henny et al. 1982).

Seabirds along the Pacific coast have great potential to be exposed to contaminants from oil spills, chemical releases, pesticide use, and other general sources. Oregon has experienced large die-offs of pre and post-fledging juvenile common murres occurring from July to October. These die-offs of juvenile common murres occur almost annually and infrequently die-offs of adult murres have occurred during the summer months, the causes of the mortality events are unknown. Several beach transects near Newport, ranging from 4.4 to 7.5 km in length, were monitored for many years to document mortality events and one beach transect has been monitored continuously year-round from 1978 to present. Observations found that murre carcasses can exceed 1,000 individuals on a 7.5 km stretch of beach per year (Bayer et al. 1991). Numerous carcasses of juvenile and adult common murres have been sent to the USGS National Wildlife Health Center in Madison, Wisconsin for analysis. The cause of these mortality events remain unknown, however, necropsies results indicate poor body condition, emaciation, no fat and no food items in the digestive system suggesting starvation (USFWS unpubl. data). The highest mortality occurs prior to fledging of juvenile murres when they are still dependent on the adult male parent at sea. Forage fish populations sustaining these birds may disappear locally and neither the juvenile murre nor the attending adult male can fly to seek forage elsewhere. The lack of forage fish and the stress of swimming long distances to seek prey can result in starvation and death. In 1995, Service personnel collected common murre father/chick pairs at sea near Newport to determine if contaminants and biotoxins played a role in the annual common murre mortality events. Results of this study indicated that there did not appear to be any immediate life threatening abnormalities in inorganic and organic concentrations measured. However, the condition of the birds and the concentrations of various potentially harmful chemicals detected in tissues indicate that the birds were experiencing cumulative stressors, which ultimately contribute to their poor health and increase susceptibility to pathogens and mortality. A 1969 study found body weights of dead common murres were significantly lower than healthy birds collected during a die-off period. Necropsy of the emaciated dead birds suggested drowning was the proximate cause of death and all DDE and PCB levels were considerably less than reported lethal concentrations in other bird species, however, environmental stress may have been sufficient to contribute to mortality (Scott et al. 1975).

Double-crested cormorants were collected on Hunters Island in 1992 (Kiff 1994) and 1993 (Buck and Sproul 1999). Eggs were collected at Hunters Island to serve as a reference site for studies being conducted in the Channel Islands in California (Kiff 1994) and the lower Columbia River (Buck and Sproul 1999) where contaminant levels in double-crested cormorants were known or suspected to be elevated. Eggs were analyzed for the presence of DDT and transformation products, PCBs, dioxins, and furans. Concentrations of DDT and DDE were present in Hunters Island eggs but at significantly lower concentrations than in eggs from the lower Columbia River cormorants (Buck and Sproul 1999). Eggshells measured from Hunters Island by Kiff (1994) were thicker compared to eggshells from the lower Columbia River, indicating these birds experience little or no effects from DDE exposure. Few PCB congeners were above detection limits in Hunters Island eggs. Likewise, all dioxin and furan congeners tested were below detection limits, whereas these compounds were elevated above effects-thresholds in eggs of lower Columbia River cormorants (Buck and Sproul 1999). Overall, organochlorine contaminants in eggs from Hunters Island cormorants were insufficient to impair reproduction or cause mortality.

3.7 Surrounding Land Uses

There are no large cities on the Oregon coast, mainly due to the lack of deep commercial harbors with access to the inland agricultural and metropolitan areas. The largest population area on the South Coast consists of the bordering cities of Coos Bay and North Bend, with a population of approximately 25,000 people. On the north coast the population centers are the cities of Newport and Astoria (approximately 10,000 each). The relative isolation of the coast from nearby large population centers of Portland, Salem, and Eugene has given the coast a reputation for being somewhat rustic, being a mixture of old logging towns, fishing villages, seasonal resorts, and artists' colonies. Tourism, commercial fishing and logging are the major industries on the coast.

3.7.1 Land development

The Oregon coast offers breathtaking scenery, mild temperatures and climate, wide open spaces, outdoor recreational activities, and many other desirable features that attract people from all over the world. Oregon coast real estate has become a popular commodity and many coastal lands are being or have already been developed into vacation resorts, commercial property, and residential communities. New residential subdivisions and other developments have emerged along the coast at a rapid rate in the last 20 years. Many new residential communities are in close proximity to the ocean and structures are being built near water’s edge. Building structures and development continue to encroach upon the remaining undeveloped lands and threaten biological resources.

3.7.2 Logging

The logging industry began in the Pacific Northwest at the beginning of the twentieth century and has been a dominant industry in Oregon's economy. Many old-growth forests have disappeared and the resources associated with the habitat have frequently declined as a result. Refuge lands are protected; however, forested areas surrounding Cape Meares NWR have undergone extensive logging and development during the past century.

From 2002 through 2007, Oregon's timber harvest averaged 4 billion board feet (Oregon Department of Forestry). Over the last two decades timber production has declined by 30-50% in all coastal counties, with the sole exception of Clatsop, where timber production has increased. Yet the coast remains one of the largest producers of timber in Oregon; in 2002, the coast accounted for more than a quarter of all timber production in the state.

3.7.3 Agriculture

Agriculture is important along the Oregon coast and thousands of acres of farmland are in close proximity to the refuges. In 2001, gross farm sales on the Oregon coast totaled more than $175 million (Oregon Agricultural Information Network 2001). Dairy products brought in nearly $95 million in sales, which is more than one third of the state's dairy production. Tillamook County alone produces $85 million in dairy products annually (OAIN 2002). Farms on the south coast, in Curry County, account for 90% of the Easter lily bulbs (Curry County website) and in Coos County, 35 million pounds of cranberries are produced near the city of Bandon (Nakano 2002).

3.7.4 Recreation

Millions of people annually visit Cape Meares NWR, the Coquille Point Unit of Oregon Islands NWR, Yaquina Head, Cape Arago and other viewing areas or parks along the Oregon coast. Along the entire Oregon coast, outstanding natural, scenic, cultural, historical, and recreational sites for education and enjoyment are available to the public. All land within 16 vertical feet of the average low tide mark belongs to the people of Oregon and guarantees the public has free and uninterrupted use of the beaches along Oregon's 363 miles of coastline (Oregon Shores Conservation Coalition website). Locals and visitors can find a large number of private and state owned campsites with access to Oregon's beaches. The Oregon Parks and Recreation Department administers 19 parks on the north coast, 37 on the central coast, and 28 on the south coast (OPRD website). The refuge works cooperatively with OPRD to maintain wildlife viewing structures, interpretive facilities, and lands for the benefit of present and future generations.

3.8 Global Climate Change

A continuously growing body of scientific evidence supports the theory of global climate change. During the 20th century, the global environment experienced variations in average worldwide temperatures, sea levels, and chemical concentrations. Global air temperatures on the earth's surface have increased by 1.3°F since the mid 19th century (Solomon et al. 2007). Eleven of 12 years from 1995 to 2006 are the warmest on record since 1850 (IPCC 2007).

During the next 20-40 years, the climate of the Pacific Northwest (PNW) is projected to change significantly. Global climate models project mid-21st century temperatures in the PNW that are well outside the natural range of temperature observed in the 20th century. They also suggest important changes in future precipitation: nearly all the climate models project wetter winters and drier summers in the 2020s through the 2040s (Mote et al. 2003).

3.8.1 Sea level rise

The National Wildlife Federation engaged sea-level rise modeling expert Jonathan Clough, of Warren Pinnacle Consulting, Inc., to simulate how sea-level rise during this century would affect coastal habitats in 10 areas in Puget Sound as well as the Pacific Coast from northwestern Oregon to southwestern Washington. One of the sites included in this report was the mouth of the Columbia River. While there have been several past studies of sea-level rise in the Pacific Northwest, this study provides the most comprehensive and detailed analysis to date of the potential impacts of sea-level rise on the region's coastal habitats.

The model used for this analysis is called Sea Level Affecting Marshes Model, Version 5.0 (SLAMM 5.0), which was designed to simulate the dominant processes involved in wetland conversion and shoreline modification under long-term sea-level rise. The model integrates information about projected global sea-level rise with area-specific NOAA tidal data, detailed wetland information from the Service's National Wetlands Inventory, regional Light-imaging Detection and Ranging (LiDAR) data, and USGS Digital Elevation Maps to project habitat changes associated with sea-level rise. The study maintains that global average sea level increases could increase by an average of 0.28 meters (11.2 inches) by 2050 and by 0.69 meters (27.3 inches) for the study locations in the Willapa Bay, Columbia River, and Tillamook Estuary (Glick et al. 2007). The impacts of these changes to Oregon's coastal ecosystem include a projected increase in ambient temperature, more frequent and intense wildfires, changes in stream flow and freshwater systems, and rising sea levels that will inundate coastal areas (Alley et al. 2007, Westerling et al. 2006).

The potential large-scale impacts of global warming on the Pacific Ocean and nearshore environment include increase in sea-level and sea-surface temperatures; changes in salinity, alkalinity, wave and ocean circulation patterns and upwelling; and loss of coastal marshes, estuaries and ocean beaches (National Wildlife Federation 2007). The consequences of these changes to Oregon's marine environment include direct loss of habitat through coastal inundation and flooding, changes in species biogeography, including species of marine wildlife (e.g., phytoplankton, krill, forage fish, seabirds, pinnipeds) and invasive species (e.g., animals, plants, microbes and pathogens).

Radically different weather patterns influence wind and ocean currents that precipitate seasonal upwellings. The upwellings bring nutrients into the photic zone, stimulating plankton blooms close to the surface. These upwellings have been inconsistent over the last 10 years (Defenders of Wildlife 2006). During this time, large numbers of seabirds, including species not typically part of the standard annual dieoff, have washed up on the Oregon beaches, apparently casualties of shifts in the California Current's primary productivity (Johnson 2007). The system is primed to be warm and somewhat unproductive, which translates in less food for piscivorous (fish-eating) and planktivorous bird species (Lawler et al. 2008). In extreme events of change in upwelling, there is the potential of increased dead zones where low oxygen levels in ocean waters will inhibit most forms of marine life (Barth et al. 2007).

3.8.2 Potential changes to refuge habitats

There have been no specific studies documenting potential affects to refuge habitats from future climate change. However based on the various climate modeling scenarios for the Pacific Northwest, there are several potential problems that are envisioned by the refuge planning team. One of the main concerns is potential loss of available nesting and roosting areas for pinnipeds and seabirds. Large concentrations of harbor seals, California sea lions, Steller sea lions, and northern elephant seals use refuge lands to rest and breed, and an estimated 1.2 million seabirds breed on the Oregon Islands and Three Arch Rocks NWR (Naughton et al. 2007). Under the modeling done by the National Wildlife Federation Study, the sea level could rise almost a foot by 2050. This could cause significant loss of surface area on rocks and islands, and subsequent competition for available areas would cause wildlife displacement, abandonment, reduced breeding success, and increased bodily stress. Another potential loss of habitat would occur from the increased intensity of storm/wave events resulting from higher sea levels as well as precipitation, both of which could erode soil and vegetation and eliminate burrow-nesting habitat.

Numerous other changes to the refuges' habitats and wildlife would likely result from increases in ambient temperature and precipitation over the next 50-100 years. However, until a more detailed analysis of the effects of global climate change can be completed on specific refuge units, more generalized modeling will continue to be used to assess how and what the Complex should do to prepare for upcoming changes to the natural environment. While this management plan is intended to cover a 15-year time span, it is clear that for the Complex to adequately plan for climate change, it will have to look further into the future. During the 15-year time span of this management plan, the Complex will be monitoring changes in conditions and using adaptive management to properly manage, conserve and perpetuate the unique wildlife and habitat with which it was entrusted.

3.9 Environmental Consequences

This section provides an analysis of the environmental consequences of implementing the alternatives described previously in Chapter 2. Impacts are described for the physical aspects of the environment described in this Chapter. Both adverse and beneficial effects of implementing each alternative are described, as are the cumulative effects.

3.9.1 Summary of effects

Table 3.1 provides an overview of the effects under each alternative by indicator. Effects are described in terms of the change from current conditions. Thus Alternative 1, the no-action alternative (current management), has a neutral effect because no changes to management programs would occur under this alternative. Although the analysis shows that none of the alternatives would be expected to result in significant effects, some positive (beneficial) or negative effects are expected. To interpret these terms, “intermediate” is a higher magnitude than “minor,” which is of a higher magnitude than “slight.” The word “neutral” is used to describe a negligible or unnoticeable effect compared to the current situation.

Table 3.1 Summary of Physical Environment Effects under CCP Alternatives.

Indicator	Alternative 1	Alternative 2
Visual Quality	Neutral effect.	Neutral effect to slight negative impact initially from additional facilities; long term minor positive effect.
Effects to Wilderness Characteristics	Neutral effect	Intermediate positive effect due to increased invasive plant and animal species control, inventory, and monitoring efforts. Minor positive effect resulting from increased law enforcement efforts.
Hydrology	Neutral effect.	Slight positive effect resulting from collaborative studies to better understand and manage local hydrology.

3.9.2 Physical Environment Effects

Topics addressed under the physical environment section include direct and indirect effects to visual quality, wilderness characteristics, and hydrology. The criteria used in this document to determine if a particular impact represents a significant adverse effect are present below for each topic:

- **Visual Quality** – A proposal that would substantially alter the natural landform, or block public view to a public resource from designated open space or public roads, would be considered a significant adverse effect on visual quality. Analysis and discussion of effects to visual quality are necessarily from the human perspective.

- **Wilderness Characteristics** – A significant adverse effect to the wilderness characteristics of the Oregon Islands and Three Arch Rocks Wilderness Areas would occur if visually intrusive alterations and physical changes to the environment resulted due to management actions proposed under Alternative B. Also, certain public activities would cause significant adverse effects to the wilderness character if not monitored, regulated, or prohibited.

- **Hydrology** – Impacts to hydrology, including water quality and quantity, would be considered significant if the actions would violate any water quality standards or waste discharge requirements, substantially increase downstream or ocean sedimentation, introduce contaminants (nonpoint source pollution) into the ocean, watershed or stream, or substantially alter water quantity.

3.9.2.1 Effects to visual quality

Neither of the alternatives is expected to have more than slight effects on visual quality (i.e., scenery). Alternative 2 may result in a very minor negative effect on visual quality of some refuge locations through the installation of new interpretive facilities including kiosks, interpretive panels, signs and viewing decks. However, these improvements would be placed on OPRD lands overlooking refuge rocks and islands and would be designed to enhance visitors' appreciation of the natural and visual resources contained within these areas, resulting in an overall slightly positive effect. Similarly, the installation of facilities including trash cans and pet waste removal stations under Alternative 2 could initially be considered a slightly negative effect on visual quality, but the end result of public usage of these facilities would be a minor to intermediate positive effect for visitors. Installation of boundary signs following the boundary survey proposed under Alternative 2 could result in a slight negative effect on visual quality in some areas. Finally, both alternatives involve removal of invasive plant species from areas visible to the public, to a greater extent in Alternative 2. This action could initially result in a slight negative effect if the affected area is left bare of vegetation; however, the end result would be a minor to intermediate positive effect when native plants are returned to the site.

3.9.2.2 Effects to wilderness characteristics

Under both alternatives, the Refuge Complex would continue to promote and preserve the wilderness characteristics of Oregon Islands and Three Arch Rocks Wilderness areas by inventorying ecological systems (plant and animal species and communities) and evaluating impacts from internal and external forces on these systems; initiating management actions to control, and where possible eliminate, invasive species to protect native wildlife populations and habitats on islands with the highest potential to sustain irreversible damage to wilderness character from invasive species; avoiding visually intrusive alterations; and working to foster an understanding and appreciation by the public for the importance of wilderness.

Under Wilderness Act implementation guidance, "untrammeled" quality refers to modern human actions that intentionally control or manipulate the components or processes of ecological systems inside the wilderness. The Complex's staff have concluded that maintenance of the untrammeled quality should include removal of selected plants and animals when it is determined that their presence is negatively impacting the wilderness ecological system and processes in a manner that will cause irreversible harm to the native species. A botanical survey and subsequent treatment of invasive plant species, as well as predator surveys and removal, would result in an intermediate positive effect on wilderness characteristics through the re-growth and restoration of native plants and subsequent increased use by native wildlife. This would have a long-term minor to intermediate positive effect on the wilderness characteristics of the affected rocks and islands through the continued viability of nesting seabird habitat.

Wilderness Act implementation guidance states that the "natural" quality refers to wilderness ecological systems that are substantially free from the effects of modern civilization. Alternative 2 proposes more efforts by refuge staff toward working with local residents and commercial properties as well as city, county and state agencies and planning departments, to prevent increased light and noise intrusion into the wilderness as a result of new construction. This coordination would result in a slight positive effect to wilderness characteristics. Increased efforts would be devoted toward actively working with OPRD to locate commercial fireworks displays away from wilderness areas, resulting in a slight positive effect.

Oregon Islands Wilderness and Three Arch Rocks Wilderness are two of only 10 wilderness areas in the country closed to public access, yet the dramatic scenery they provide is highly visible to residents and visitors of the Oregon coast. Like the natural resource values and benefits of these refuges, wilderness values and benefits can also be enjoyed and appreciated from a distance without actually entering the area. The incorporation of wilderness themes and messages into new or updated pamphlets, brochures and interpretive panels, and the inclusion of wilderness information and education in all interagency, volunteer and Friends Group training, would potentially have a slight positive effect on wilderness characteristics if these activities resulted in changes to the public's behavior and attitudes toward wilderness protection.

The presence of structures, installations, habitations and other evidence of modern human presence or occupation is considered to degrade the "undeveloped" quality of wilderness, as does the use of motorized equipment or mechanical transport. Boundary and regulatory signs and interpretive panels on the adjacent mainland and at ports along the Oregon coast would continue to be maintained under both alternatives, resulting in a neutral to slight negative impact initially from the presence of these structures. Maintenance of these signs, and installation of additional signs and similar structures, are actions which carry the potential for degrading the undeveloped quality of the wilderness at the particular location. However, at some locations trespass is a serious and recurring problem, necessitating the placement of boundary and regulatory signs just above the intertidal zone at accessible sites on the rocks and islands. The installation and maintenance of regulatory and other signs and panels near wilderness is expected to have a long term minor positive effect through resulting changes in the public's behavior regarding trespass. In addition, under both alternatives any temporary structures used for wildlife management or research purposes would employ the use of the Minimum Requirements Decision Guide to choose the minimum tool necessary to accomplish the work.

3.9.2.3 Effects to hydrology

Both alternatives are expected to have a neutral effect on the local hydrology, with potential for a slightly positive effect resulting from collaborative studies to better understand and manage local hydrology. There are two small freshwater streams or stream systems on these refuges, Sand Creek within the Crook Point Unit of Oregon Islands NWR, and the small braided streams within Cape Meares NWR. Neither of these streams would be affected by the public uses proposed under both alternatives nor by the additional interpretive facilities proposed under Alternative 2. Additional inventory and monitoring activities proposed under Alternative 2 would have a neutral or slightly positive effect on the hydrology of these two streams, since information gleaned through inventory and monitoring could result in more informed management of both streams. All research activities proposed under Alternative 2 would be subject to the Service's Compatibility Determination process if proposed by an outside entity, or evaluated carefully before initiation by Complex staff, and therefore, research activities would be expected to have a neutral effect on the refuges' hydrology. No changes are proposed to the trail adjacent to the Cape Meares streams.

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