U.S. Department of the Interior
National Park Service

Natural Resource Program Center
Water Resources Division
Fort Collins, Colorado

Assessment of Coastal and Marine Resources and Watershed Conditions at Redwood National and State Parks (California)

Natural Resource Report NPS/NRWRD/NRTR—2007/368

ON THE COVER:

Coastline of Redwood National and State Parks
Top Photo: Gold Bluffs Beach
Bottom Photo: South of Enderts Beach

Photography by: Adelman K. and G. Adelman. 2002-2004. California Coastal Records Project (www.californiacoastline.org).

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ABBREVIATIONS

The following abbreviations are used in the report:

ACEC	Area of Critical Environmental Concern
AFWO	Arcata Fish and Wildlife Office
a.k.a.	also known as
AQRV	Air Quality Related Values
ASBS	Area of Special Biological Significance
BLM	Bureau of Land Management
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CC	California Current
CDFG	California Department of Fish and Game
CDPR	California Department of Parks and Recreation
cfs	Cubic feet per second
CICORE	California Center for Integrative Coastal Observation, Research and Education
cms	Cubic meters per second
C-MAN	Coastal Marine Automated Network
COCMP	Coastal Ocean Current Monitoring Program
CODE	Coastal Ocean Dynamics Experiment
CO-OPS	NOAA Center for Operational Oceanographic Products and Services
CSZ	Cascadia Subduction Zone
CTZ	Coastal Transition Zone
DO	Dissolved Oxygen
DWR	California Department of Water Resources
DPS	Distinct Population Segment
ELMR	Estuarine Living Marine Resources
ENSO	El Niño-Southern Oscillation
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GLOBEC	Global Ecosystems
GMP	General Management Plan
HA	Hydrologic Area
HHW	Higher High Water
HLW	Higher Low Water
HSA	Hydrologic Subunit Area
IMPROVE	Interagency Monitoring of Protected Visual Environments
KFMC	Klamath Fishery Management Council
km	kilometers
KRTF	Klamath River Task Force
LHW	Lower High Water
LIDAR	Light Detection and Ranging
LLW	Lower Low Water

Abbreviations continued:

MARINe	Multi-Agency Rocky Intertidal Network
MCL	Maximum Contaminant Level
MEI	Multivariate ENSO Index
MHHW	Mean Higher High Water
mi	miles
MLLW	Mean Lower Low Water
MMA	Marine Managed Area
MPA	Marine Protected Area(s)
NBSP	National Benthic Surveillance Project
NCCCS	Northern California Coastal Circulation Study
NCHR	North Coast Hydrographic Region
NDBC	National Data Buoy Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Service
NPS	National Park Service
NS&T	National Status and Trends
PDO	Pacific Decadal Oscillation
PFEL	Pacific Fisheries Environmental Laboratory
PISCO	Partnership for Interdisciplinary Studies of Coastal Oceans
PRC	Public Resources Code
RNP	Redwood National Park
RNSP	Redwood National and State Parks
SCR	Surface Current Radar
SOI	Southern Oscillation Index
STRATAFORM	Strata Formation on Margins
RWQCB	Regional Water Quality Control Board
SWQPA	State Water Quality Protection Area
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TOPEX	Ocean Topography Experiment
UNESCO	United Nations Educational, Scientific, and Cultural Organization
USBR	Unites States Bureau of Reclamation
USACE	Unites States Army Corps of Engineers
USDC	United States Department of Commerce
USDI	United States Department of the Interior
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WIS	Wave Information Studies Program
WWII	World War II

EXECUTIVE SUMMARY

Redwood National and State Parks (RNSP or park) are located along the Pacific Coast in northern California. Originally encompassing 23,470 ha (58,000 ac), Redwood National Park was established in 1968 to preserve significant examples of the primeval coastal redwood forest and the streams and seashores with which they are associated. The Park lands were adjacent to Prairie Creek Redwoods State Park, Jedediah Smith Redwoods State Park and Del Norte Coast Redwoods State Park. In 1994, the California Department of Parks and Recreation (CDPR) and the National Park Service (NPS) agreed to joint management of the four-park area to ensure maximum resource protection, making RNSP the most integrated park system in the NPS Pacific West Region. Today, RNSP comprises 45 percent of all the old-growth redwood forest remaining in California. Together, these parks are designated a World Heritage Site and International Biosphere Reserve by the United Nations and currently total over 45,500 ha (112,500 ac), including 52 km (37 mi) of unspoiled coastline.

Redwood National and State Parks are located in a relatively unpopulated, rural area and the coastline is one of the least developed areas of coast in California. As a result, many of the problems commonly associated with anthropogenic effects are not generally observed along the park's coastline. Historically, the coastline has been considered pristine and, consequently, an area of low priority for research and management. Much of the coastline is not easily accessible, making monitoring and research difficult, but also keeping direct human impacts low. In addition, local population is relatively small. RNSP is located in two coastal California counties: Humboldt and Del Norte. In 2003, the population of Del Norte County was estimated at only 27,913 people, while Humboldt County had 127,915.

In January 2004, RNSP held its first marine scoping session to address the state of the Parks' coastal and marine resources. As a follow up to the scoping session, this coastal and marine assessment was conducted in concert with other surveys of marine resources along portions of the 52 km (37 mi) RNSP coastline. This study applies to public lands and coastal waters within the boundaries of RNSP. The resource management objective is to describe resources and conditions of coastal water bodies, identify primary contributors and potential sources of water resource impairment, and develop an approach for managing those contributors.

There is considerable existing information on the flora, fauna and function of the coastal watersheds within RNSP. Several studies were initiated more than thirty years ago and continue to the present day. In particular, the Redwood Creek watershed is one of the most well studied watersheds in North America. Much less is known about the impact of these watersheds on the coastal park waters.

Many of the local American Indian and the RNSP staff have been working to identify cultural resources in the local area, including the coastal and estuarine areas. The offshore sections of RNSP have not been examined in detail to determine if, and where, submerged cultural resources may be located.

In 1977, Redwood National Park was named a Class I air quality area, receiving the highest protection under the Clean Air Act. Its coastal location, combined with prevailing northwesterly winds off the Pacific Ocean, place RNSP in a generally upwind position relative to most emission sources within the air basin. The principal air pollutants of concern are ozone precursors from mobile sources and particulates from road dust, construction, slash and waste burning, residential fuel combustion and forest fires. The visibility in the park is superior to that in many parts of the country, however visibility is sometimes impaired by both natural factors (fog, rain, low clouds, and salt spray haze) and human-caused pollutants (particulates).

The federal Clean Water Act requires states to identify water bodies that do not meet water quality standards and are not supporting their beneficial uses. Of the three major rivers in RNSP, Smith River, Redwood Creek, and Klamath River, Redwood Creek and Klamath River are listed as impaired. Redwood Creek is listed as sediment and temperature impaired in the current report. The Klamath River has multiple listings for the various sections but the lower Klamath River section west of Klamath Glen is listed as impaired due to temperature, low dissolved oxygen and nutrient input. The Total Maximum Daily Load priority is listed as medium. The smaller estuaries and streams within the park boundaries are not large enough water bodies to warrant listing under the Clean Water Act.

Redwood National and State Parks has been designated a State Water Quality Protection Area (SWQPA), also known as Areas of Special Biological Significance (ASBS), by the State Water Resources Control Board. For the RNSP SWQPA, 41 discharges, 27 outlets and 5 springs or seeps have been identified as entering the area, however no assessment of impairment or impact to coastal or marine resources were determined.

In RNSP, threatened and endangered species are protected, and potential disturbance caused by visitor use and park management activities is minimized. RNSP fish and wildlife biologists conduct surveys to assess the status and distribution of threatened and endangered species in the parks. Threatened and endangered species that have been found within RNSP include the American peregrine falcon (*Falco peregrinus*), bald eagle (*Haliaeetus leucocephalus*), California brown pelican (*Pelecanus occidentalis californicus*), marbled murrelet (*Brachyramphus marmoratus*), western snow plover (*Charadrius alexandrinus nivosus*), northern spotted owl (*Strix occidentalis caurina*), Steller sea lion (*Eumetopias jubatus*), humpback whale (*Megaptera novaengliae*), olive ridley sea turtle (*Lepidochelys olivacea*), Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), tidewater goby (*Encyclogobius newberryi*), Oregon silverspot butterfly (*Speyeria zerene hippolyta*), and beach layia (*Layia carnosa*).

The California Coastal National Monument, established on January 11, 2000, includes over 11,500 rocks, islands, exposed reefs, and pinnacles off the California Coast totaling approximately 3.4 km (883 ac) along 1350 km (840 mi) of coastline. Since 1983, the Bureau of Land Management managed these resources in cooperation with the California Department of Fish and Game. Two threatened and endangered species are known to inhabit the offshore pinnacles of RNSP. The brown pelican and peregrine falcon have both been observed utilizing some of these islands. Although the peregrine falcon has recently been de-listed by the federal government, it is still listed by the state of California as endangered. In addition, the bald eagle also uses RNSP coastal areas.

The most intensely studied coastal areas within RNSP are the two major estuaries that affect the park: the Klamath River and Redwood Creek. Both of these watersheds are of major concern because they provide critical habitat for threatened salmonid species. Both watersheds have been heavily impacted by land use. In addition, the Klamath River has been a special source of controversy between different interest groups because of the diversion of river flows for agricultural purposes that are necessary for the health of salmonid populations. The overall health of the coastline is good, but is influenced by surrounding land uses and human activities. Careful monitoring, ongoing assessment, and discussion and collaboration with other stakeholders in the region are all critical to maintaining the pristine condition of the RNSP coast. Assessment of potential sources of pollutants and stressors to the biological resources of the RNSP coastline needs to be addressed in greater detail.

The freshwater and marine fish species that live within RNSP are known. Abundance and distribution of freshwater fish has been well studied within the park. However, the distribution of many marine species is not as well known. Little is known about the abundance of most marine fish and invertebrate species beyond gross catch data provided by commercial fishermen to the California Department of Fish and Game.

Recreational and commercial fishing occurs offshore, nearshore, and from the beaches of Redwood National and State Parks. Most recreational fishing occurs on the Klamath River and its estuary, the Smith River, and Redwood Creek and is focused on salmonid species during their adult migration to upstream spawning grounds in the fall and winter. Three commercial fisheries occur within or adjacent to the quarter mile offshore boundary of RNSP; crab, commercial beach fishing for surf smelt/night smelt and redtail surfperch, and live rockfish fishery. In addition, an American Indian fishery exists. The Yurok Tribe gill nets Chinook adults within the Klamath River estuary. Klamath salmon are allocated 50:50 between the tribal share (Yurok and Hoopa Tribes) and non-tribal share (ocean commercial and recreational, and river recreation fisheries) (Pierce 1998).

What is known about intertidal and subtidal resources is largely based on surveys done in the 1970s. Since 2004, several studies have been initiated to update the status of intertidal resources, and to assess the status of additional intertidal resources. Recently completed studies have contributed to our knowledge or the abundance and distributions of rocky intertidal algae and invertebrates, tidepool fish, subtidal sandy-shore fish, sand beach invertebrates, and juvenile rockfish. Additional ongoing studies are characterizing intertidal habitat diversity along the RNSP coastline. Subtidal habitats have not been re-surveyed since 1980 (Boyd and DeMartini 1977, Boyd et al. 1981). Subtidal and offshore habitats are difficult to study because of very poor visibility and rough seas. Comparisons with subtidal habitats off Trinidad, California indicate that subtidal biological assemblages are similar offshore from northern Humboldt and Del Norte counties (Boyd et al. 1981), but these assemblages may be distinct from those of Mendocino and Sonoma Counties to the south (Seltenrich 1979, Boyd et al. 1981). Currently, benthic trawls and hook-and-line sampling are being used to survey subtidal fish at five sites along the RNSP coast.

Coastal strand vegetation occurring on sandy beaches above the highest high tide line is well known. Common species associated with this habitat type are the invasive European beach grass, beach primrose, sand verbena, and beach morning glory. European beach grass is an introduced species, and is especially invasive at Gold Bluffs Beach and Caruthers Cove. One threatened plant species, the beach layia occurs within the coastal zone of RNSP.

At least 190 exotic species are among the flora of RNSP, most of which entered the park and became established within the past 150 years. To the south in Humboldt Bay, 95 possibly non-indigenous marine species have been identified. Many of the identified species were found to co-occur in both San Francisco Bay, to the south, and in Coos Bay, to the north. Of these 95 possibly non-indigenous species found in Humboldt Bay, 12 invertebrate and one algal species also occur in RNSP.

The morphology and structural character of the RNSP coast is directly influenced by the local tectonic setting. The area is north of the Mendocino triple-junction where the Pacific, North American and Gorda tectonic plates interact. As a result, the north coast of California is one of the most seismically active regions in the continental United States. The tectonic activity has a direct effect on the character of the parks and their coastal sections. The coast can be subdivided into four major units based on the underlying rock types: Franciscan Formation mélange, Franciscan Formation schist, Franciscan Formation sandstone, and the Gold Bluffs Formation. This underlying geology is largely responsible for the coastal stability as well as the coastal morphology that is observed in RNSP.

Limited beaches front the steep coastal bluffs in many locations. These beaches are generally composed of coarse sand, pebbles, cobbles and boulders. More extensive beaches occur along the RNSP coastline, primarily along the southern section of the parks. Beaches of significant size are located adjacent to Freshwater Lagoon, near the mouths of Redwood Creek and the Klamath River, adjacent to Gold Bluffs and on Crescent Beach. These beaches are composed of medium and coarse sands. The primary sediment source has been attributed to the Klamath River. The beaches in northern California have a dynamic behavior and have thus been described as likely to be the most dynamic resource within RNSP. The seasonal variations in physical processes vary over seasonal, annual and decadal cycles. These variations also drive changes in coastal morphology, especially on the sandy sections of the coast.

The entrances to the local rivers and streams change seasonally as well. Redwood Creek seals from direct connection with the ocean each year, typically during May or June and remains closed until fall rainfall events. The Klamath River has also sealed from direct connection with the sea, albeit much less often. The effects of such closure on the estuarine fish populations in Redwood Creek have been documented but the effects on offshore populations have not.

No comprehensive mapping of marine habitat types and locations has been conducted along the RNSP coast. Currently, there is a very poor understanding of the intertidal and subtidal habitats in the area. Initiating such a mapping effort is paramount for determining the nature of intertidal and subtidal resources in RNSP. As mentioned above, the coastal morphology is linked to the coastal geology and should be considered when surveying the intertidal and subtidal communities.

The direct impact of the ocean on the coastal environments is observable and obvious. Much of our understanding of coastal ocean conditions and flows near RNSP is based primarily on knowledge of the general ocean circulation of the coastal eastern Pacific. There is currently a fair understanding of the basic oceanographic processes that occur offshore of the study area. These processes have been much better studied to the north and to the south of RNSP.

It is fairly well understood that the coastal circulation is greatly influenced by the local and regional wind fields and that the circulation is variable over seasonal time scales. These physical processes and characteristics have a direct influence on the coastal marine ecosystem. During winter, phytoplankton in this region have relatively little sunlight and nutrients to aid in growth. By early spring, the phytoplankton are usually nutrient-limited. The upwelling of deep nutrient-rich waters to the near-surface waters in late spring and early summer provides the necessary nutrients and the phytoplankton population, as well as the rest of the food chain, can grow relatively rapidly. Such upwelling events typically occur in May and June along the northern California coast and play a critical role in jump-starting biological productivity of the entire marine food chain during these periods.

The impacts of longer-term variability, including El Niño/La Niña events and the Pacific Decadal Oscillation are much less understood. These events have been observed to have direct impact on the coastal biological community in areas to both the north and south and they undoubtedly have an impact on RNSP marine resources as well. One curious consequence is that the region tends to receive higher precipitation and larger waves during both major El Niño and La Niña events.

Many of the effects that result from El Niño, La Niña and the Pacific Decadal Oscillation (PDO) are a result of these events correlating with increased cyclone activity, rainfall, sea-surface temperature, sea level, and coastal erosion. Included among the range of potential effects are the following three examples: 1) The direct impact of coastal erosion during El Niño events on intertidal and subtidal communities has been observed elsewhere, but the impact within RNSP has not been documented in detail; 2) A period of "warm phase" PDO appears to be correlated with increased biological productivity off the coast of Alaska and simultaneously reduced productivity off the west coast of North America; during "cool phase" PDO, the opposite pattern in coastal productivity has been observed; 3) The relatively new observation of hypoxic (low oxygen) water conditions off the coast of Oregon in 2002 and 2006, which resulted in massive die-offs of fish and invertebrates has not been documented within RNSP but has the potential to occur. It is important to understand these processes because these are the mechanisms which will cause change in biological systems, move stressors from place to place, and change habitats.

Rivers and streams emptying into the coastal ocean play significant roles in the coastal environment (e.g. freshwater input, the transport of nutrients and materials such as sediments). The Klamath River is the largest river affecting the area and one of the largest on the U.S. west coast; Redwood Creek is the second largest local source, with a mean stream flow of about 5.7 percent of the Klamath River. In addition to large freshwater sources, the rivers of northwest California are also supplying large volumes of sediment to the coast. Freshwater outflow is typically less dense than seawater however offshore of rivers carrying exceptionally high sediment loads, a river plume can become denser than seawater.

Although no detailed investigation has been conducted on the impact of these freshwater sources on the coastal ecosystems, a few effects can be surmised. The discharge is highly seasonal, as is the coastal circulation. During the winter, the river discharge will be directed to the north and toward the coast. If the sediment concentrations in the plume are high enough, then the plume may become denser than seawater (hyperpycnal) and flow offshore along the sea floor. During late spring and summer, the river discharge will be directed southward and offshore and the plume is unlikely to become hyperpycnal. One likely consequence is that the intertidal areas to the north and to the south of the river mouth will have very different fresh water and suspended sediment influences and resulting impacts.

Both low salinity and high suspended sediment loads are likely stressors to the intertidal and possibly to the subtidal communities. Along the RNSP coast, these potential effects appear likely to have variable influence to the north versus to the south of the river mouth. The impacts of large-scale freshwater and suspended sediment input along the seafloor have not been examined in detail. However, reductions in both fish catch and intertidal invertebrate abundance were noted during the most recent Klamath River flood event in 2006.

Recommendations

As a result of this investigation, many of the following recommendations center on the need for baseline information. The timing of the current considerations for future work is quite good, as a number of marine monitoring efforts are currently being considered for the U.S. Pacific coastal ocean that includes the RNSP coastline. Many of these opportunities are identified below.

We recommend the following:

- **Conduct basic mapping of the coastal and nearshore environment to classify habitats and investigate the possible existence of submerged cultural resources within RNSP boundaries**.

  We recommend RNSP develop a collaborative partnership with CICORE (California Center for Integrative Coastal Observation, Research and Education). CICORE is a coastal ocean monitoring program supported by NOAA and conducted by several marine-related institutions of the California State University system. As a part of the CICORE program, key remote sensing measurements are being made along the California coastline using both hyperspectral overflights and marine acoustic swath-mapping to characterize coastal habitats, among other tasks. Future overflights or acoustic mapping may be able to include RNSP.

- **Conduct longer-term measurements of important water characteristics in the nearshore RNSP. Such measurements would be key for determining the influence of seasonal and longer term climatic variations on the marine resources of RNSP**.

  CICORE is also invested in real-time, automated, *in situ* measurements of key water characteristics (e.g., temperature, salinity, dissolved oxygen, turbidity, pH, chlorophyll concentration, and water level) using standardized instrumentation. We recommend that RNSP collaborate with CICORE to investigate the possibility of establishing and maintaining similar measurement systems along the RNSP shoreline. Ideally, in order to capture the undoubtedly significant influence of the Klamath River plume along the shoreline (and the influence of coastal currents on the plume itself), measurements should be made at two sites: one site north and one site south of the Klamath River mouth.

- **Characterize the coastal and nearshore currents along the RNSP coastline.**

  We recommend RNSP develop a collaborative partnership with the Coastal Ocean Current Monitoring Program (COCMP). This program, supported by the California Coastal Conservancy, is designed to provide measurements and model predictions of coastal ocean currents. At present, a single surface current radar (SCR) system is sited on the coast in Crescent City and is operated by Oregon State University. As the regional representative of COCMP, Humboldt State University intends to establish up to four more SCRs along the north coast of California to measure and generate hourly maps of ocean surface currents. The proposed systems would provide roughly 5 km (3.1 mi) resolution. In order to support detailed understanding, monitoring, and prediction of flows closer to the shoreline, higher resolution observations in the park region will likely be needed, either on a temporary or permanent basis. Such measurements would also likely support the development of improved predictive models. A collaborative partnership with COCMP would improve the prospects for justification of such a high-resolution current monitoring system.

- **Characterize the erosional and depositional environments along the RNSP coastline, including the rates of erosion and deposition.**

Shoreline change data are scheduled to be collected every three years using LIDAR mapping techniques on USGS overflights. Data currently are not analyzed for the RNSP section of the coast. Perhaps a cooperative agreement could be developed to broaden the current area of analysis to include the RNSP coastline.

- **Identify the beach littoral cells and develop a beach sediment budget for the RNSP coast.**

Researchers have suggested that much of the coastline of RNSP is accreting which is in contrast to much of the Oregon and California coastline. It has also been suggested that these same beaches may be sediment impaired with respect to the supply of riverine sediments. This apparent contradiction clearly indicates the need for a closer examination of the sources and sinks of sediment along the RNSP coast. We suggest that the development of a littoral cell sediment budget would be the most direct method to work toward a better understanding of local coastal processes and responses.

- **Conduct a baseline inventory of the intertidal and subtidal habitats and associated biological communities within RNSP.**

Biological inventories of algae, invertebrates, and fish occurring in select rocky intertidal and sand beach habitats were conducted in 2005 as part of the Marine Resources Survey. Biological inventories of intertidal fish, invertebrates, and algae should continue to occur approximately every 3 to 5 years. Standardized protocols should be favored as they would have more power to detect and identify change and make comparisons with other regions. Intertidal habitat inventories were begun in the summer of 2005 to identify and describe variations in geology, beach morphology, and biological communities along the entire RNSP coastline. These data should be used to develop a GIS dataset and layers for the coastline. Subtidal inventories consist only of qualitative data gathered in the mid to late 1970s and the ongoing subtidal fish surveys. Subtidal surveys are very difficult in RNSP because of poor water visibility attributed to rough water and high runoff. Remote sensing options should be explored for identifying subtidal habitats and vegetation types. All subtidal and intertidal inventories would be greatly enhanced by a mapping effort (hyperspectral overflights and marine acoustic swath-mapping; see recommendation 1).

- **Continue long term intertidal monitoring at regular intervals.**

Long term monitoring allows managers to understand and predict how environmental change, including human impacts affect biological communities. Initial intertidal monitoring data collected by the Marine Resource Survey (bi-monthly June 2004-November 2005) provides a baseline of natural dynamics in RNSP, but continued monitoring is necessary for tracking long-term changes. Monitoring is now being conducted in late spring and fall through a cooperative agreement with the University of California, Santa Cruz. It is extremely important to continue biannual monitoring. These data can be used to detect and document the occurrence and extent of change due to natural catastrophes, temperature changes, biological invasions, and anthropogenic disturbances such as oil spills. Monitoring of tidepool fish abundance and diversity should be considered for integration into current rocky intertidal monitoring activities to broaden the range of organisms monitored, and provide managers with more insight to this complex ecosystem.

- **Establish a comprehensive monitoring program for marine invasive species**.

There are 12 possibly non-indigenous species known to occur in the park's intertidal habitats. It is recommended that a comprehensive monitoring program for marine invasive species be put in place for RNSP. This monitoring program could be conducted in conjunction with inventory and monitoring efforts. The first step for detection would be to compile a list of non-indigenous species with potential to occur in RNSP. This list should also provide information about what habitat types each species occurs in, and indicate if a particular species is invasive elsewhere. This list should be cross checked with all species found in past and future inventories. Detecting exotic species could be achieved through routine inventories at select sites, or through observations conducted during regular intertidal monitoring events. The most cost and time effective way to monitor the RNSP coast for invasive species would be to determine which species are known to be invasive, and routinely search the habitats with which they associate. Once detected, the abundance of non-indigenous populations should be eradicated or monitored regularly to determine if the population is increasing. Species that are known invasives should be targeted for eradication or monitored most frequently.

A. ASSESSMENT OBJECTIVES

In January 2004, Redwood National and State Parks (RNSP or park) held its first marine scoping session to address the state of park coastal and marine resources. The scoping session identified stressors that may cause abnormal conditions of marine ecosystem health, identified vital signs useful for providing early warnings of abnormal conditions and compiled preliminary background information.

As a follow up to the scoping session, this assessment of coastal and marine resources and conditions in RNSP was initiated for public lands and coastal waters within the boundaries of RNSP. This coastal and marine resources assessment report:
a) synthesizes existing information, b) describes biological and physical resources and conditions of coastal water resources, and c) identifies primary contributors and potential sources of water resource impairment. The Report also identifies information gaps and issues that are likely to require more detailed investigation for assessing marine-related conditions and threats to park coastal water resources.

Several coastal and marine projects were conducted concurrently with this assessment including: a baseline inventory of rocky intertidal and sandy beach sites (Cox et al. 2006), an inventory of coastal habitat typing and biological communities by Humboldt State University of the accessible park coastline and nearshore marine fish sampling over rocky and sandy substrates offshore of the park.

This assessment will assist the National Park Service (NPS) in better understanding and determining the current condition of coastal water resources within the park unit. Information synthesized in this report will contribute to a management strategy to reduce and prevent impairment of RNSP's coastal waters and natural resources through park-based efforts and regional-based collaborations with state, local and federal partners.

B. PARK DESCRIPTION

B1. Background

B1a. Location and Setting

Redwood National and State Parks are located along the Pacific Coast in northern California's Humboldt and Del Norte Counties (Figure 1). Preservation of redwood forests in the name of Redwood National Park was first proposed to the California Legislature in 1852 by U.S. Senator Henry A. Crabb. Originally encompassing 23,490 ha (58,000 ac), Redwood National Park was established by Congress (Public Law 90-545) in 1968 to preserve significant examples of the primeval coastal redwood forest and the streams and seashores with which they are associated. The legislated national park boundary encompassed state parklands: Prairie Creek Redwoods State Park, Jedediah Smith Redwoods State Park and Del Norte Coast Redwoods State Park. Following establishment of Redwood National Park, controversy arose over the damaging effects of logging upstream and upslope of the newly created national park. After a decade of litigation and scientific studies, the National Park boundary in 1978 was expanded to the watershed boundary of the lower third of the Redwood Creek watershed (Public Law 95-250).

In 1994, the California Department of Parks and Recreation (CDPR) and the National Park Service signed a memorandum of understanding which agreed to joint management of the four-park area to ensure maximum resource protection, making RNSP the most integrated park system in the NPS Pacific West Region. Since the Parks establishment, private, local, state and federal funds have helped the continuation of land acquisition. Today, RNSP comprises about 45 percent of all the old-growth redwood forest remaining in California.

Figure 1. Redwood National and State Parks location map.

Together, these parks are designated a World Heritage Site and International Biosphere Reserve by the United Nations and currently total over 45,560 ha (112,500 ac), including 52 km (37 mi) of unspoiled coastline.

The National Park boundary extends 0.4 km (0.25 mi) beyond the mean high tide line, and the NPS exercises jurisdiction over the waters, intertidal lands, and submerged lands. The coast jurisdiction of state park lands extends 0.3 km (1,000 ft) west of the ordinary high-water mark. Federal land extends seaward to the mean high water mark; west of the mean high water datum, the intertidal and submerged lands are in state ownership. In 2001, the NPS submitted an application to the California State Lands Commission to lease the state-owned submerged lands within the park boundary. Excluded from the NPS lease application were the submerged lands within the Yurok Reservation at the mouth of the Klamath River and the submerged lands within the park boundary south of Crescent City that the State Lands Commission granted to the Crescent City Harbor District prior to the establishment of the park. The California State Lands Commission approved the NPS application and issued a lease to the NPS in 2002. The term of the lease is 49 years, expiring December 31, 2050. The lease covers the state-owned submerged lands from mean high water mark to a point 0.3 km (1,000 ft) seaward for the entire length of the park, with the exclusions described above.

B1b. Area History and Human Utilization

For thousands of years before the Euro-American population arrived to the local area, American Indians of the north coast of California, had adapted well to the redwood forests and associated ecosystems (Malcolm 1994). There were many tribes in the region and their villages were scattered along the coast and major rivers. Each was essentially independent, yet associated through intricate social, economic and religious relations. They used the natural resources of the area, including the marine resources. In 1850, when gold was discovered along the Trinity River, settlers came to the area and American Indians were removed from most of their lands. Although treaties were later signed to allocate reservation lands for these north coast tribes, the California Congressional delegation voted against them, stating that the reservations would allow tribes to control too much land. However, local Indian reservations were later declared through administrative decree. Figure 2 shows the Tolowa, Yurok, Chilula, and Hupa (a.k.a. Hoopa) ancestral lands with respect to RNSP. Today the Yurok, Tolowa, and Hupa Tribes have tribal governments and the park consults with federally recognized tribes that are ancestral to lands now within RNSP.

As settlers moved west in the early 1800s, the demand for timber to build homes and growing cities came as well. Redwood was quickly gaining in popularity due to its size and workability. By 1853, three years after gold was discovered along the Trinity River and the city of Eureka was established, nine mills were in full operation in the Eureka bayside community. Vast redwood stands had begun to disappear by the end of the 1800s. At the time, a growing economy and new and improved logging methods caused extensive deforestation and reduced the once vast redwood stands to small fractions of their original extent. In 1910, a group of concerned citizens formed the Save-the-Redwoods League and would eventually take part in establishing Jedediah Smith

Redwoods State Park, Del Norte Coast Redwoods State Park, and Prairie Creek Redwoods State Park for preservation of the redwood forests and their surrounding ecosystems. Deforestation accelerated by WWII and through the economic surge of the 1950s. By the 1960s, nearly 90 percent of the old-growth redwood forests had been eliminated. Redwood National Park was established in 1968 with the priority of preserving uncut redwood forests and associated ecosystems. In 1978, a decade later Congress increased the park size with land that included previously harvested areas in the Redwood Creek watershed. Park resource managers have since developed a large-scale watershed restoration program.

Figure 2. Location of the Tolowa, Yurok, Chilula and Hupa (a.k.a. Hoopa) ancestral lands with respect to RNSP (from http://data2.itc.nps.gov/hafe/hfc/carto-detail.cfm?Alpha=REDW#).

Unique biologic diversity exists within the parks. Today, visitors to RNSP will not only find old-growth redwood groves but also open prairie lands, three major coastal watersheds, and a pristine California coastline. Many threatened and endangered species make their home within the park including the western snowy plover, the brown pelican and coho salmon. The Klamath River and Redwood Creek estuaries are key habitat for threatened anadromous fish populations. The intertidal invertebrate species found along the coast are incredibly varied and colorful giving an excellent opportunity for tidepooling.

Park visitation data available for the last 25 years (1981 to 2005), indicated an average of 458,300 visitors per year, with a high of 677,150 visitors in 1988. In the last five years (2001 to 2005), average visitation has declined to 397,500 visitors per year (from Inside.nps.gov.parks: rnsp: 400).

B1c. State, Federal, and International Designations

Area of Special Biological Significance (State Water Quality Protection Area)

Redwood National Park was designated an Area of Special Biological Significance (California Marine State Water Quality Protection Area) by the State Water Resources Control Board (SWRCB) in 1974. These are areas with sensitive species or biological communities in which alteration of natural water quality is undesirable. Point source run-off and discharge of temperature-elevated wastes is prohibited. Non-point source wastes are to be controlled as much as possible (Maughan et al. 1979). This designation should help to protect the coastline of the park from pollution by industrial or municipal sources. At the present time, the coastline is largely undeveloped, and the designation has been mainly regulatory thus far. It should be noted that such a designation cannot protect against non-point source wastes of unmonitored and unknown origins.

Assembly Bill 2800, approved by the Governor of California on September 8, 2000, added sections to the Public Resources Code (PRC) that are relevant to Areas of Special Biological Significance (ASBS). Section 36700 (f) of the PRC defines a state water quality protection area (SWQPA) as "a non-terrestrial marine or estuarine area designated to protect marine species or biological communities from an undesirable alteration in natural water quality, including, but not limited to, areas of special biological significance that have been designated by the State Water Resources Control Board through its water quality control planning process." Section 36710 (f) of the Public Resources Code states: "In a state water quality protection area point source waste and thermal discharges shall be prohibited or limited by special conditions. Non-point source pollution shall be controlled to the extent practicable."

The change in designation from Area of Special Biological Significance to State Water Quality Protection Area occurred on January 1, 2003 as required under Section 36750 of the PRC. The Areas of Special Biological Significance were originally given numerical designations based on the State Water Resources Control Board resolutions in which they were established. These numerical designations are not related to their geographic positions along the coast. Previous editions of SWRCB publications (up to and including the 1999 edition) have provided maps of the ASBS in numerical rather than geographic order. The RNSP Area of Special Biological Significance/State Water Quality Protection Areas is referred to as Region 1, ASBS #8 (Figure 3).

Figure 3. California State Water Quality Protection Areas. The Redwood National and State Park Area of Special Biological Significance is highlighted. Region 1, North Coast Regional Water Quality Control Board ASBS No. 8. (from http://www.swrcb.ca.gov/plnspols/asbs_info.html).

California Coastal National Monument

The California Coastal National Monument, established on January 11, 2000, includes over 11,500 rocks, islands, exposed reefs, and pinnacles off the California coast, totaling approximately 3.6 km^2 (1.4 mi^2) along 1352 km (840 mi) of coastline. It does not include the major islands, such as Santa Catalina and the other Channel Islands, the Farallon Islands, or the islands of San Francisco Bay nor does it include rocks within the boundary of RNSP. The average size of rocks and islands in the monument is less than 283 m^2 (0.07 ac). The monument protects "all unappropriated or unreserved lands and interest in lands owned or controlled by the United States in the form of islands, rocks, exposed reefs, and pinnacles above mean high tide within 12 nautical miles (22 km) of the shoreline of the State of California." (BLM 2003).

The proclamation creating the monument directed the Secretary of the Interior to manage the monument through the Bureau of Land Management (BLM). This includes the geologic formations and the habitat these areas provide for seabirds, pinnipeds, and plant life. Off the California coast, from San Diego County to Del Norte County, these unappropriated rocks and small islands have been under Federal government jurisdiction and administered by the BLM and its predecessor, the General Land Office, since the time of California statehood.

Since 1983, the BLM has managed these resources in cooperation with the California Department of Fish and Game, which remains a critical partner in monument management. The BLM works with many partners to manage these offshore resources in a manner consistent with the management of California's other coastal natural resources. In the spring of 2000, the BLM, California Department of Fish and Game, and California Department of Parks and Recreation signed a Memorandum of Understanding to work jointly to manage the monument, develop a greater understanding of its resources, and provide information to the public.

The Bureau of Land Management designated the California Rocks and Islands Wildlife Sanctuary as an Area of Critical Environmental Concern (ACEC) in 1990. The special designation applied to all rocks, pinnacles and reefs along the coast of California, from Oregon to Mexico. These lands had already been withdrawn from mining, mineral leasing, settlement, and sale under laws that protect the islands and established the California Islands Wildlife Sanctuary in 1983. The ACEC designation increased the visibility and management protection of the wildlife sanctuary and ensured that the wildlife values associated with these lands are not overlooked in the BLM's everyday operations. Griffin (2003) reported that "…the Monument is some of the only relatively undisturbed intertidal zone remaining on the California coast…providing an important baseline reference habitat."

The California Department of Fish and Game (CDFG) manages the wildlife sanctuary through an interagency memorandum of understanding. The Department of Fish and Game regulates public use, allowing only that which is compatible with the protection of the wildlife resources. Specifically, CDFG prohibits removal of products, some of which may have commercial values, and limits activities during the pelagic bird nesting seasons which are detrimental to breeding.

Three threatened and endangered species are known to inhabit the offshore rocks of RNSP. The brown pelican, peregrine falcon and Steller sea lion have been observed utilizing some of these islands. Although the peregrine falcon has recently been de-listed by the Federal government, it is still listed by the state of California as endangered. The bald eagle also uses the RNSP coastal areas (Bensen 2004a) and Steller sea lions use offshore rocks as haul-out sites (RNSP unpublished data). The management of rocks and islands extends to the rocks off the coast beyond the quarter mile boundary of RNSP and adds an extra layer of protection for breeding bird species (BLM, 2003).

Pacific Whiting Klamath River Salmon Conservation Zone

Designed to prevent by-catch of salmon in the whiting fishery, the Pacific Whiting Klamath River Salmon Conservation Zone includes offshore waters of the park and is managed by National Oceanographic and Atmospheric Administration (NOAA) and National Marine Fisheries Service (NMFS) under the mandate of the Endangered Species Act (Figure 4).

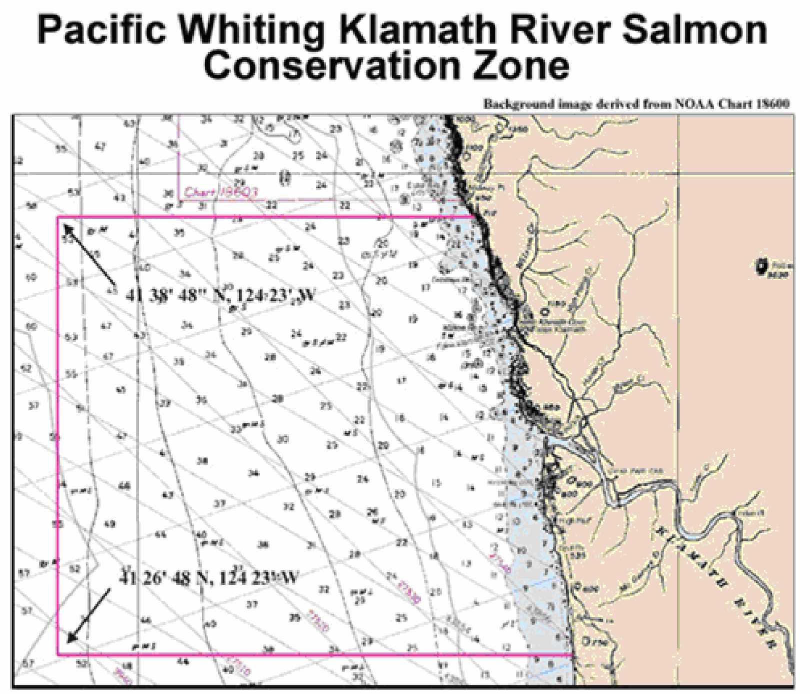


Figure 4. Located off the coast of RNSP and centered around the Klamath River estuary, the Pacific Whiting Klamath River Salmon Conservation Zone was designated to prevent the by-catch of salmon in the whiting industry (from http://www.mpa.gov).

World Heritage Site

Nominated by the Secretary of the Interior, RNSP was designated a United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Site in 1980. Designations are based on the outstanding universal values of areas of exceptional natural beauty and outstanding examples of ongoing ecological and biological processes.

Man and the Biosphere (MAB) Reserve

RNSP is part of the California Coast Ranges Biosphere Reserve that includes temperate rain forests and coastal marine habitat. Designated part of the UNESCO International Biosphere Reserve program in 1983, the primary aim of the reserve is ecosystem management.

B1d. RNSP Coastal Management Issues

Coastal Watershed Impairment Affecting Nearshore Waters

Two large watersheds discharge along the RNSP coast: Redwood Creek and Klamath River. Both are federally listed as impaired under the Clean Water Act from a combination of logging, road building, and agricultural activities. Watershed impairments include high nutrient and low dissolved oxygen concentrations (organic enrichment) for the Klamath River and high sediment and temperature for Redwood Creek. Discharge from these impaired rivers (nutrients, elevated temperature, sediment and large wood) may affect the nearshore waters. For example, these rivers deliver large amounts of sediment to nearshore environments. However, coastal sediment transport and deposition is poorly understood for RNSP's coastal zone. Large sediment loads are likely to impact the physical characteristics and biological community structure of both subtidal and intertidal habitats (McGary 2005).

Redwood Creek Estuary Function

The estuary at the mouth of Redwood Creek has been directly impacted by the construction of the flood control levees, upstream and adjacent land uses, and uncontrolled breaching of the berm at the mouth of Redwood Creek. The 1968 construction of a U.S. Army Corps of Engineers flood control project (levees and channelization) drastically altered the aquatic resources of the lower 5.5 km (3.4 mi) of Redwood Creek and impaired the physical and biological functioning of the estuary and adjacent wetlands. The flood control levees bypassed and isolated the last downstream meander of Redwood Creek, reduced circulation into the south and north sloughs, and contributed to an increase in sedimentation. Approximately 50 percent of the lower estuary has filled in with ocean derived sediment and/or become isolated from the embayment since the project was completed. The resultant reduced circulation between the sloughs and embayment has resulted in degraded water quality conditions in both sloughs. The levees have reduced fish habitat area and water depth in the estuary. In addition, removal of adjacent spruce forests, agricultural practices, and increased sediment load from upstream have negatively affected the estuary, its aquatic resources, wetlands, and riparian vegetation.

Shoreline Change

Shoreline change can be driven by both natural processes and human activities. Although sand accretion budgets are not known for the beaches of RNSP, there has been considerable widening of some sections of Gold Bluffs Beach. It is unknown if this beach accumulation is natural or if increased sediment loads in the Klamath and Redwood Creek watersheds have contributed to beach widening. However, effects on nearshore ecosystems should be considered when planning modifications to adjacent watersheds, especially when increased sediment or other debris is likely to discharge. Additionally, the geological setting of the shoreline at RNSP makes it susceptible to catastrophic events such as earthquakes and tsunamis that can drastically alter nearshore environments. The coastline of RNSP is ranked at low to moderate risk on the USGS Coastal Vulnerability to Sea-Level Rise scale. This ranking is based on a model of regional climate, coastal geomorphology, rate of sea-level rise, and past shoreline evolution (USGS 2001).

Invasive Species

Invasive exotic species can alter the abundance and distribution of native species, or the ecological relationships of native assemblages. Invasive species are most prevalent in the flora of RNSP. The goal of exotic plant management in RNSP is eradication, if possible. It is important to eradicate invasives especially where they affect threatened and endangered species, and where they affect ecosystem function. Exotic plants are prioritized for management based on their threat level or invasiveness. Exotic plants that threaten a rare, or threatened and endangered native species; threaten to hybridize with a native species to create a viable hybrid; or have the potential to seriously alter a vegetation community receive highest priority for control.

Exotic marine species are not well known within the RNSP boundaries. There are 12 possibly exotic species known to occur in the park’s intertidal habitats (11 invertebrate and 1 algal species).

Fishing

Recreational, and commercial fishing occurs offshore, nearshore, and from the beaches of Redwood National and State Parks. Three commercial fisheries occur within or adjacent to the quarter mile offshore boundary of RNSP: crab, commercial beach fishing for surf smelt/night smelt and redtail surfperch, and live rockfish fishery. The California Fish and Game Commission promulgates fishing regulations and the California Department of Fish and Game enforces all fishing regulations for sport and commercial fishing and manages the fisheries, including those within the park. Little is known about the abundance of most marine fish and invertebrate species beyond gross catch data provided by commercial fishermen to the California Department of Fish and Game.

Pollution

The coastline of RNSP is relatively pristine due to its remote location and low population density. However, there is a considerable amount of ship traffic off the RNSP shoreline. The coastline is also difficult to navigate due to fog and numerous offshore rocks, hence oil spills are a definite possibility. If an oil spill were to occur off the RNSP coast, it would likely injure or kill sea birds and mammals. If a spill reached offshore rocks or the coastline, invertebrate and algal communities could be adversely affected. Currently, monthly carcass surveys are being conducted by RNSP staff, in part to search for oiled birds or mammals. Ongoing intertidal monitoring is an important method for managers to use for assessment of the damage and recovery status of these communities if an oil spill were to occur.

B2. Geologic Setting and Physical Processes

B2a. Geology

The landscape and structural character of RNSP is directly influenced by the local tectonic setting. The Parks are located about 115 km (71 mi) north of the Mendocino triple junction where the Pacific, North American and Gorda tectonic plates interact (Figure 5).

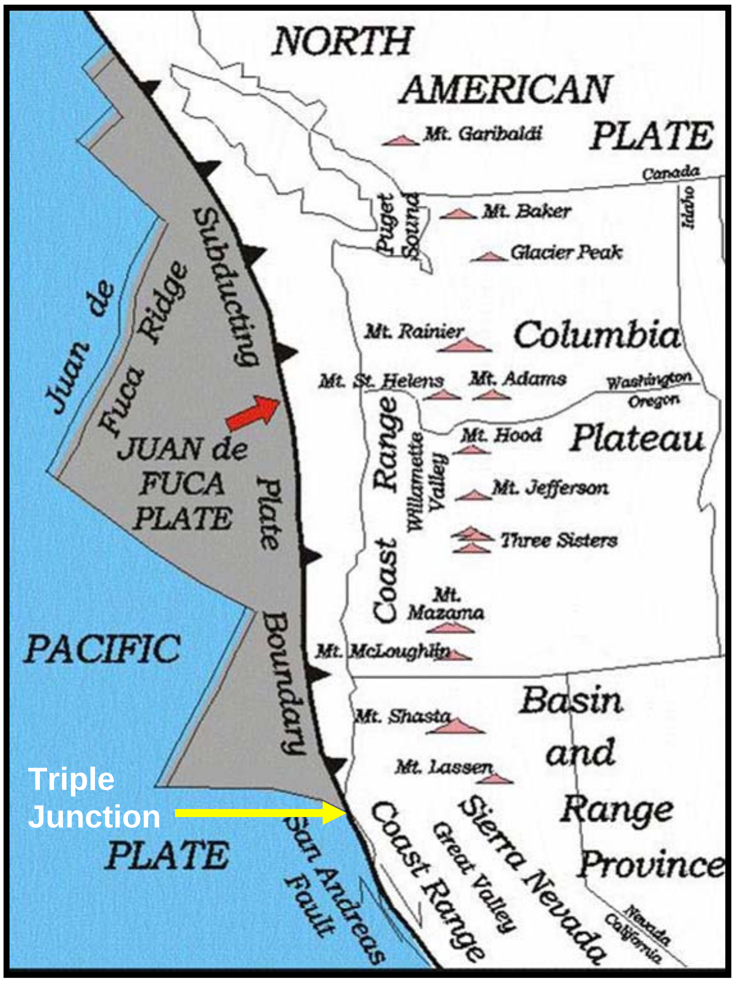


Figure 5. Location of the Mendocino triple junction, where the Pacific, Gorda and North American plates converge (from Lillie 2005).

The triple junction formed about 29 million years ago and has migrated northward for the last 24 million years to its current position (Atwater 1970). The triple junction is a region of uplift and deformation located near Cape Mendocino. The region represents the transition from strike-slip deformation south of the triple junction that is associated with the San Andreas Fault system to subduction-related deformation north of the triple junction in conjunction with Gorda-North American collision (Figure 6). As a result, the north coast of California is vulnerable to earthquakes from many sources and is one of the most seismically active regions in the continental United States (Clarke 1992).

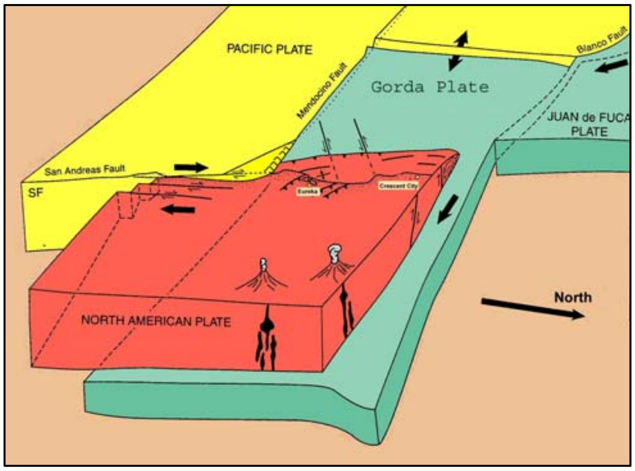


Figure 6. Schematic of the Mendocino Triple Junction plate interactions and geometry (after McPherson 1992).

Redwood National and State Parks are situated along the south end of the Cascadia Subduction Zone (CSZ) where the Gorda oceanic plate is being driven beneath the North American continental plate. The CSZ is located about 56 km (35 mi) offshore of RNSP and dominates the tectonic setting near RNSP (Figure 7). The Gorda plate subducts beneath the North American plate at a rate of about 2-4 cm/yr and Gorda intraplate seismicity accounts for the majority of the seismic activity in the region. The collision of the Gorda and North American plates has resulted in E-NE compression and is reflected in the north-northwest trending faults and associated folds throughout the region (Nilsen and Clarke 1987; Clarke 1992) (Figure 8).

The CSZ is capable of producing great earthquakes and associated large tsunami similar to the 2004 Indonesian tsunami (Lori Dengler, Geology Professor, Humboldt State University, personal communication). A great earthquake can permanently change the coastline. Some coastal areas may subside, others may uplift, and shaking may trigger coastal landslides. For example, a 7.0 magnitude earthquake in 1992 near Petrolia, California uplifted about a 16 km (10 mi) section of coastline up to 1.3 m (4 ft) which stranded some intertidal communities above the intertidal zone, resulting in their demise. The next great Cascadia earthquake will also likely produce a local tsunami that may reach the coast of RNSP within minutes; such a tsunami is expected to have an average tsunami inundation height of about 12 m (40 ft) along the coast. The 2004 Indonesia tsunami also stripped soil to bedrock up to 15 m (50 ft) above sea level (Lori Dengler, Geology Professor, Humboldt State University, personal communication). Potential physical and biological impacts to the parks coastal and nearshore marine resources from a large Cascadia earthquake and tsunami are unknown.

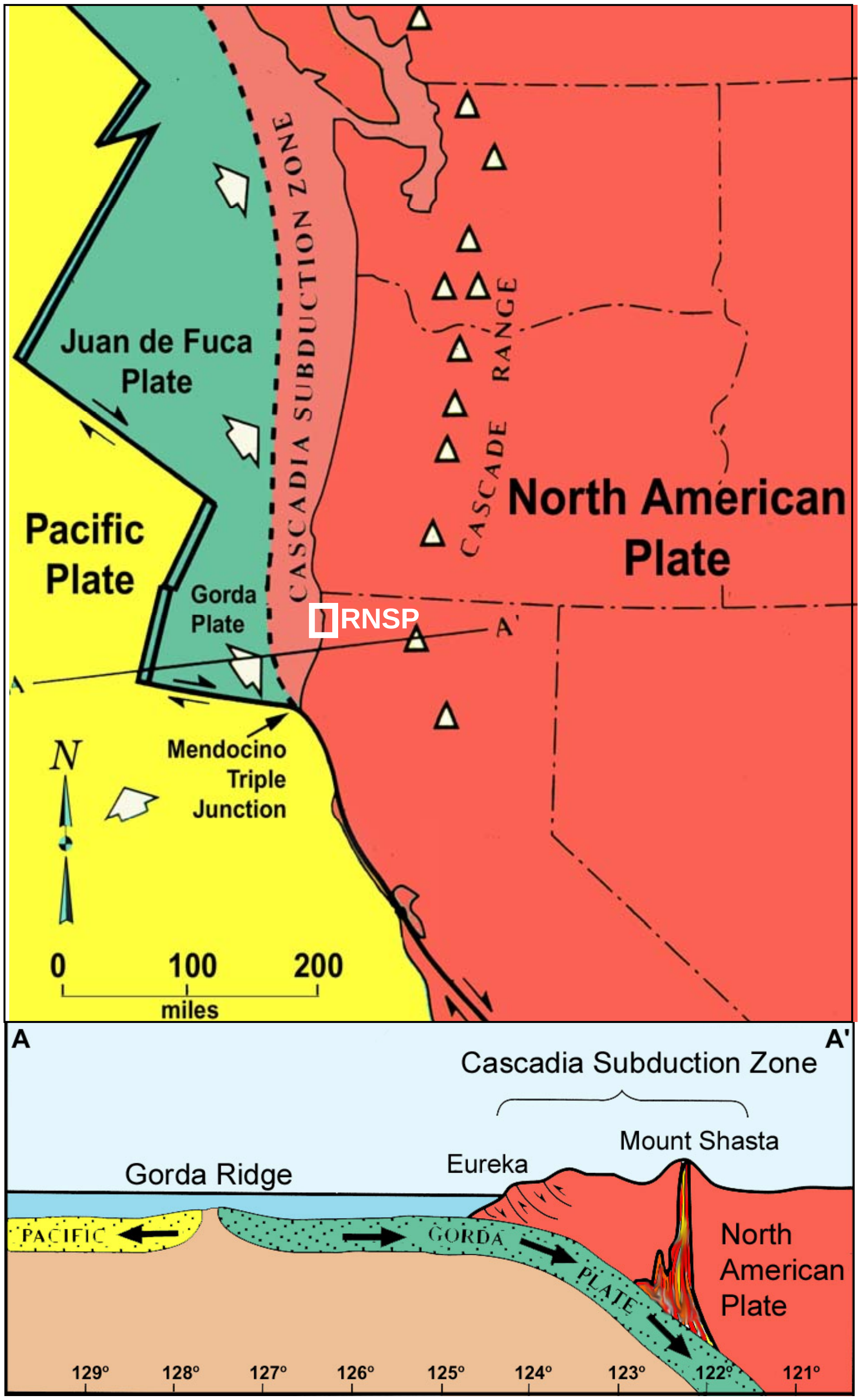
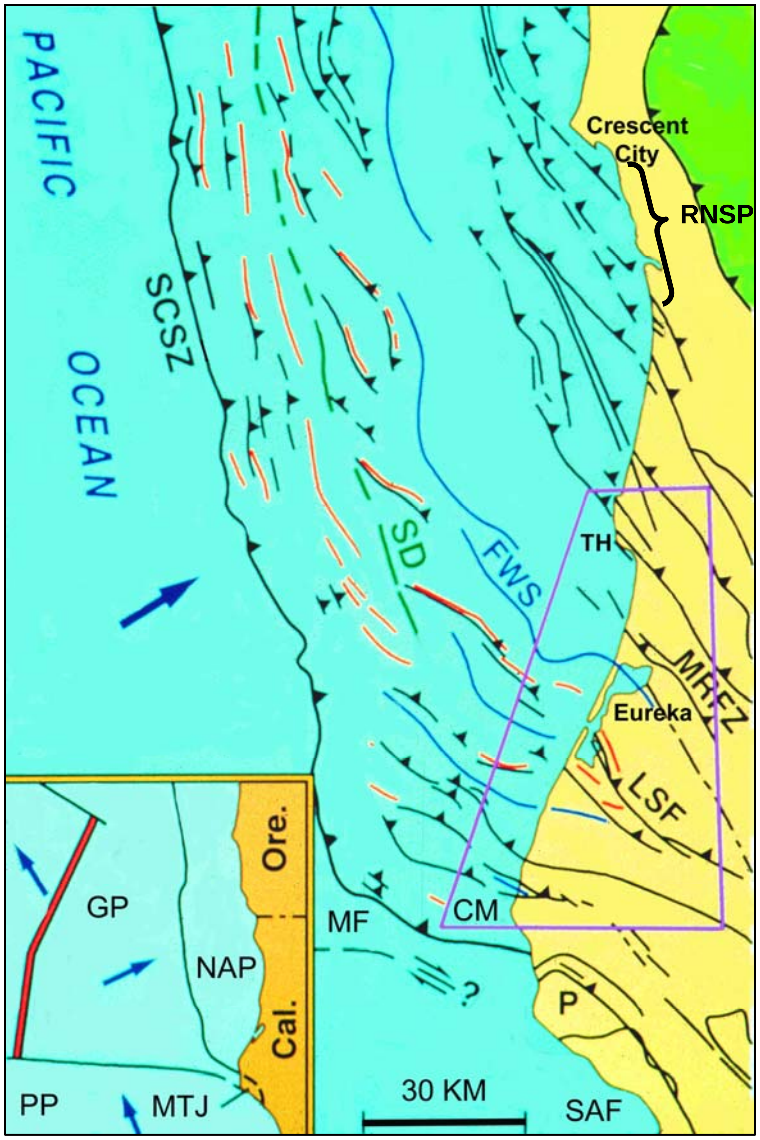


Figure 7. Illustration of the North America, Gorda and Juan de Fuca plates and the Cascadia Subduction Zone in relation to northern California, Oregon, Washington and British Columbia. Redwood National and State Parks lie along the southern end of the CSZ (from http://www.humboldt.edu/~geology/earthquakes/rctwg/index.html).



Legend:
CM Cape Mendocino
FWS Freshwater Syncline
GP Gorda Plate
LSF Little Salmon Fault
MF Mendocino Fault
MRFZ Mad River Fault Zone
NAP North American Plate
PP Pacific Plate
RNSP Redwood National and State Parks
SCSZ Southern Cascadia Subduction Zone
TH Trinidad Head

Figure 8. Fault and fold orientations along the northern California coastal area from Point St. George to Cape Mendocino. The area includes the coast line of Redwood National and State Parks (from Clark and Carver 1992).

B2b. Continental Shelf

The continental shelf west of RNSP extends from the coast to about 135 m (440 ft) depth and varies in width from 15 to 30 km (9-18 mi). The continental shelf is narrow when compared to the worldwide average of 75 km (45 mi) (Curray 1965). The nearshore zone, to a water depth of 50 to 60 m (164-197 ft), is covered by fine to very fine sands. Silts and clays dominate the middle shelf, in water depths from 60 to 120 m (197-394 ft). Sediments on the outer shelf, deeper than 120 m (394 ft), are more variable, ranging from sandy silts to silty sands (Borgeld 1985). The water depths at the seaward park boundary, 0.4 km (0.25 mi) offshore, are on the order of 10 to 12 m (33-39 ft).

B2c. The Coast

The coastal trend in RNSP is generally north-south with an overall arcuate shape which is convex seaward. The most eastern point on the coast is located near Ossagon Creek; the coast south of that point tends SSW-NNE; the coast north of that point trends SSE-NNW. Smaller exceptions to the trend are noted along the coast. The park coastal section has steep hillslopes, with limited pocket beaches. Exceptions occur near Gold Bluffs Beach and near the mouths of the Klamath River and Redwood Creek, where sand beaches are more extensive.

The coastal section of RNSP, from Orick to Crescent City (approximately 52 km, 37 mi), is composed primarily of four major rock types found in two recognized geologic formations (Smith 1978): the Franciscan Formation, which can be subdivided into three basic units, mélange, schist and sandstone, and the Gold Bluffs Formation which is composed of weakly consolidated sandstones and conglomerates. The indurated rocks have been inferred as part of the Franciscan formation of Cretaceous-Jurassic or Pre-Cretaceous age (Strand 1962, 1963). The variations in coastal geology are largely responsible for the differences in coastal stability observed (Figure 9). The coastal character changes are discussed in more detail below.

From Freshwater Lagoon to Major Creek (south end of Gold Bluffs Beach) Franciscan Formation Schist is exposed (Figure 10a). The coast is composed of metamorphosed sandstone, siltstone, and volcanics; and is, overall, the most stable stretch of coastline in the parks.

From Major Creek to Ossagon Creek, the coastal bluffs exposed adjacent to the beach are composed of the sandstones and conglomerates of the Gold Bluffs Formation with remnants of the formation found on the ridge crests farther inland (Figure 10b). These units are composed of loosely consolidated sand and gravel deposits that have been interpreted to be of fluvial origin from an ancestral Klamath River (Trexler 1989). The composition of sand along the southern section of the coast indicates a Klamath River source (Borgeld 1985; Ricks 1985, 1995). These coastal bluffs were formed during wave induced cliff retreat. These cliffs rise vertically 25-75 m (80-250 ft), and are fronted by beaches with backing dunes along most of their expanse.

From Ossagon Creek to just north of Footstep's Rock (north of False Klamath Cove) the coast is composed of isolated blocks of Franciscan Formation mélange, solid rock in a matrix of sheared sand and siltstone (Figure 10c). The matrix easily alters to clay when exposed to water, creating an extremely unstable slope. This unit is considered the most unstable geologic unit along the parks coastline.

From just north of Footstep's Rock to Enderts Beach the coastal section is composed primarily of Franciscan Formation sandstone (Figure 10d). This unit is a massive, bedded greywacke sandstone with inter-bedded siltstone. The rocks are extensively jointed and faulted and are characterized by steep slopes. While the unit may be classified as moderately stable, the nature of the beds and the coastal environment in which it's located makes it perhaps the most physically unstable unit in the study area.

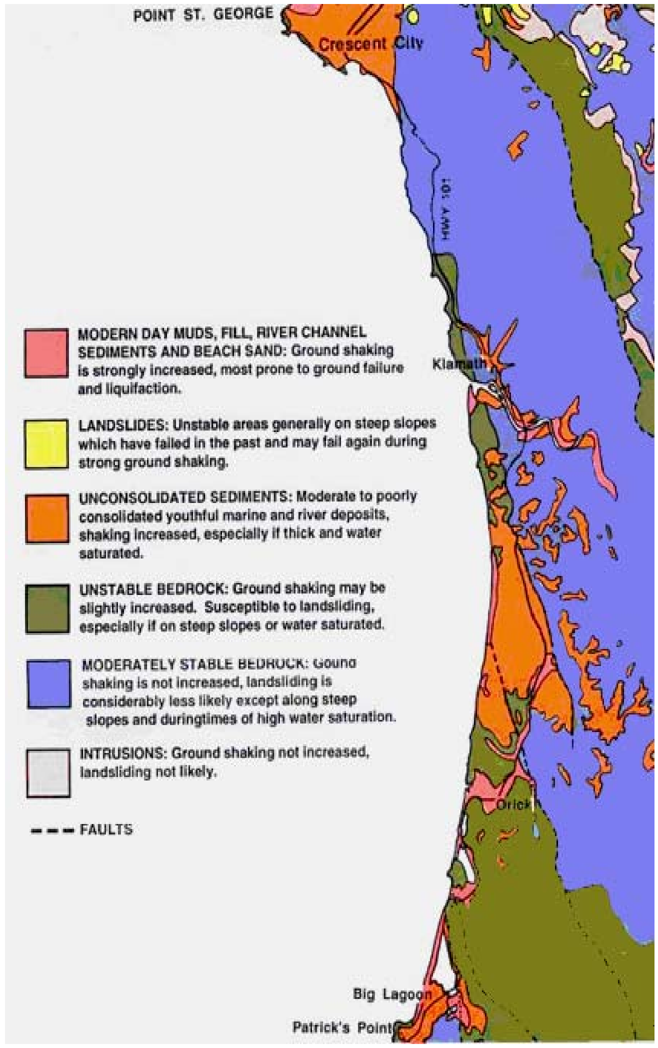


Figure 9. Coastal stability map of the northern California coast from Patrick's Point to Point St. George, as related to the underlying geology (after Moley and Dengler 1992). The area includes the coastline of Redwood National and State Parks.

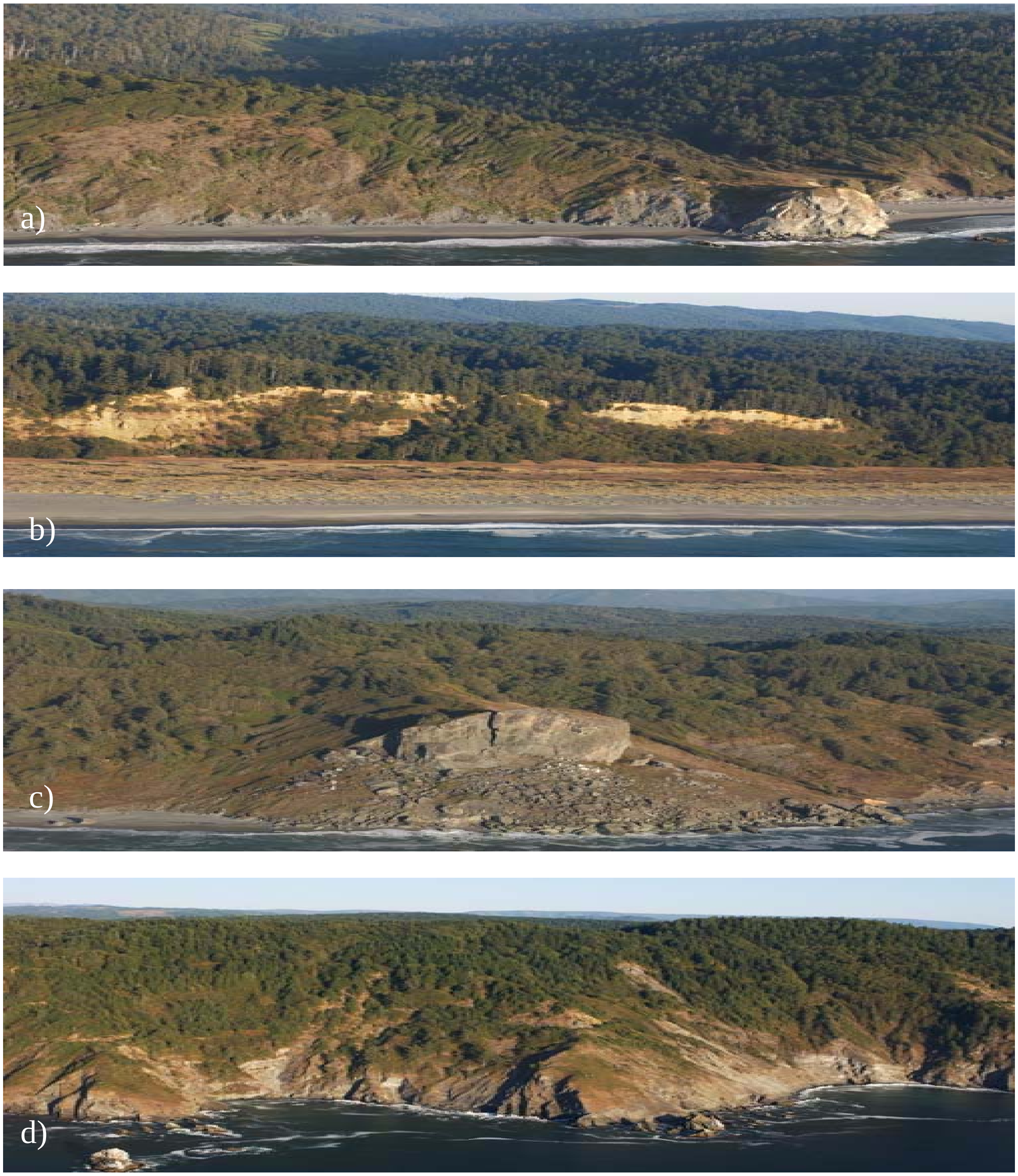


Figure 10. Aerial images depicting the four major rock types (found in two recognized geologic formations) found along the RNSP coastline (from Adelman and Adelman 2004-2005 www.californiacoastline.org).

(10a) Franciscan Formation schist found from Freshwater Lagoon to Major Creek. This area is considered the most stable coastal section in RNSP.

(10b) Gold Bluffs Formation sandstone and conglomerate found from Major Creek to Ossagon Creek.

(10c) Isolated blocks of Franciscan Formation mélange found from Ossagon Creek to just north of Footstep's Rock. This area is considered the most unstable coastal section in the Park.

(10d) Franciscan Formation sandstone found from just north of Footstep's Rock to Enderts Beach. This is considered to be moderately stable.

B2d. Beaches

As mentioned above, the majority of the coastline is steep coastal bluffs fronted by limited beaches in many locations. More extensive beaches occur along the RNSP coastline, primarily along the southern section of the parks. Beaches of significant size are located adjacent to Freshwater Lagoon, near the mouths of Redwood Creek and the Klamath River, adjacent to Gold Bluffs and on Crescent Beach at the very north end of the Park. These beaches are composed of medium and coarse sands (Glogoczowski and Wilde 1971). As discussed above, the primary sediment source has been attributed to the Klamath River (Borgeld 1985; Ricks 1985, 1995).

The beaches in northern California have a dynamic behavior and have thus been described as likely to be the most dynamic resource within RNSP (Klein 1993). The sediments that compose the beaches are constantly responding to the ever-varying nature of the physical environment. Waves, tides and local sea level variations drive changes in the beach profiles as the sediment shifts from the exposed beach to the offshore and back again. These two primary morphologies are referred to as berm-type and bar-type beach profiles (Figure 11). These changes have been commonly referred to as seasonal, or winter/summer, profile changes in many locations (Komar 1998). For example, just to the south at Trinidad State Beach, the beaches typically change profiles on a seasonal basis (David 2003). A transition typically occurs during March or April where beach sands aggrade and form an onshore berm, shifting from a bar to a berm-type profile. Around November or December, the profile shifts back from a berm to a bar-type profile as the beach sands move offshore and form a bar. In October and November of 2002, David (2003) measured the removal of a prominent onshore berm at Trinidad State Beach within a 2-week period (Figure 12). This degradation period was associated with high wave energy, verified in data collected by the NOAA buoys #46022 and 46027.

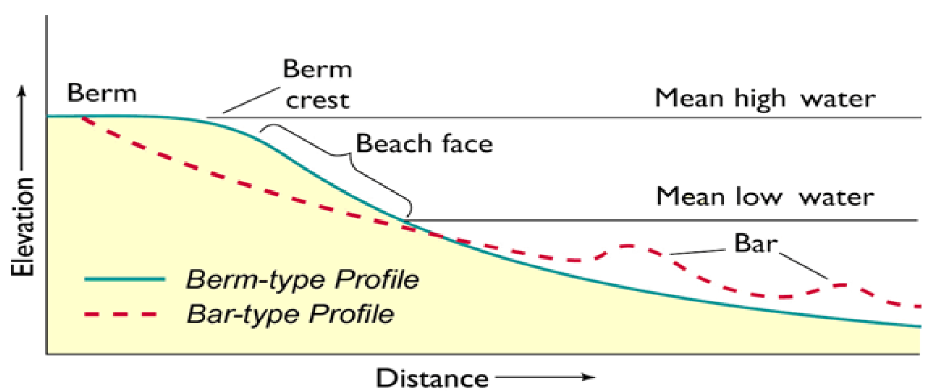


Figure 11. Sketch of two most common cross-sectional profiles on beaches: Berm-type and Bar-type profiles. On most northern California beaches, Berm-type profiles occur commonly from March to October and Bar-type profiles occur from November to March, although variations occur. Profile shifts occur in response to changes in nearshore wave and current conditions.

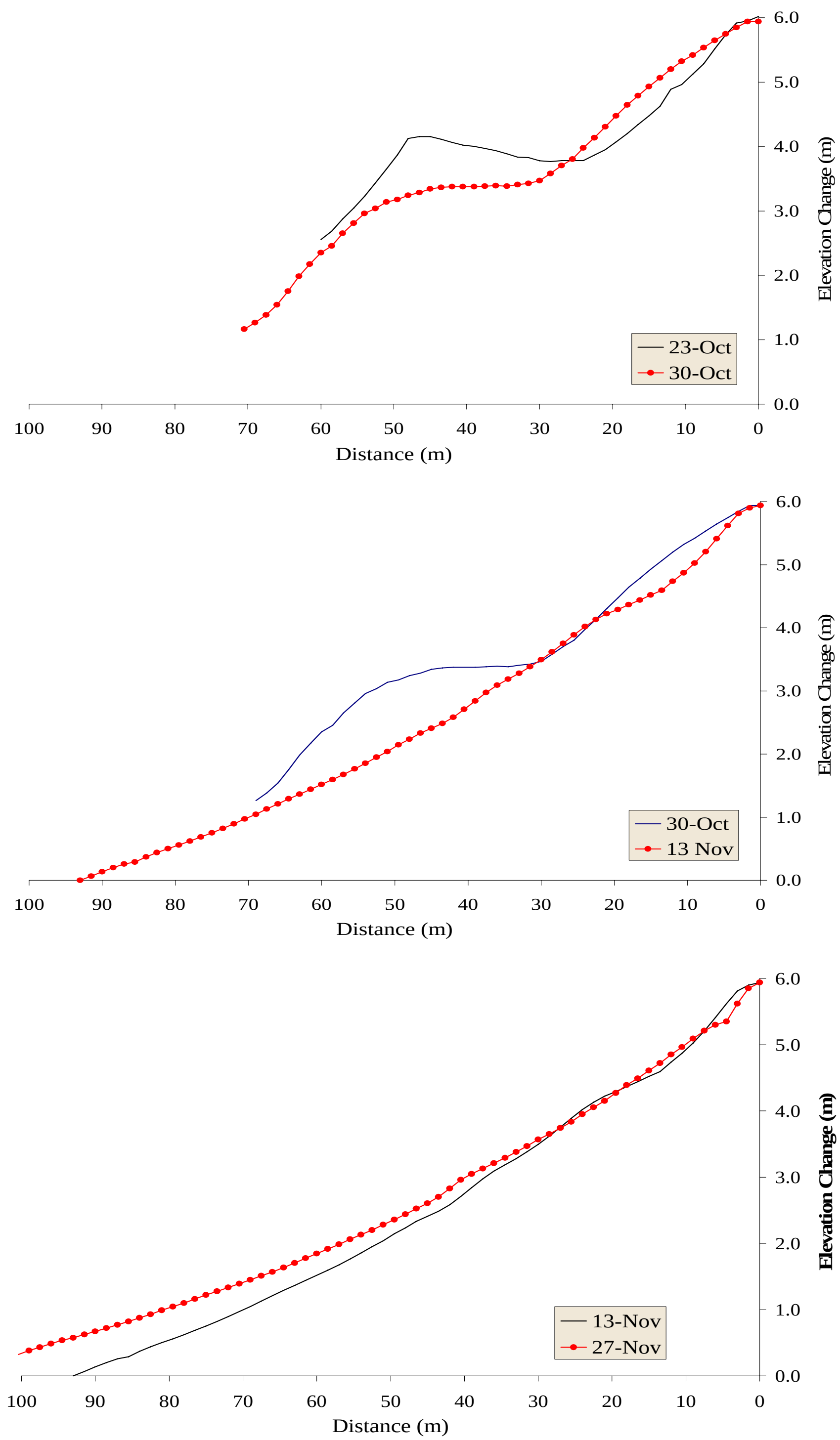


Figure 12. Cross-sectional profile changes at Trinidad State Beach, California in November 2002. The top graph shows a reduction in berm elevation from October 23-30. The middle graph indicates continued and complete removal of the berm from October 3-November 13. Once the profile shift occurred, the beach exhibited only minor changes through the rest of November 2003. This shift coincided with greater wave energy attacking the coast (from David 2003).

The long term fate of beaches depends on the balance between waves, nearshore currents, sea level changes and the sediment supply available for transport. An integrated evaluation of these concepts has led to the construction of coastal sediment budgets along much of the nation's coastline (USACE 1984; Rosati and Kraus 1999). The coastal sediment balance or budget is calculated from sediment contributions and losses to coastal sections that act as a unit. These coastal units are referred to as littoral cells. RNSP has been identified as being in the Klamath River littoral cell (California Coastal Sediment Management Workgroup 2006) (Figure 13). Much like a bank account, there are deposits (e.g., sediment contributions from streams, sea-cliff erosion, etc.) and withdrawals (e.g., losses from the beach by wind, to the offshore, etc.) and a budget balance (beach accretion or erosion).

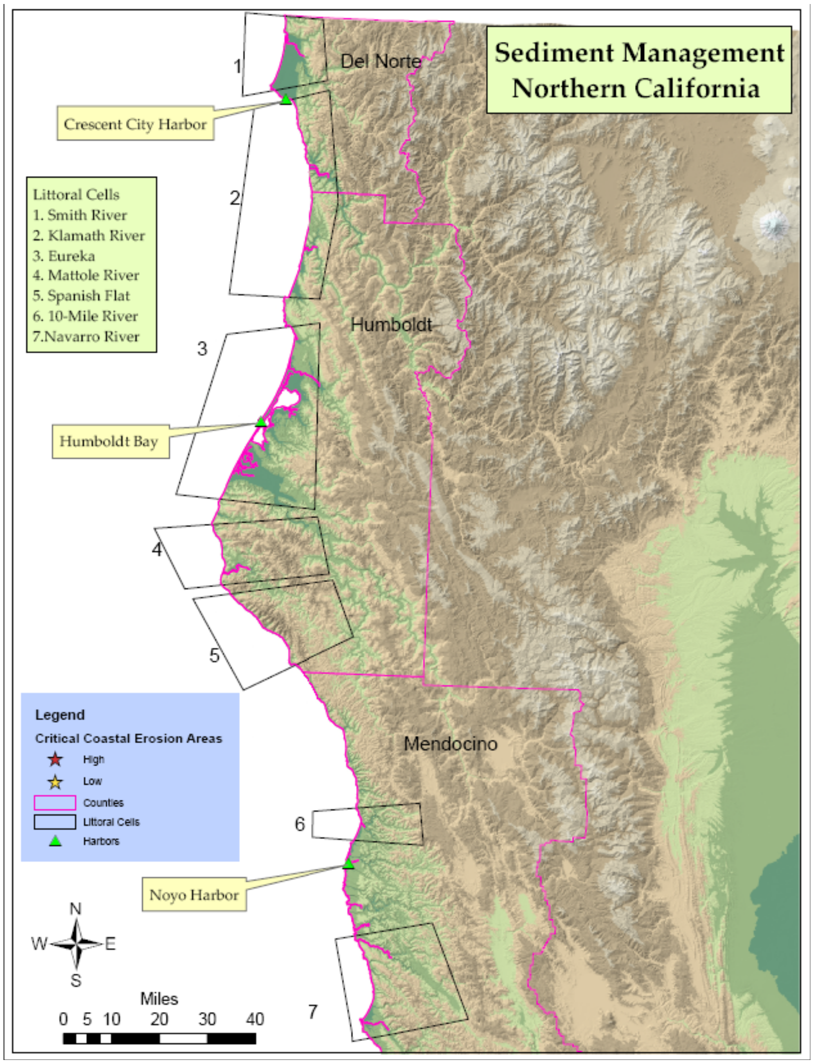


Figure 13. California Critical Coastal Erosion Areas, Potential Sediment Sources, and Littoral Cells – Northern California (DRAFT) (from California Coastal Sediment Working Group 2006).

Detailed and coordinated surveys of the beaches within RNSP boundaries have not been conducted. A one-year study of beach profiles was conducted by Boyd and DeMartini (1977). Beach profiles were measured every month with a stadia rod and level from July 1974 through June 1975 at Crescent Beach, Gold Bluffs Beach, and Redwood Creek Beach. Sand samples were also collected every month at each beach to determine particle size. The only other beach profile measurements within the RNSP boundaries that we could locate were near the mouth of the Redwood Creek estuary (Anderson 2005) and along the beach west of Freshwater Lagoon (Klein 1993). Each of these studies were short term. Near Redwood Creek, longitudinal beach profiles of the berm crest (highest point) were measured monthly, from May to September for the period from 1998–2002, as part of an USACE breaching permit. Surveys were used to determine where the estuary might naturally breach the sand berm when it is closed off from the ocean. Five estuary cross sections were also surveyed annually to determine changes in the estuary volume. Measurements recorded west of Freshwater Lagoon were along 10 cross-sections during September 1992 and again in October 1993. Beach surveys by RNSP provided basic data for planning and management of the Freshwater Spit. Neither of these studies focused on the seasonal shifts that occur on RNSP beaches.

The major sediment supplier for this section of the coast is the Klamath River. Willis and Griggs (2003) estimated that dams on the river have reduced the mean annual sand and gravel discharge by as much as 37 percent (1.7×10^6 m^3) as compared to the undammed river. They suggested that such a reduction could result in the local beaches being sediment impaired. By examining the coastline in detail Hapke et al. (2006) determined that the coastline between the Klamath River and Redwood Creek has been accreting over both the short and long term. This apparent contradiction points to the need for a closer examination of the sources and sinks of sediment along the RNSP coast. The development of a littoral cell sediment budget would go a long way toward a better understanding of local coastal processes and responses (Table 1).

Developing a budget of beach sediments can be difficult to assess accurately due to the number of sources of contribution and loss (Table 1). Contributions from rivers can be evaluated using a variety of techniques. Gaging stations found on some rivers monitor discharge and in some cases suspended and bedload transport. USGS gaging stations on the Klamath River and Redwood Creek measure water temperature and water level (stage height) and determine stream discharge. Unfortunately, sediment transport data are not currently available for the Klamath River stations, but suspended sediment and limited bedload data are available for the two gaging stations on Redwood Creek. Flow and sediment discharge data can be used to produce rating curves and estimates of the annual suspended sediment yield from the rivers. This volume can then be revised to estimate the quantities of sand and gravel that are sufficiently coarse to remain on the beach, eliminating the size fraction that is too fine and is quickly lost offshore. An analysis of the grain-size distribution of beach sediment can establish which sizes are likely to remain. No grain-size distribution has been estimated for RNSP beaches.

Table 1. The Budget of Littoral Sediments (after Bowen and Inman 1966).

SEDIMENT CREDIT	SEDIMENT DEBIT	BALANCE
Longshore transport in	Longshore transport out	Beach accretion or erosion
River transport	Wind transport off beach	
Sea cliff erosion	Offshore transport	
Onshore transport	Deposition in submarine canyons	
Biological particles deposition	Solution and abrasion	
Chemical precipitates deposition	Sediment mining	
Wind transport onto beach		
Beach nourishment		

B3. Hydrologic Information

B3a. Oceanographic Setting

Understanding the oceanic processes that directly influence RNSP will require an understanding of the dynamics that influence and drive the coastal ocean. Processes ranging from meteorological conditions, shelf circulation patterns, wave characteristics, tidal influence, variations in sea level and freshwater influence all have a significant impact on oceanographic phenomena that influence the RNSP coastline. These parameters are highly complex in addition to being highly dependent on one another.

Meteorological Conditions

The atmosphere, weather, and climate have direct influences on the physical environment of the coastal ocean. Daily and seasonal variations in heating and cooling of the ocean change the temperature structure in the ocean. Variations in precipitation, evaporation, and runoff from coastal rivers and creeks impacts the salinity and, to some extent, the temperature of the coastal ocean both spatially and temporally. Seasonal changes in wind patterns play a major role in driving coastal circulation over the continental shelf, as well as modifying the temperature, salinity, and density structure in the ocean through mixing processes. In addition, wind waves generated by both local winds and storms at sea travel to the shoreline, expending their energy in the nearshore environment where they break (the surf zone) and, depending on their orientation relative to the shoreline, can establish a net longshore current within the surf zone and swash zone of the beach and rocky coast.

Seasonal variations in the winds occur primarily due to the two alternating major weather systems in the north Pacific. From late fall to spring, the Aleutian Low represents the major pressure system, which directs strong storms and waves towards the northwestern U.S. from the south or southwest. In the spring, the Aleutian Low is replaced by the

North Pacific High, which directs winds to northern California from the north and northwest. In late summer and early fall, winds tend to be highly variable.

Rainfall measurements have been made at Prairie Creek Redwoods State Park since 1937. Some rain occurs each month in most years, although the amounts are small during the late summer and early fall. The average annual precipitation at the Park is 170 cm (67 in.), but interannual variations can be significant. The minimum annual recorded rainfall was 87.4 cm (34.4 in 1992 water year) and the maximum was 258.6 cm (101.8 in) in 1983. Roughly 90 percent of a year's precipitation falls between October and April.

Significant climatic variations occur on times scales of years and decades and have received much attention of late (e.g., Smith et al. 2001; Ryan and Noble 2002; Dean and Kemp 2004). One such mode of variability is ENSO (El Niño-Southern Oscillation), also known as the El Niño-La Niña cycle (Figure 14). In order to explain El Niño and La Niña events, however, we first describe typical, or average, conditions. In brief, the trade winds near the equator typically push the warm surface waters to the western side of the Pacific, maintaining a warm pool of water there. The warm surface temperatures in the western tropical Pacific cause atmospheric convection, which carries warm, moist air aloft. Much of that moisture rains back down over the western Pacific; the air then moves eastward at altitude and sinks back towards the surface of the Earth then flows back towards the western Pacific near the surface. This atmospheric pattern results in lower atmospheric pressures in the western Pacific (e.g., Darwin, Australia) than in the central Pacific (e.g., Tahiti).

During an El Niño event (Figure 14), the trade winds can slacken, equatorial upwelling can subside, and the warm water pool in the western Pacific can flow back towards the eastern Pacific. Some of this warm water will then travel north and south along the west coast of the Americas. In the meantime, the atmospheric circulation changes in response. The region of strong atmospheric convection shifts to the central Pacific, leading to higher precipitation in those regions and drought conditions in the western Pacific; in addition, sea level atmospheric pressure is less at Tahiti than at Darwin. This flip-flop is referred to as the Southern Oscillation (Bakun 1996, Trenberth 1997).

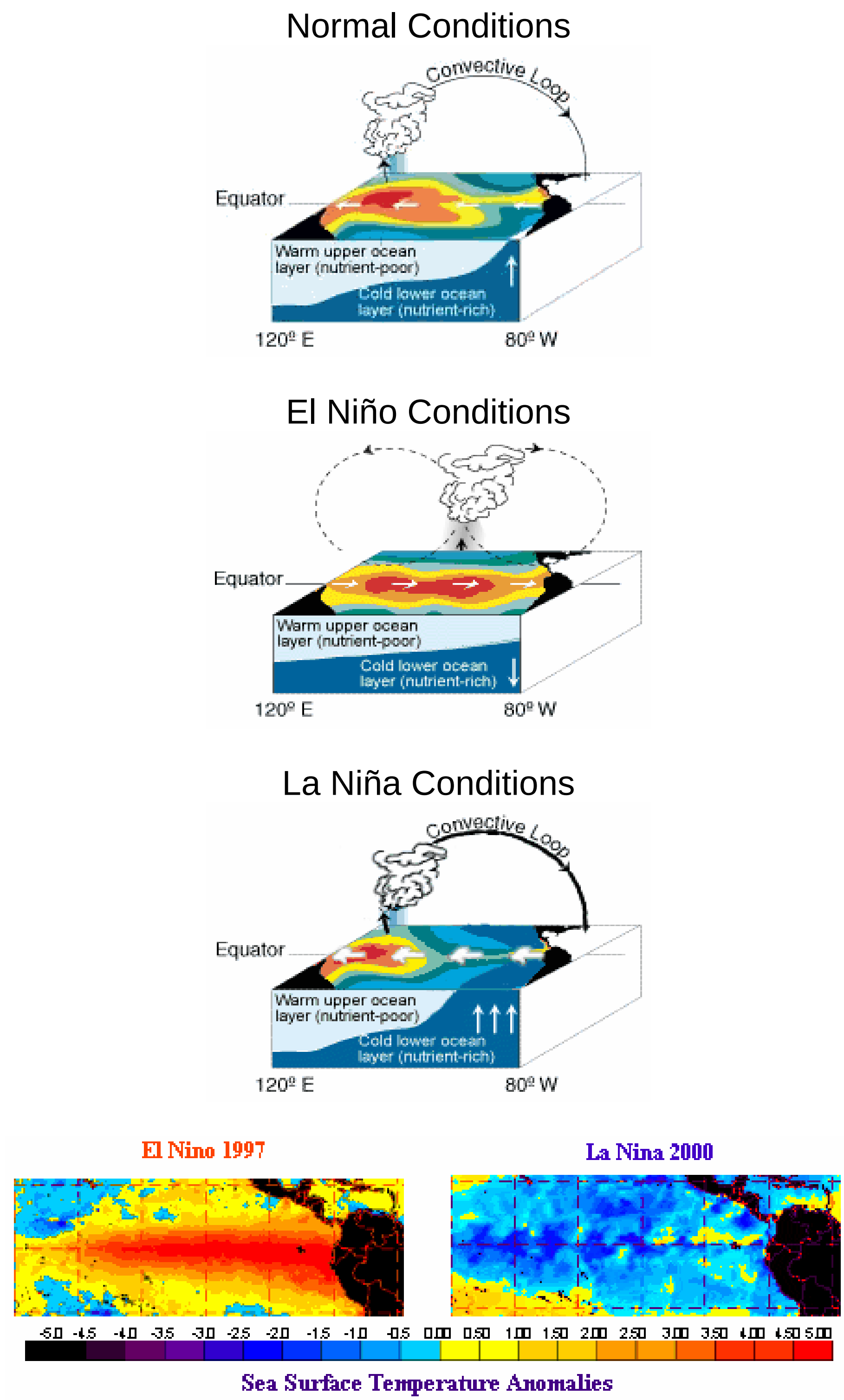


Figure 14. Images depicting atmospheric convection and oceanic temperature anomalies that occur during normal, El Niño and La Niña events in the tropical Pacific. Bottom image depicts actual measured sea surface temperature anomalies during the 1997 El Niño and 2000 La Niña events (from http://www.solcomhouse.com/ElninoLanina.htm).

The atmospheric pressure anomalies that occur between Tahiti and Darwin are illustrated in Figure 15. These anomalies show a strong negative correlation giving rise to the term Southern Oscillation. Because the ocean surface temperature changes and the pressure reversals are often simultaneous, scientists now often refer to the overall conditions as El Niño/Southern Oscillation, or ENSO for short.

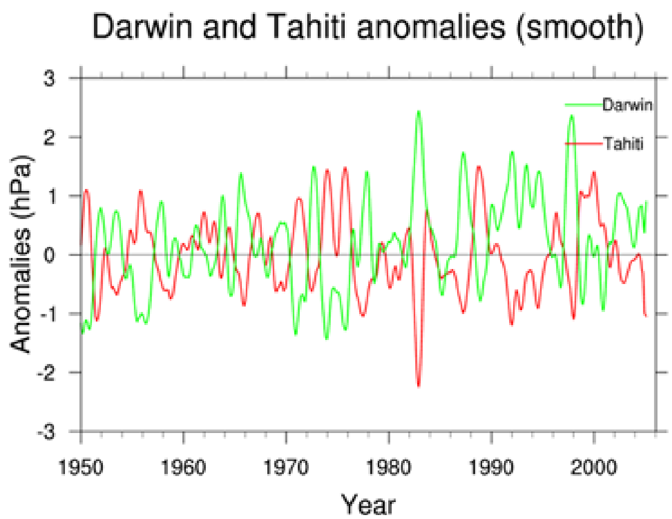


Figure 15. Times series of the Southern Oscillation anomalies in the western Pacific at Darwin, Australia and in the central Pacific at Tahiti, from 1950 to present (from National Center for Atmospheric Research and UCAR Office of Programs http://www.cgd.ucar.edu/cas/catalog/climind/soi1.gif).

Up until the last 10 years or so, the climate extremes in the equatorial Pacific were interpreted as normal and El Niño conditions. Retrospective analysis, however, has led to a new description, in which the extreme opposite to El Niño has been dubbed La Niña. During a La Niña event (Figure 14), there is intensification of the trade winds and an enhanced atmospheric pressure gradient across the western equatorial Pacific, as well as enhanced upwelling and cooler surface waters along the equator and eastern subtropical Pacific coastline. Precipitation tends to be greater than average in the western Pacific and drought conditions may prevail in the central and eastern equatorial Pacific.

The concept of normal or average conditions, then, becomes somewhat vague, but many researchers consider conditions mid-way between the two extremes as normal. A number of measures of the strength of ENSO events have been developed to monitor current conditions, including the Southern Oscillation Index (SOI) and the Climate Diagnostics Center's Multivariate ENSO Index (MEI).

ENSO events occur every two to seven years, lasting typically between 4 and 18 months, and have a significant impact on climate over much of the rest of the world as well. In northern California, one curious consequence is that the region tends to receive higher precipitation during both major El Niño and La Niña events; lower rainfall amounts are usually recorded during intermediate conditions (Kelly Redmond, Regional Climatologist, Western Regional Climate Center, personal communication). Storlazzi and Griggs (2000) found that, along the central California coast, moderate- to high-intensity El Niño events were correlated with increased cyclone activity, rainfall, sea-surface temperature, sea level, and coastal erosion. Komar (1986) has found similar effects along the coast of Oregon. Upwelling may also be reduced along the California coast during El Niño conditions (Chavez, 1996). Similar effects may be expected along the RNSP coast.

Another longer-term form of climate variability that affects the area is the Pacific Decadal Oscillation (PDO). The PDO and ENSO events have qualitatively similar types of spatial patterns of variability, but PDO events appear to persist for 20 to 30 years (Figure 16). In addition, most of the direct influence of the PDO is in the northern Pacific, with secondary influences in the tropics. ENSO events, on the other hand are most fundamentally a tropical phenomenon, with secondary effects elsewhere, including the northern Pacific.

The PDO has a “cool” phase, with cooler waters in the eastern North Pacific and a “warm” phase (Figure 16). Analysis of historical conditions has suggested that there were just two full cycles of the PDO in the 20th Century, with warm periods prevailing from 1925-1946 and from 1977 until perhaps 1999, while a cool phase was dominant from 1890-1924 and from 1947-1976. It may be too soon to determine if a new phase is currently underway.

The PDO has been linked to variations in: winds, sea level pressure, sea surface temperature (Trenberth 1990; Trenberth and Hurrell 1995; Graham 1994; Zhang et al. 1997), streamflow, drought conditions in the U.S. (Nigam et al. 1999), salinity (Overland et al. 2000), and fish populations (Beamish 1993; Mantua et al. 1997; Francis et al. 1999). While a standardized PDO index has not been established, Mantua et al. (1997) offer one such index based upon sea surface temperature anomalies (Figure 16), while Trenberth and Hurrell (1995) use sea level pressure anomalies to define a North Pacific index to look at variability on decadal time scales. In particular, warm PDO periods appear to be correlated with increased biological productivity off the coast of Alaska and simultaneously reduced productivity off the west coast of North America from Washington State to Baja California; during cool PDO periods, the opposite pattern in coastal productivity has been observed (Mantua et al. 1997; Peterson and Schwing 2003).

Relatively little is known about what causes the PDO, or if and how the PDO and ENSO influence each other. Most analyses of climate variations for PDO and ENSO detection have relied on the separation of time scales between these two phenomena (Gershunov and Barnett 1998). It is likely, however, that the two mitigate or enhance climatologically-induced changes to the environment (including biological responses), depending on the phase of the PDO and ENSO. In particular, one would expect the greatest reduction in marine biological productivity along the California coastline (including RNSP) when a strong El Niño occurs during a warm PDO phase.

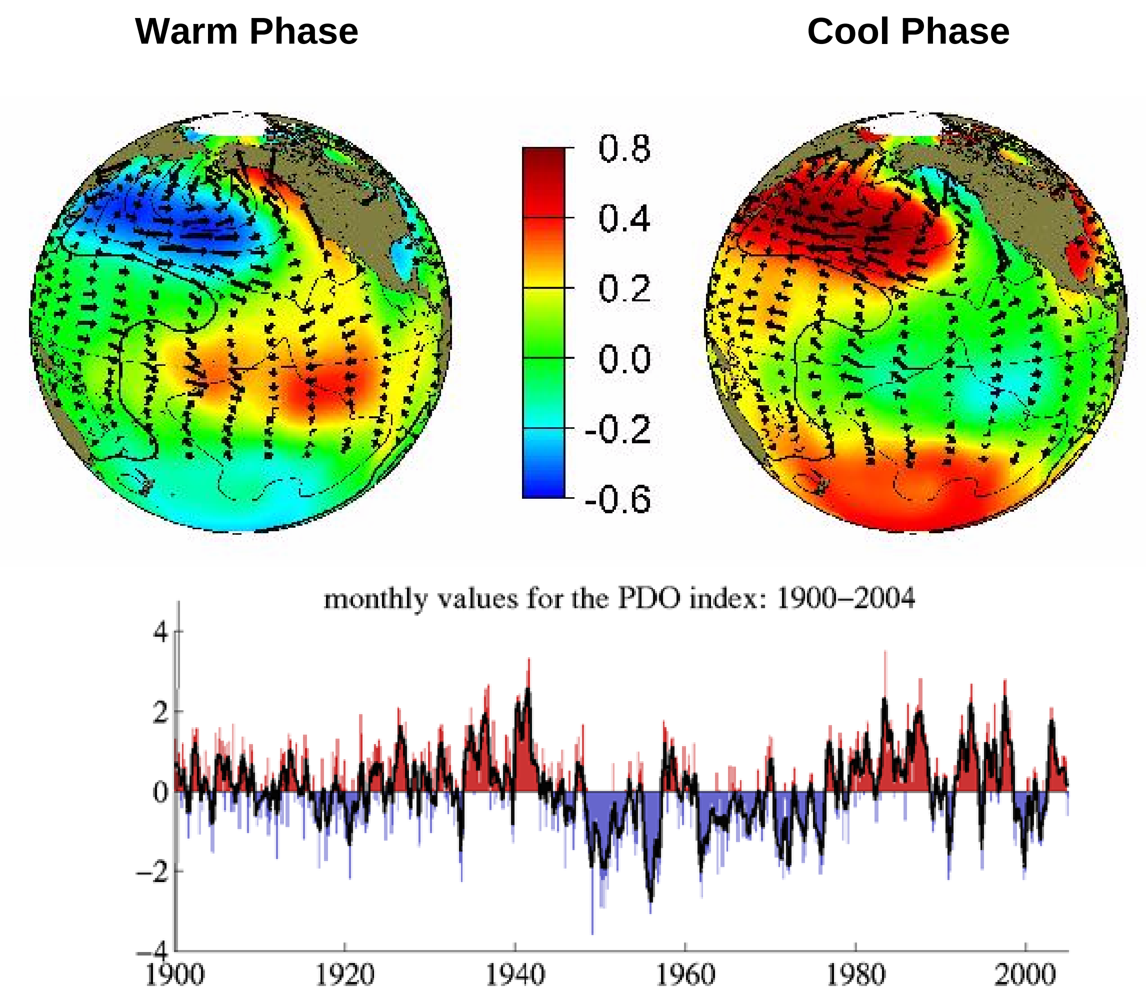


Figure 16. Typical winter sea surface temperatures indicated in colors, surface wind stress indicated with arrows and sea level pressure indicated by contours for the cool and warm phases of the Pacific Decadal Oscillation (PDO). The PDO index time series illustrates a similar pattern seen during ENSO events (from http://tao.atmos.washington.edu/pdo/).

Coastal Circulation

Much of our understanding of coastal ocean conditions and flows near RNSP is based primarily on knowledge of the general ocean circulation of the coastal eastern Pacific. Although the northern California coast has not been studied frequently, there have been occasional sampling programs in the region. Here we describe basic features and identify relevant studies.

The California Current (CC) dominates the flow pattern just beyond the continental margin of Oregon and California. This current represents the eastern branch of the North Pacific Subtropical Gyre and refers to the generally equator-ward flow along the west coast of the continental United States and Mexico (Figure 17). Source waters for the CC derive from the North Pacific Current, which separates into the CC and the Alaska Current (a pole-ward flowing component) well offshore of North America, just south of 50°N (Wyrtki 1975; Reid and Arthur 1975).

The large-scale ocean circulation over the continental margin itself is strongly influenced by a number of phenomena. Over the continental slope, a subsurface flow known as the California Undercurrent carries warmer, saltier water pole-ward in a narrow (10-40 km) jet from Baja California to at least Vancouver Island (Hickey 1979; Chelton 1984). Peak flow speeds for the undercurrent are about 0.4 m/s and are typically found at depths of 100-300 m (328-984 ft). There can, however, be significant seasonal and longer-term variations in the intensity of the undercurrent flow (Chelton 1984; Ramp et al. 1997). This variability is possibly due to variations in the alongshore pressure gradient (Hickey and Pola 1983; Largier et al. 1993).

Figure 17. General gyre circulation patterns in the Pacific Ocean. Note the California Current along the eastern boundary of the North Pacific Gyre flowing equator-ward.

As mentioned previously, prevailing wind conditions in the region are determined by the large-scale atmospheric circulation in the North Pacific. From late fall through winter, the Aleutian Low pressure system dominates the atmospheric circulation in the North Pacific, leading to predominantly southwesterly winds along the west coast of the continental United States. This pole-ward wind stress leads to a generally shoreward transport of the surface waters and a generally pole-ward flow (known as the Davidson Current) at all depths over the shelf and inner slope. Modeling work by Pullen and Allen (2001) suggests that the flow can be strongly modulated by individual winter storms, whose strong winds can last for two or three days in the coastal region. In addition, high river runoff from the Klamath and Eel Rivers appears to modify the surface circulation substantially between Crescent City and Cape Mendocino during these periods.

As winter gives way to spring, the North Pacific High pressure system shifts northward and becomes the dominant weather pattern in the region, bringing generally northerly winds along the coast. These winds push surface waters offshore (as a consequence of the Coriolis force), leading to upwelling of colder, deeper, and nutrient-rich waters over the continental shelf. The winds also lead to suppression of the Davidson Current (often leading to southward flow over the shelf; Huyer et al. 1991), and the development of a coastal upwelling front and an associated equator-ward jet off Oregon over the shelf or slope (Huyer et al. 1978; Huyer 1983). The transition from southerly to northerly winds at the coast in spring usually occurs over a short period of time and nearly simultaneously over several degrees of latitude (Huyer et al. 1978; Strub et al. 1987a, 1987b). This onset of persistent coastal upwelling is known as the "spring transition".

As spring leads into summer and coastal upwelling continues, the coastal jet separates from the continental margin south of Cape Blanco, Oregon (about 43°N). Occasionally, winds over the shelf slacken or reverse for several days, leading to some relaxation of the upwelling system and subsequent onshore advection. In any case, by late summer, winds generally slacken, coastal upwelling ceases, and a general relaxation of the upwelling system occurs over the shelf.

These physical processes and characteristics have a direct influence on the coastal marine ecosystem. During winter, phytoplankton in this region have relatively little sunlight and nutrients to aid in growth. By spring, the phytoplankton are usually nutrient-limited. The upwelling of deep nutrient-rich waters to the near-surface waters in late spring and early summer provides the necessary nutrients and the phytoplankton population, as well as the rest of the food chain, can grow relatively rapidly. Such upwelling events typically occur in May and June along the northern California coast and play a critical role in jump-starting biological productivity of the entire marine food chain during these periods.

Coastal upwelling conditions can be inferred from the upwelling index, originally developed by Bakun (1973). This index is determined from the strength of the alongshore component of the wind and provides a measure of the wind-driven transport of ocean surface waters away from or towards the shoreline. Currently the NOAA Pacific Fisheries Environmental Laboratory (PFEL) provides upwelling indexes at 15 locations along the west coast of North America, on a 6-hourly and monthly basis. The nearest location to RNSP for these upwelling index products is 42°N, 125°W (roughly 40 miles WNW of Crescent City, California). Figure 18 shows the average monthly upwelling indices for this location.

Detailed studies of coastal oceanographic conditions in the general vicinity of RNSP have been carried out a number of times in the past half-century or so, although the focus has frequently been on regions north of Cape Blanco, Oregon, or south of Trinidad Head, California. Such studies have provided measures of environmental and biological conditions and processes in this broad geographic region. Data and results of these investigations may be useful in developing climatological parameterizations of oceanographic environmental conditions, analyzing historical variations on a variety of time scales, and providing a context for interpreting contemporary conditions.

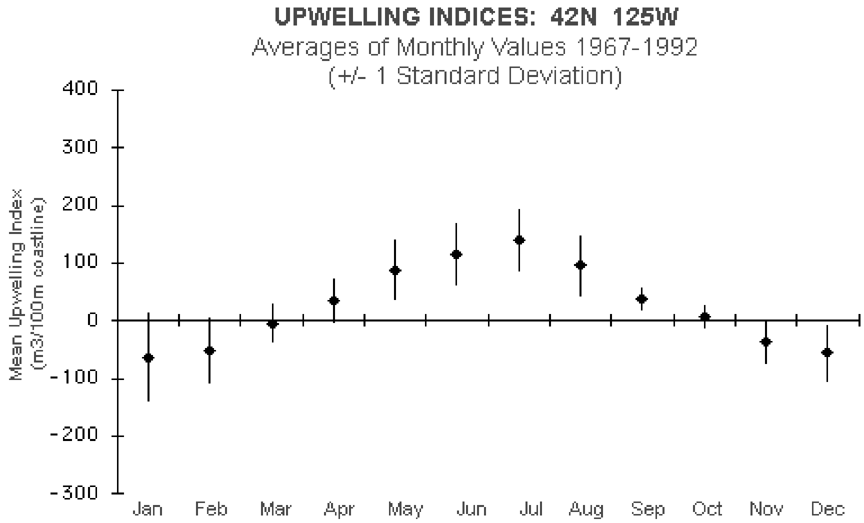


Figure 18. Average monthly upwelling indices for 42º N 125º W from 1967 to 1991. Positive values are indicative of upwelling conditions. Uncertainties are given by the vertical bars as one standard deviation (from Pacific Fisheries Environmental Laboratory www.pfel.noaa.gov).

The California Cooperative Oceanic Fisheries Investigations (CalCOFI) long-term monitoring program has periodically (1949-1952; 1958-1962; 1969-1972; 1987) included stations west of Crescent City and Eureka, California, as a part of temporarily expanded study areas. Sampling has included an array of physical, chemical, and biological water characteristics. A coastal monitoring and assessment program was undertaken between Trinidad Head and the Eel River from 1958 to 1962 (Allen 1964), characterizing physical, chemical and biological conditions (including the benthos) within 10 miles of the shoreline. Freitag and Halpern (1981) measured hydrographic conditions (temperature, salinity, density) off the California coast between 37°N (roughly at San Francisco) and 43°N (Cape Blanco) during the spring of 1977.

The Coastal Ocean Dynamics Experiment (CODE; Beardsley and Lentz 1987) focused on meteorology and oceanographic conditions between 38° and 40° N (north of San Francisco and south of Cape Mendocino) between 1981 and 1982. Measurements included currents from moorings and drifters, temperature and salinity profiles, sea level observations, and various meteorological measurements. Additional current and hydrographic measurements were obtained along the continental shelf from 1982 to 1984 during SuperCODE (Strub et al. 1987a).

The Northern California Coastal Circulation Study (NCCCS) involved a detailed look at ocean circulation on the continental shelf and slope around Cape Mendocino from 1987 to 1989 (EG&G 1988, 1989a, 1989b, 1991; Largier et al. 1993). Observations from this study included temperature and salinity transects every few months, time series of currents from moorings along the continental shelf, and occasional current measurements using drifters released sporadically in the region. Transects and moorings were established at various locations in the vicinity of the Klamath River, Eureka, and Cape Mendocino. Additional measurements were conducted towards the edge of the shelf, in the coastal transition zone, during 1987 and 1988 as a part of the Coastal Transition Zone (CTZ) research program (Kosro et al. 1991). As a part of the Global Ecosystems (GLOBEC) Northeast Pacific research program, physical, chemical and biological sampling across the continental shelf was undertaken quarterly from 1999 to 2004 between Newport, Oregon and Crescent City, California (Barth et al. 2005).

Sauer et al. (1998) measured hydrography, nutrients, and phytoplankton along three transects south of Trinidad Head, from the shoreline to the continental slope, in June of 1998. This study took place near the end of the 1997-1998 El Niño.

The Strata Formation on Margins (STRATAFORM) program focused on flows and sediment transport on the Eel River margin, from Cape Mendocino north to roughly Trinidad Head during the period 1995-2000 (Nittrouer 1999; Wheatcroft et al. 1997; Ogston et al. 2000). Data and analyses from this program may provide insight to distribution processes of freshwater and sediments that exit the Klamath River.

Estuarine influences in the coastal ocean can also be detected. The Columbia River plume has been detected from 40° to 49° N, and seaward to about 600 km (373 mi) (Barnes et al. 1972). The Eel River in northern California has a relatively small (roughly 9000 km^2) drainage basin, but discharges large amounts of sediments (about 10^7 tons/year) to the continental shelf (Nittrouer 1999). These phenomena are themselves influenced by coastal winds and runoff. Studies such as these may provide guidance for investigating the influence of fresh water, particularly from the Klamath River, on the coastal ocean and shoreline.

Finally, in summer 2002, hypoxic (low oxygen) water conditions were observed off coastal Oregon, which resulted in massive die-offs of fish and invertebrates (Grantham et al. 2004). The conditions were attributed to an anomalous invasion of cold, nutrient-rich, oxygen-poor subarctic water into the California Current system, which was then transported to the inner shelf by upwelling processes. While phytoplankton populations grew rapidly, respirers died off. Several related articles were published in a special issue of Geophysical Research Letters describing this unexpected phenomenon (Huyer 2003). It is unknown whether this event, or other similar events have occurred on the Klamath River margin, but the similarity in oceanic conditions raises the possibility.

Waves

The earliest investigation to characterize the wave conditions along the northern California coast was that of Johnson et al. (1971). They recognized three wave groupings, depending on the season and area of wave generation. From April through October, basically the summer months, the dominant wave energy component is the prevailing swell generated by winds in the north-central Pacific. The wave heights in deep water are generally 1 to 3 m (3-10 ft), and arrive from the west and west-northwest quadrants. This long-period swell undergoes sufficient refraction that the waves reach the coast with their crests nearly parallel to the shoreline, or at most have very small breaker angles. During approximately the same period, from May to August, waves are also generated by local northwest winds. They have shorter periods, with average heights of 1 to 3 m (3-10 ft), with a maximum height of about 5 m (16 ft). When they occur, these locally generated waves may be superimposed on the prevailing long-period swell. During the winter months, November through March, Johnson et al. (1971) characterized the waves as very high-energy seas, which reach the coast from the west and west-southwest. These winter waves are larger than during the summer, averaging 3 m (10 ft) in height, and ranging up to 11 m (36 ft) during severe storms. The winter waves are generated by storm fronts passing through the study area, coinciding with periods of high rainfall, and therefore are important to the initial movement of river-derived sediments along the ocean beaches.

The characterization of wave climate by Johnson et al. (1971) was based on limited information for storm conditions and associated waves. An improvement on their analysis was provided by the Wave Information Studies Program (WIS) of the U.S. Army Corps of Engineers (Corson et al. 1987; Jensen et al. 1989). The WIS investigation provided estimates of wave heights and periods by using current wave forecasting techniques on older synoptic weather charts. These hindcast wave estimates were made over a 20-year period, from 1956-1975. Initially, hindcast wave estimates were made for a number of deep-water stations offshore of the U.S. coasts, but in a later phase of the analysis wave hindcasts were made for deep-water waves refracted to a series of stations at 10 m (32 ft) water depths, that is, just seaward of the expected zone of wave breaking along the coast.

Hindcast data for WIS Station 32 (41.31°N, 125.03°W), an offshore deep-water site, are most salient (Corson et al. 1987; Jensen et al. 1989). The 10 m (32 ft) depth inshore stations that correspond to RNSP are numbers 61 through 64, shown in Figure 19. Wave heights and directions measured at station 66 (Figure 20) indicated that about 38 percent of the waves arriving directly from offshore have heights greater than 3 m (10 ft), with smaller waves arriving from the northwest.

It was not until the 1980s that buoys were placed offshore of northern California by the National Oceanic and Atmospheric Administration (NOAA), which operates the National Data Buoy Center (NDBC). Wave statistics (heights and periods) and some meteorological information are obtained hourly, and transmitted via satellite to the laboratory for analysis of the wave energy spectra, significant wave heights (the average of the highest one-third of the waves), average zero-up-crossing wave periods, and the peak spectral wave periods. In an analysis of the wave climate for the coasts of Oregon and Washington, Tillotson and Komar (1997) found poor agreement between wave heights determined by the Wave Information Studies Program using hindcast analyses based on weather charts, versus direct measurements of waves on the Oregon coast. On average the WIS deep-water significant wave heights were 20 percent larger than the measured waves. Thus, magnitudes of wave heights given in the hindcast data may be too large, but the general pattern of longshore variation due to wave refraction remains valid, and this analysis by WIS provides the main available documentation regarding the importance of wave refraction and diffraction along the shoreline (Figure 20).

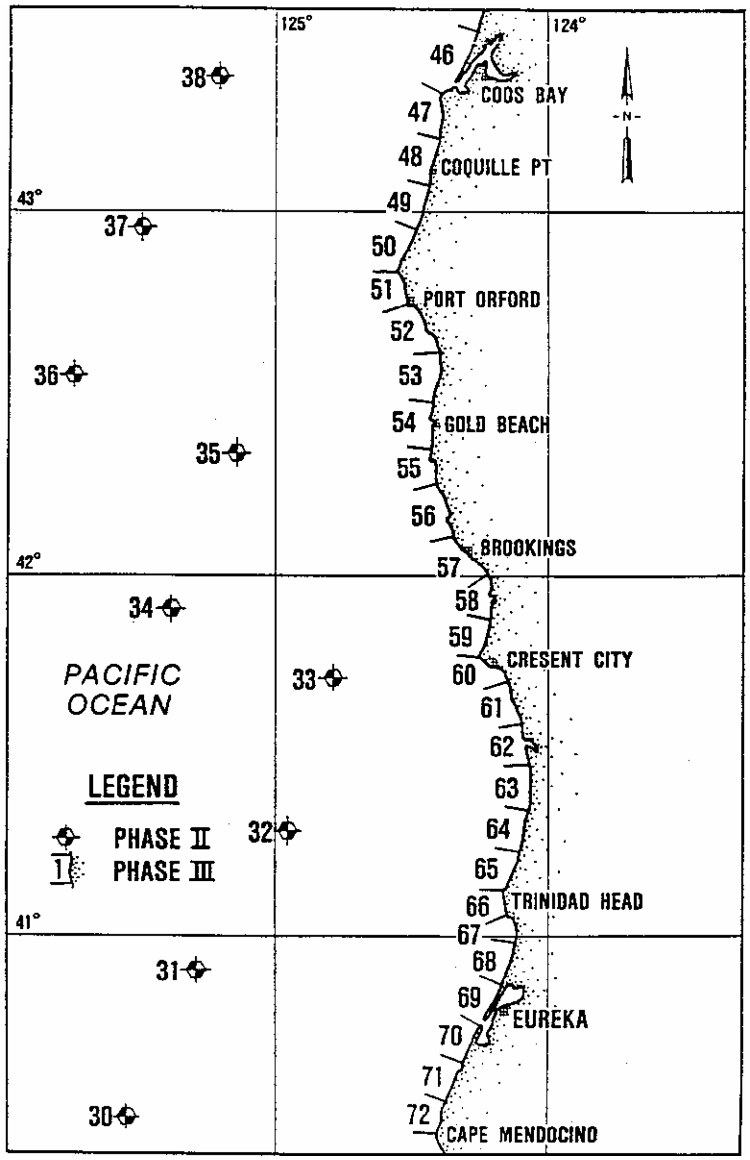


Figure 19. Map illustrating location of Wave Information Studies Program, offshore, deep-water stations and inshore 10-meter depth stations in relation to the RNSP coastline (after Jensen et al. 1989).

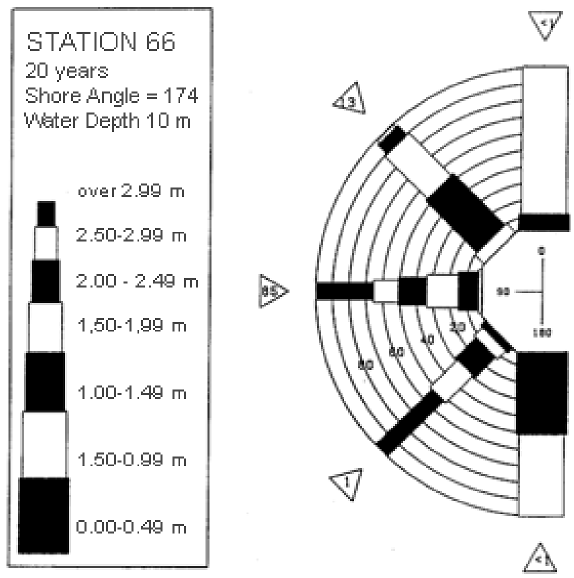


Figure 20. Rose diagram shows wave heights and direction for Wave Information Studies Program station 66, located near RNSP, south at Trinidad Head (after Jensen et al. 1989).

The NOAA National Data Buoy Center currently provides hourly observations from a network of 90 buoys and 60 Coastal Marine Automated Network (C-MAN) stations. The nearest buoys to RNSP are numbers 46027 and 46022, located 8 nautical miles (9.2 mi) west-northwest of Crescent City and 17 nautical miles (19.6 mi) south-southwest of Eureka, respectively. Figure 21 illustrates the average monthly significant wave heights at buoy #46027 from 1985 to 2001. The graphs show a strong seasonality, with the lowest wave conditions occurring in August with an average significant wave height of only 1.7 m (5.6 ft). October through March represents the period of highest wave activity, with average significant wave heights nearing 3 m (9.8 ft) and a maximum of 10 m (33 ft). Wave periods show a similar average seasonality pattern (Figure 22).

An unusually high number of severe storms marked the winters of 1997-1998 and 1998-1999 as seen in comparison with significant wave heights averaged over a 25-year period, from 1974 to 1999 (Figure 23). Of interest, these two winters respectively represent El Niño and La Niña climate events that are known to produce major erosion occurrences along the West Coast of the United States. The winter wave height averages increased to between 3.5 and 4.0 m (11 and 13 ft) during the most recent El Niño winter, with February 1998 having experienced an average wave height of 4.8 m (16 ft). The severity of the storms may be better appreciated in the graph of Figure 21, which shows the monthly maximum wave heights. The significant wave heights reached between 8.3 and 10.0 m (27.2 and 32.8 ft). With such extreme wave conditions during the 1997-98 El Niño and 1998-1999 La Niña, it is not surprising that considerable erosion and morphologic change took place along the entire coast.

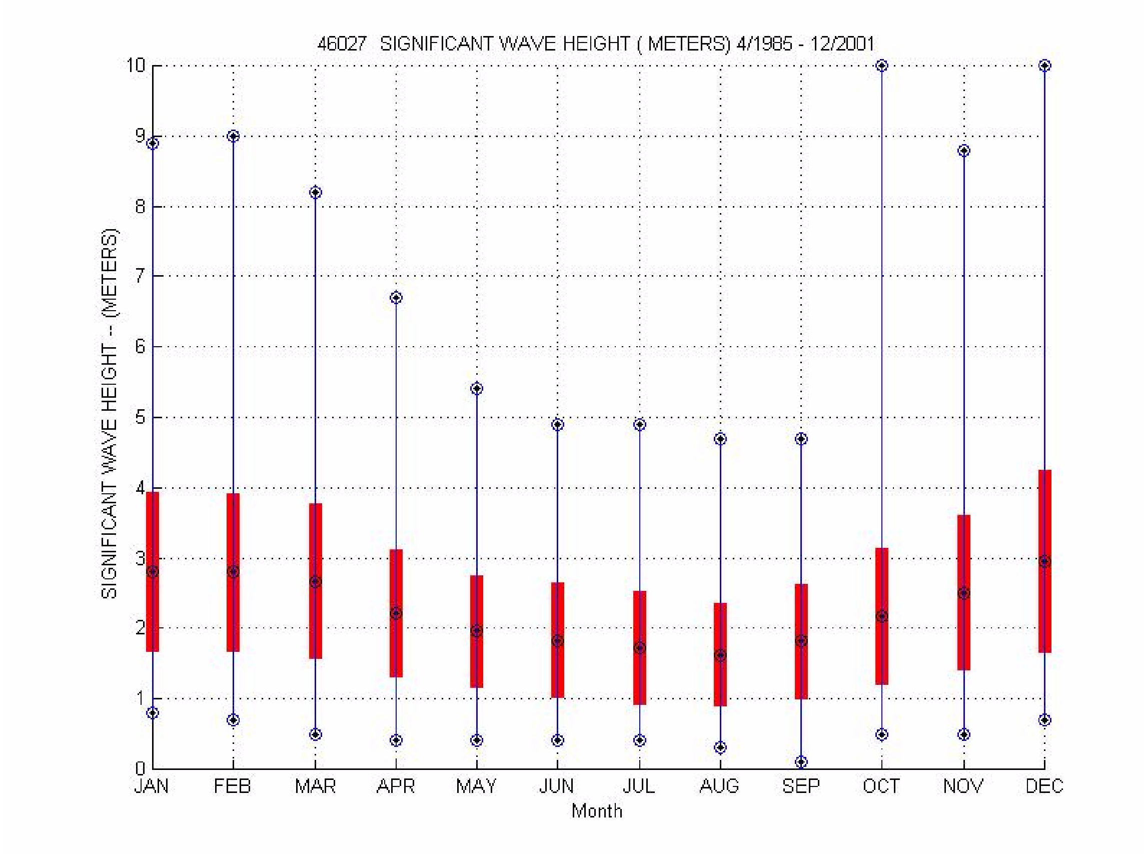


Figure 21. Significant wave heights averaged (red bars show a range) monthly from 1985 to 2001 for NDBC buoy #46027. Circles at the top and bottom of the graphed data represent maximum and minimum significant wave heights for each month (from http://www.ndbc.noaa.gov/station_page.php?station=46027.

It should also be noted that sometimes several waves arrive at the same time as a large set, known colloquially as a sneaker wave (rogue wave or sleeper wave). As a consequence, a large volume of water rushes quickly onshore, substantially farther up the beach than average. Very occasionally, these waves engulf visitors to the beach, sweeping them out to sea and occasionally causing fatalities. For example, between January 1, 2004 and June 1, 2005, five deaths were caused by sneaker waves occurring between Point Reyes, California, and the Oregon border (John Lovegrove, Warning Coordination Meteorologist, National Weather Service, personal communication). At Freshwater Lagoon beach in RNSP, four deaths, including young children, have occurred since 2004. Without warning, the park visitors were knocked down and dragged into the ocean by a large wave.

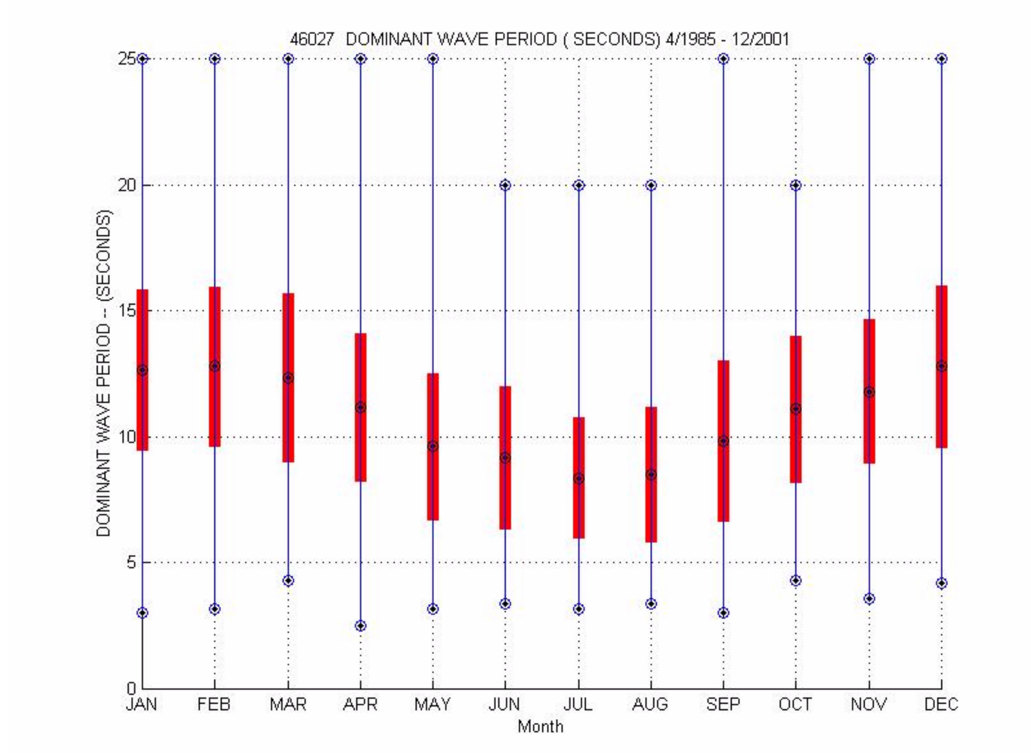


Figure 22. Monthly-averaged dominant wave period (seconds) averaged (red bars show a range) monthly from 1985-2001 for NDBC buoy #46027. Circles at top and bottom of the graphed data represent maximum and minimum dominant wave period (from http://www.ndbc.noaa.gov/station_page.php?station=46027).

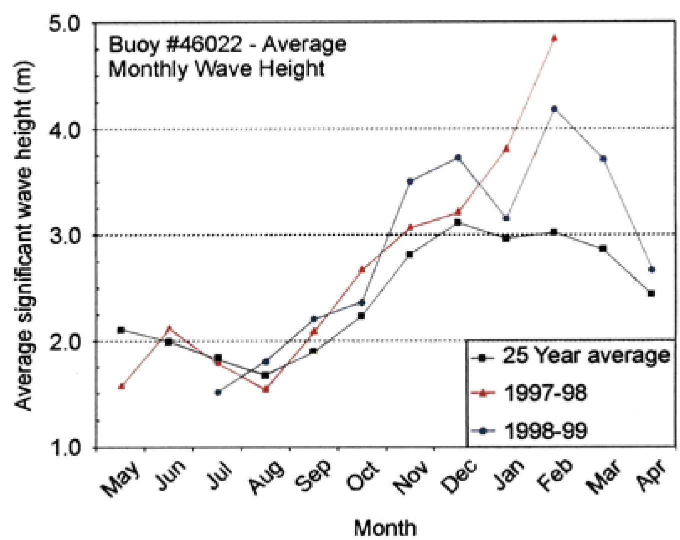


Figure 23. Monthly average deep-water wave height (meters) measured by NDBC buoy #46022 from 1974 to 1999 showing a strong seasonality of wave conditions (squares; data from http://www.ndbc.noaa.gov/station_page.php?station=46022). Also graphed are the monthly variations for the 1997-1998 El Niño event (triangles), and the 1998-1999 La Niña event (circles).

Tides

Tidal energy is an important dynamic involved in producing sea level fluctuations. The tides play an integral part in attacking the coastline, in that they achieve the maximum water elevation in combination with storm waves, therefore determining the extent of salt water intrusion as well as coastal erosion. Additionally, the tides are important to the exchange of water between the ocean and estuaries, and as such, are relevant specifically to developing the morphology of river mouths, particularly when the tidal exchange of water is greater than the fresh water discharge of the river.

Tides along the west coast of North America are mixed, with two high tides (of differing height) and two low tides (of differing height) roughly every day. The period of repetition is closely tied to a lunar day, or 24 hours 50 minutes. The high tides are referred to as Higher High Water (HHW) and Lower High Water (LHW), while the two low tides are known as Higher Low Water (HLW) and Lower Low Water (LLW). Two standard measures that describe the average highest and lowest daily tides are the Mean HHW (MHHW) and Mean LLW (MLLW), respectively. The mean diurnal tidal range marks the vertical difference between MHHW and MLLW.

The tidal measuring station closest to RNSP is operated by the NOAA National Ocean Service (NOS). NOS has operated a water level station in Crescent City, California (#9419750) since 1933. The mean diurnal tidal range is 2.09 m (6.87 ft). The maximum and minimum observed tides were 1.16 m (3.79 ft) above MHHW and 1.04 m (3.42 ft) below MLLW, respectively (NOAA NOS CO-OPS http://co-ops.nos.noaa.gov/cgi-bin/station_info.cgi?stn=9419750+Crescent+City,+CA).

Longer Term Sea Levels

The tide gage record at Crescent City coupled with other gages to the north and south can be used to assess the longer term variation in sea levels along the coast. The data were collected by NOAA and are available at http://tidesandcurrents.noaa.gov. Variations in average sea levels occur seasonally, during El Niño-Southern Oscillation events, and over longer time scales in response to variations in global sea levels due to ice volume and seawater temperature changes and to land movement related to local tectonism.

Seasonal fluctuations in coastal sea levels result in response to coastal winds that transport surface sea water toward or away from the coast. During the spring and early summer, coastal winds transport seawater away from the coast shift and transport seawater toward the coast which results in higher average sea levels. This seasonal effect can be easily seen in daily average sea levels measured at Crescent City (Figure 24). Sea levels in the spring and summer are approximately 200 mm (0.7 ft) lower than daily average sea levels in winter (Figure 24).

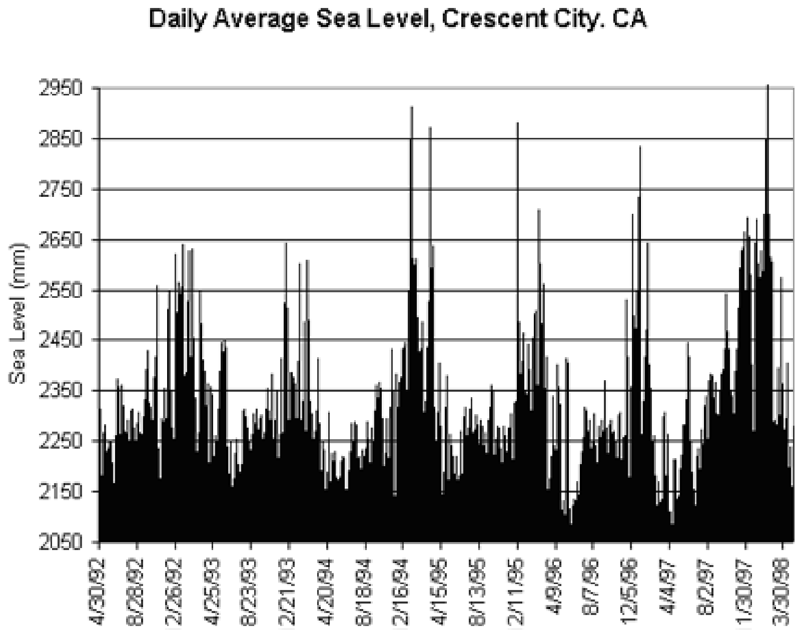


Figure 24. Daily average sea level in Crescent City, California from April 1992 to April 1998. Note that sea levels in the spring and summer were approximately 200 mm (0.7 ft) lower than sea levels in the winter. Winter sea levels during the El Niño–Southern Oscillation event of 1997-1998 were 200–300 mm (0.7-1.0 ft) higher than in the five winters prior (from http://tidesandcurrents.noaa.gov/).

During ENSO events this effect can be magnified; winter sea levels can be 200 mm (0.7 ft) higher than normal winter levels during an ENSO event (Figure 24). For example, note the higher sea level elevations at Crescent City during the last major ENSO event during 1997-1998 (Figure 25). Winter sea levels during the ENSO event of 1997-1998 were 0.80 - 0.85 m (2.6-2.8 ft) higher than in the preceding spring.

Longer term sea levels vary in response to changes in global sea levels (due to changes in ice volume and seawater temperature) and to land movement related to local tectonism. The planet is currently experiencing a rise in sea level. Since 1992, satellite altimetry from TOPEX/Poseidon indicates an average rate of 3-4 mm/yr (Nerem and Mitchum 2000). In some coastal locations, local land movement can accentuate or lessen the global rise. The closest long-term gage to RNSP is at Crescent. From 1933 to 1999, Crescent City has experienced very little sea level change; the sea level has been dropping at an average rate of 0.48 mm/yr (0.16 ft/century) (Figure 26). The rest of California is experiencing a sea level rise. Rising sea levels are a significant stressor on most coastal communities. Sea level variations along the RNSP coastline have not been studied in detail and the potential exists that long term sea level may be fairly stable.

Interannual variation of mean sea level 1980 – 2006: Crescent City, California

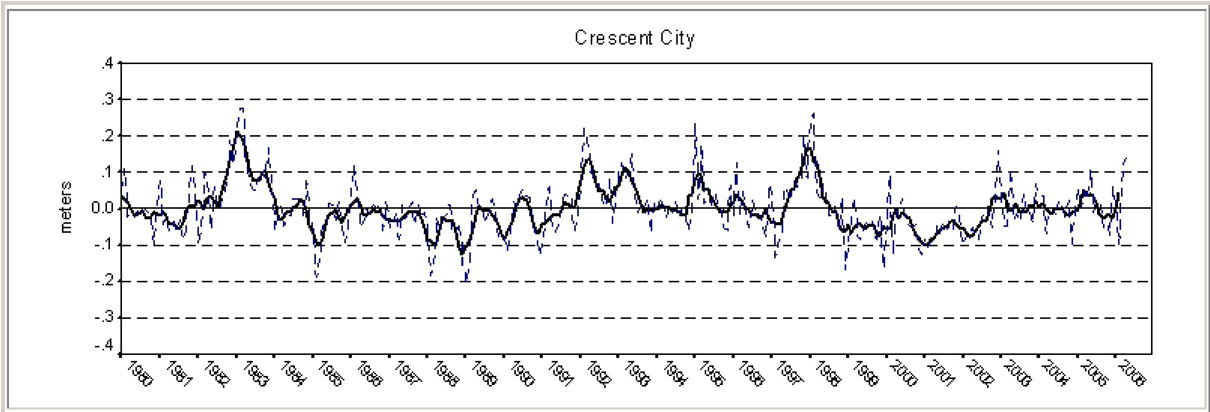


Figure 25. Monthly mean sea level at Crescent City, CA (gauge #9419750). Five-month mean (solid line) with average seasonal cycle removed (dashed curve). Values relative to 1983-2001 sea level datum. Note the higher sea levels during the last two major El Niño/Southern Oscillation events: 1982-83 and 1997-98 (from http://tidesandcurrents.noaa.gov).

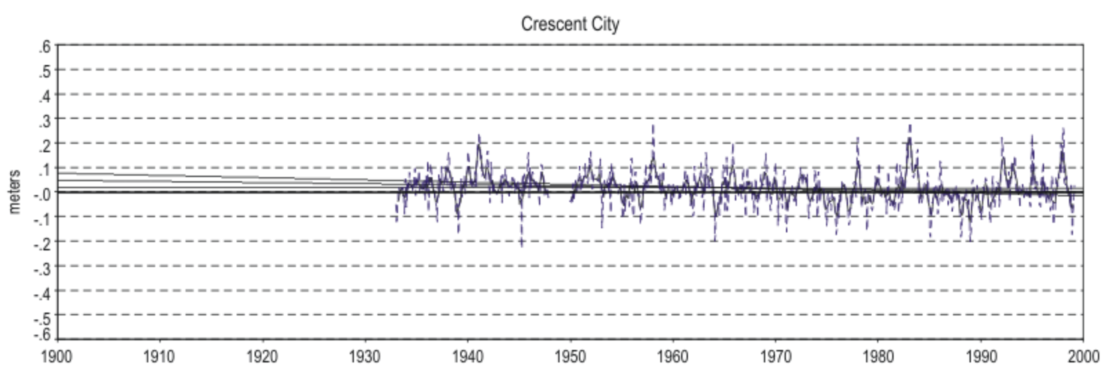


Figure 26. Mean sea level trend at Crescent City, California based on monthly mean sea level data from 1933 to 1999. The mean sea level trend is -0.48 mm/year (-0.16 ft/century) with a standard error of 0.23 mm/yr. The negative trend means that average local sea levels are falling (from http://tidesandcurrents.noaa.gov).

B3b. Coastal Hydrology Affecting the Parks

Rivers and streams emptying into the coastal ocean play significant roles in the coastal environment (e.g. freshwater input, the transport of nutrients and materials such as sediments). This freshwater input is an essential component to the hydrologic cycle. Freshwater outflow is typically less dense than seawater. In well-mixed estuaries, minimal density gradients are observed. However, in partially-mixed or salt wedge estuaries, like those within RNSP boundaries, mixing is comparatively less, often resulting in a clearly-defined freshwater plume on the ocean surface. Sharply defined gradients with sufficient riverine nutrient concentrations have been noted as areas of high primary and secondary productivity (Grimes and Kingsford 1996, Lohrenz et al. 1999).

Offshore of rivers carrying exceptionally high sediment loads, a river plume can become denser than seawater. When this occurs the river plume may exit offshore as a bottom-hugging hyperpycnal flow.

Freshwater Input

Freshwater supply to the nearshore coastal ocean in the RNSP region is dominated by the Klamath River. The lower river has been gaged near the town of Klamath for the last 94 years. The mean streamflow (averaged from 1911 to 2002) was 495 cubic meters per second (cms) (17,480 cfs). The peak flow during the 94-year period was 157,000 cms (557,000 cfs) on Dec. 23, 1964. The river also represents the primary sediment supplier to the coast. The river supplies an average annual suspended sediment discharge of 10.8 million metric tons per year, one of the highest suspended loads along the U.S. west coast (Brown 1973, Brown 1975, Brown and Ritter 1971). The bedload supplied by the river is much less understood. The percent of the total load carried as bedload varies greatly among watersheds. Estimates suggest that the bedload is about 10 percent of the suspended load of the river (Brown 1973, Brown 1975, Brown and Ritter 1971).

Redwood Creek, the second largest source of freshwater to the park coast, has been gaged since 1953. The mean streamflow (averaged from 1954-2005) was 28.4 cms (1,004 cfs), or about 5.7 percent of that of the Klamath River. Peak flow on Redwood Creek for the 52-year period was 1430 cms (50,500 cfs). From 1971-2001, the average suspended sediment discharge for Redwood Creek was about 762,000 metric tons per year. On Redwood Creek and tributaries, 15-25 percent of the total sediment load moves as bedload (Mary Ann Madej, Research Geologist, USGS, personal communication).

A number of smaller creeks drain directly to the ocean along the coastline. There is no monitoring of stream discharge on these small coastal creeks. Depending on how the water from the Klamath River is transported and diffused along the coast, it may dominate the contributions from the various creeks, except perhaps in the near vicinity of the creek mouths.

Groundwater supply to the coast has been noted. Orick Valley, at the mouth of Redwood Creek, has been identified by the state as a groundwater basin. The volume of groundwater flow that reaches the coast has not been measured but given the amount of annual rainfall in the area, it may represent a significant source to the coast, especially during late summer and early fall when rainfall and surface runoff are less common.

The largest freshwater sources outside the park include the Smith River to the north and the Mad and Eel Rivers, to the south. We believe that, because of diffusive effects and of basic freshwater plume dynamics, none of these river sources are likely to have a significant impact along the RNSP coastline.

Estuaries

The most significant estuary in the study area occurs at the mouth of the Klamath River. The Klamath River estuary is broadly defined as the lower 6.5 km (4 mi) of river subject to tidal fluctuation. The lower estuary, up to 2.5 km (1.6 mi) upstream is characterized by broad open water 2-4 m (6-13 ft) deep with sand and gravel substrate (CDFG 1996). Salt water intrusion extends 36 km (23 mi) upstream from the coast; surface water elevation changes due to tides have been documented 45 km (56 mi) upriver. A smaller, seasonal, estuary exists at the mouth of Redwood Creek. RNSP jurisdiction covers only the spit(s) at the mouth of the Klamath River and the western portion of Redwood Creek estuary.

Freshwater Lagoon lies partially within the southern end of the park. Three other lagoons, Stone, Dry, and Big Lagoons, in the Humboldt Lagoons State Park, are south of the RNSP boundary. All these estuaries and lagoons can be geomorphically classified as drowned river valleys and all of them seal at times from direct exchange with the ocean, when a sandy berm develops across the entrance. Freshwater Lagoon is permanently sealed from the ocean by the U. S. Highway 101 roadbed.

Redwood Creek estuary, in particular, closes off every year around June and usually remains closed to the ocean until the fall. The sealed creek waters provide a habitat for salmonids, but can lead to flooding of local lands. Occasionally, local residents have artificially breached the estuary to lower water levels, but these actions can destroy the salmonid habitat and flush juvenile salmonids into the ocean before they have matured sufficiently. From 1982 to 2002, the Park took over water management of estuary water levels and was responsible for balancing the environmental and community needs while considering if, when, and how to conduct artificial breaches.

An Integrated Watershed Strategy for Redwood Creek, as a part of California Proposition 50, was completed in 2006. Local, state and federal agencies, the town of Orick, and local landowners collaborated to develop the strategy. The purpose of the watershed strategy is to improve and protect water quality and water resources in the Redwood Creek watershed. Restoration of natural processes in the Redwood Creek estuary has been identified as critical to improving the degraded conditions. A fully functioning estuary will benefit federally listed anadromous salmonids and the associated fish and wildlife that utilize these resources. A long-term management strategy for the estuary identifies developing and implementing levee modifications that will provide flood control benefits, reduce levee maintenance, incorporate estuary restoration, and minimize impacts to adjacent landowners.

River Plumes and Shelf Circulation

Fresh water runoff generally enters the coastal ocean as a buoyant, surface plume of water, primarily due to the difference in salinity. Observations and modeling work of the Eel River plume and others suggest that winds and wind-driven flow can affect the mixing and dispersal of freshwater discharges significantly. In the presence of upwelling-favorable winds, a surface plume will thin and stretch offshore, while under the influence of downwelling-favorable winds the plume may hug the coastline and mix extensively (Garvine 1999; Geyer et al. 2000; Pullen and Allen 2000). If the plume of water is large enough, it can also modify the shelf circulation (Munchow and Garvine 1993, Pullen and Allen 2000). The presence of large amounts of fresh water can cause buoyancy-driven flow effects over the inner shelf.

Recent efforts to examine the sediment supply and plume dynamics of the Eel River during winter flood events have revealed that high discharge events primarily occur when downwelling-favorable winds dominate (Garvine 1999; Geyer et al. 2000; Pullen and Allen 2000; Harris et al. 2005). During these events, the shelf surface circulation is primarily to the north (Pullen and Allen 2000) (Figure 27). The river plumes are forced to the north and against the coast (Figure 28).

If the river plume persists and the suspended sediment concentrations become high enough, the plume may become denser than seawater and flow offshore as a hyperpycnal flow (Traykovski et al. 2000; Harris et al. 2005). These events have resulted in sediment deposition on the Eel River shelf up to several centimeters in thickness (Wheatcroft and Borgeld 2000) and the implication is that similar effects likely occur on the Klamath River shelf as well, 120 km (75 mi) to the north of the Eel River. The impact of such large-scale freshwater or suspended sediment input along the seafloor has not been examined in detail. However, reductions in fish catch (Table 2) and intertidal invertebrates abundance were noted during the most recent Klamath River flood event in 2006 (Tim Mulligan, Fisheries Professor, Humboldt State University, personal communication).

As mentioned above, the impact of winter flooding of the Eel River has been examined (Garvine 1999; Geyer et al. 2000; Pullen and Allen 2000; Harris et al. 2005). Spring and summer floods do not occur on the Eel River and were not considered in modeling effects. The major floods on the Klamath River also occur during winter and the Eel River modeling provides some insight into processes that likely occur along the RNSP coastline. Unlike the Eel River however, the Klamath River also experiences spring flooding fed by snow melt. Limited research has been conducted to examine the spring plume dispersion and potential impact. One recent study examined the vertical and spatial distribution of the Klamath River plume in the coastal ocean during late spring 2002 (Barnes et al. 2002). Wind conditions had been light for much of the time and the plume was difficult to identify at times. One interesting feature noted in the report was a potential modulation of the plume outflow by the tides. Montoya (2003) compared tidal heights at Crescent City, California to the Klamath River gage at Klamath, California for the period July-September 2003 and determined that, when the river flow was sufficiently low, distinct peaks appear in the gage readings that are correlated with higher high tide, though delayed by typically 30 minutes; for even lower flows, a second "pulse" appeared in the gage readings, corresponding to lower high tide. Thus, the tidal signal appears to have propagated up river. The arrival of high tides at the entrance to the Klamath River may provide some temporary blocking of the freshwater outflow during these times, and more release during the falling tides, causing the plume to pulse.

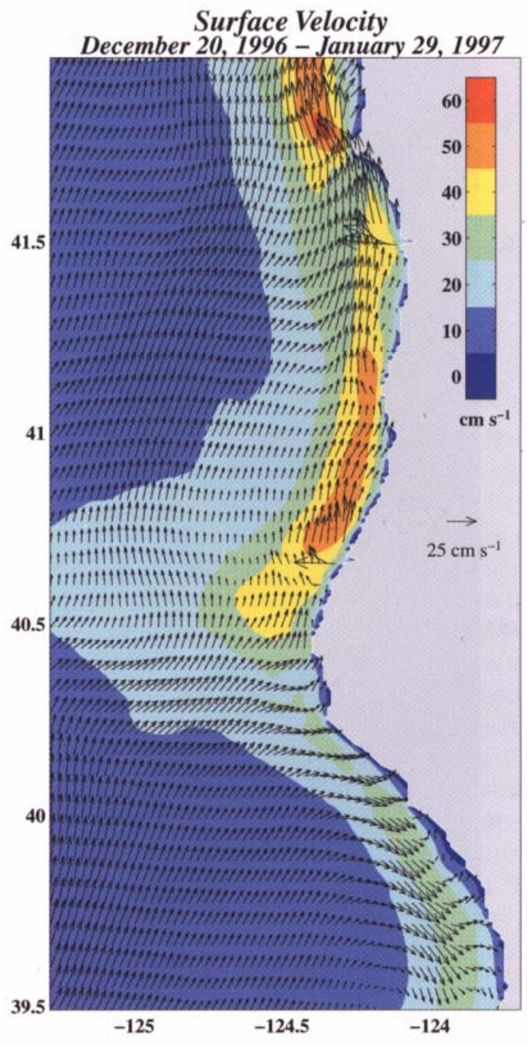


Figure 27. Model results of average shelf surface circulation on the northern California margin from December 20, 1996 to January 29, 1997 (from Pullen and Allen 2000).

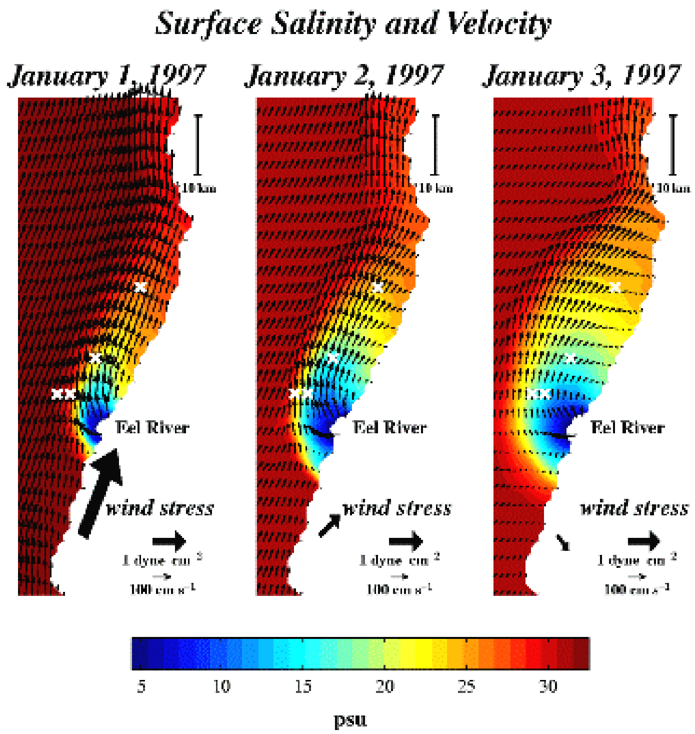


Figure 28. Eel River shelf model results of shelf surface currents and salinity on the Eel River shelf during river flooding in January 1997 (after Pullen and Allen 2000).

Table 2. Salinity and abundances of fish species collected by hook-n-line sampling within Redwood National and State Parks, Humboldt and Del Norte Counties, California, September 2005 and January 2006 (Tim Mulligan, Fisheries Professor, Humboldt State University, personal communication).

September 2005			**January 2006**		
Site	**Salinity (ppt)**	**# Caught & Species**	**Site**	**Salinity (ppt)**	**# Caught & Species**
Damnation Creek	27 – 28	26- Black rockfish 2- Blue rockfish 1- China rockfish 1- Quillback rockfish 1- Yellowtail rockfish 1- Kelp greenling 4- Lingcod 2- Cabezon 38=Total	Damnation Creek	20 – 22	13- Black rockfish 1- Cabezon 14=Total
Redwood Creek	31	101- Black rockfish 1- Cabezon 1- Common mola 2- Lingcod 105=Total	Redwood Creek	22	No Species Caught

* Salinity of Klamath River outflow plume on 21 January 2006 was 17 parts-per-thousand (ppt).

B4. Biological Resources

B4a. Brief Biological View of RNSP Coastline

A brief overview of the locations, conditions and biota of the park's coastline and water bodies will provide an outline for further examination (Figures 29 and 30).

The southwestern boundary of RNSP is located near Gyon Bluffs at the southern end of Freshwater Lagoon spit. Freshwater Lagoon spit is a long strip of sandy beach adjacent to U.S. Highway 101, which parallels the beach and serves as a barrier between the lagoon and the spit. The beach is 90-185 m (295-607 ft) wide and continues north to the mouth of Redwood Creek (Boyd et al. 1981). The National Park Service prepared a General Management Plan/Environmental Impact Statement for its recreational use and currently prohibits overnight camping along the spit. Native plant species growing on Freshwater Lagoon spit include dunegrass (*Elymus mollis*), yellow sand verbena (*Abronia latifolia*), bursage (*Ambrosia chamissonis*), beach pea (*Lathyrus latifolia*), beach morning glory (*Calystegia soldanella*), beach strawberry (*Fragaria chiloensis*) and beach evening primrose (*Camissonia cheiranthifolia*) as well as beach layia (*Layia carnosa*), a federally listed endangered plant. The invasive European beach grass (*Ammophila arenaria*) is a serious threat to the plant communities and is promoted by anthropogenic impacts such as trampling and disturbance. In 1995, the California Conservation Corps was contracted to remove European beach grass from Freshwater Spit. Yearly follow-ups remove remnant sprouting beach grass.

Surf fishing is common along the length of the beach and fishermen catch mostly redtail surfperch (*Amphistichus rhodoterus*), surf smelt (*Hypomesus pretiosus*) and night smelt (*Spirinchus starksi*) (Boyd et al. 1981). No endangered or threatened animal species are known to permanently inhabit or breed on the beach, but several can be observed in the area either seasonally or occasionally: including the California brown pelican (*Pelecanus occidentalis californicus*), and bald eagle (*Haliaeetus leucocephalus*) (USDI 1990). Marine mammals commonly seen off the coast include harbor seals, sea lions, dolphins, porpoises and whales, mostly California gray whales (*Eschrichtius robustus*).

North of the Redwood Creek estuary, a rocky outcropping known as Mussel Point separates Redwood Creek Beach from Gold Bluffs Beach. Gold Bluffs beach is a moderately-exposed sand beach that stretches for 18 km (11.3 mi) to about 0.8 km (0.5 mi) north of Johnson Creek. Boyd et al. (1981) reported that redtail surfperch, surf smelt and night smelt were commonly caught in the area by both sport and commercial fishermen. Beach seines conducted in the spring and summers of 2004 and 2005 yielded mostly redtail surfperch, jacksmelt (*Atherinopsis californiensis*), and walleye surfperch (*Hyperprosopon argenteum*) (Cox et al. 2006). Gulls, pelicans, cormorants, surf scoters, harbor seals and sea lions are commonly seen preying upon these fish species and commercial surf fishing occurs on Gold Bluffs Beach. The federally threatened western snowy plover (*Charadrius* alexandrinus) breeds on Gold Bluffs Beach (Holm 2004). Burrowing invertebrates were widely dispersed along the beach and fairly sparse in numbers, with amphipods and sand crabs (*Emerita analoga*) becoming most abundant in early summer and late fall (Boyd and DeMartini 1977, Cox et al. 2006).

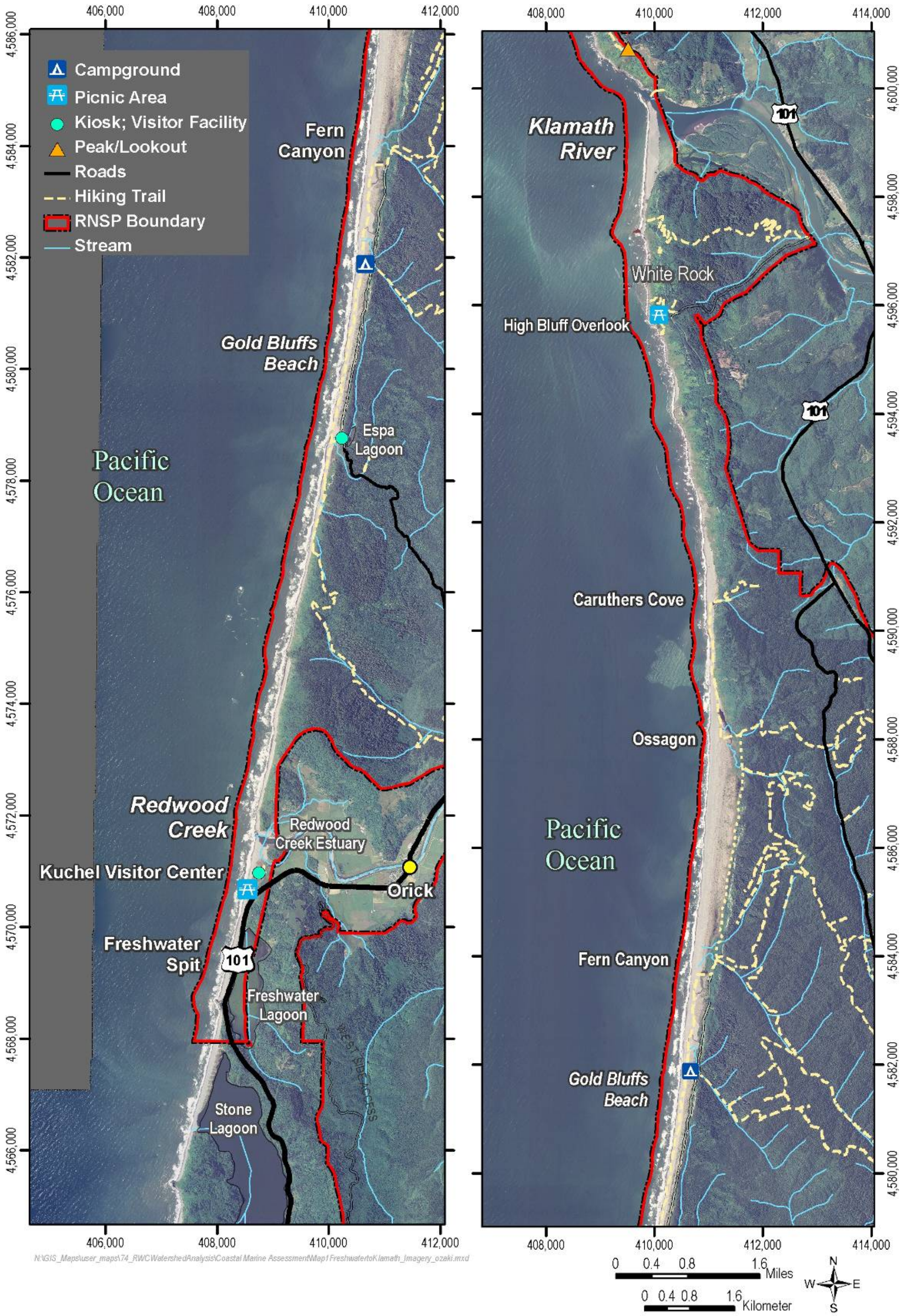


Figure 29. RNSP coastline from its southern boundary at Freshwater Lagoon to the Klamath River.

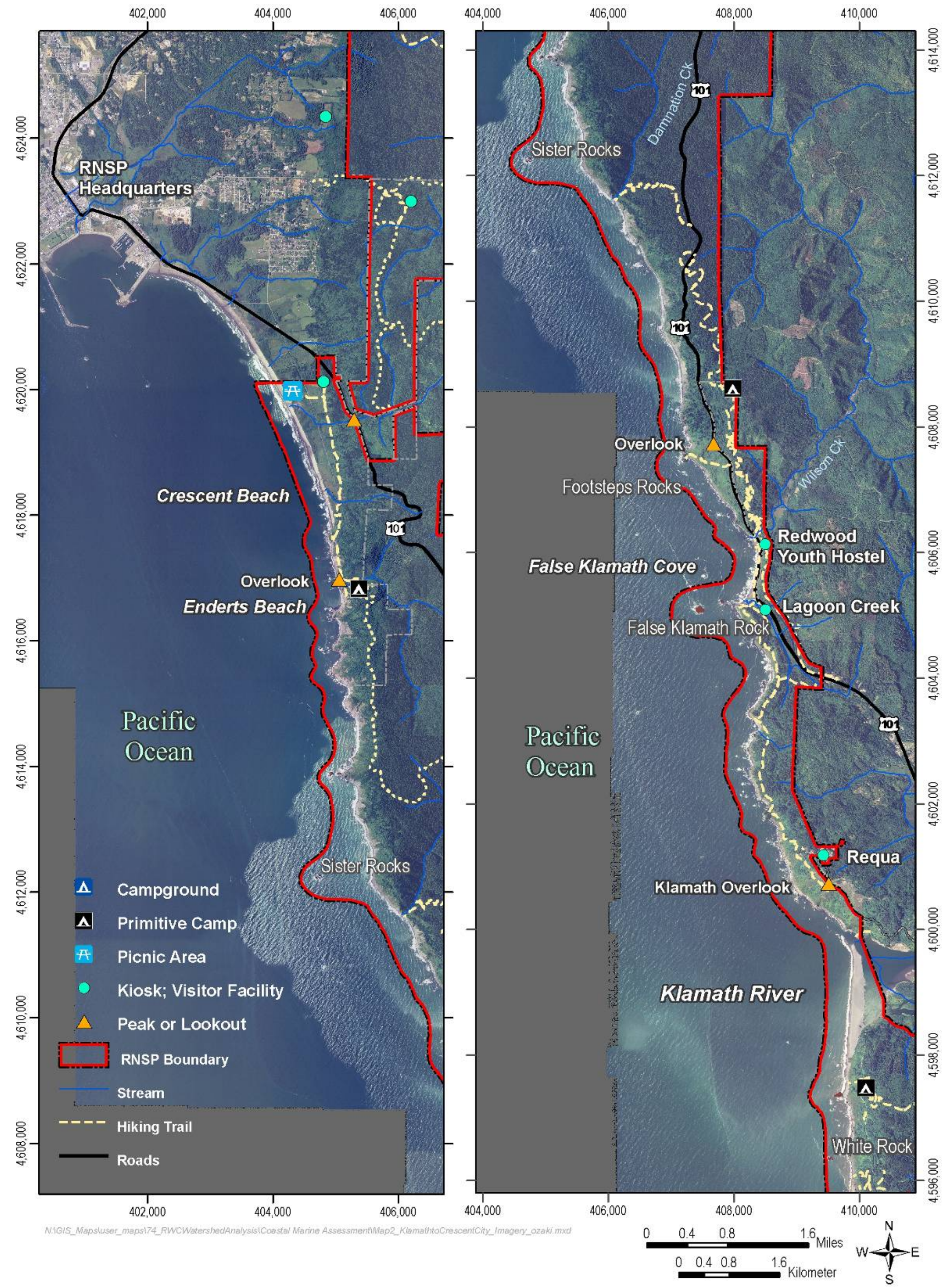


Figure 30. RNSP coastline from the Crescent City south to the Klamath River.

Ten small creeks flow into the ocean along Gold Bluffs Beach (Table 3). Fish surveys were conducted on some of these creeks in 2003 and 2004, but otherwise relatively little attention has been given them (Howard Sakai, Supervisory Ecologist, RNSP, personal communication). As well as providing salmonid habitat, many of these small creeks provide habitat for red-legged and yellow-legged frogs, the pacific giant salamander and other non-commercial fish such as various sculpin species (Holden 2003). Tidewater goby (*Eucyclogobius newberryi*) surveys were completed for some of these creeks in 2004 and no gobies were found. These small creeks provide important habitat for juvenile salmonids, so continued attention to water quality and sedimentation is recommended.

Table 3. Summary of fish surveys conducted in 2003 and 2004 in minor creeks along Gold Bluffs Beach (Howard Sakai, Supervisory Ecologist, RNSP, personal communication).

Creeks along Gold Bluffs Beach (South to North)	Fish Species
Major Creek	Not surveyed
East Creek	Cutthroat
Espa Creek	Cutthroat
Squashan Creek	Cutthroat
Unnamed creek north of Squashan Creek	Cutthroat/Steelhead hybrid
Home Creek	Cutthroat
Boat Creek	Cutthroat and Steelhead
Butler Creek	Cutthroat
Ossagon Creek	Cutthroat and Steelhead
Johnson Creek	No salmonids based on survey in 2004

North of Caruthers Cove or Johnson Creek to just south of the Klamath River estuary, the coastline becomes more steep and rocky. Scattered intertidal rocks are interspersed with small pocket beaches (Boyd et al. 1981). The habitat type is at least partially dependent on the unique geology present from Ossagon Creek to just north of the Klamath estuary at Footsteps Rock. Most rock faces are vertical and covered with mussels and barnacles. Algal cover is sparse apparently due to heavy wave action. A coarse sand beach extends about 0.5 miles south of the mouth of the Klamath River. White Rock sustains a large cormorant breeding colony and is the largest offshore brown pelican roosting site on the north coast of California (Bensen 2004b; Sowls et al. 1980).

North of the Klamath River estuary, the coast is steep and wave action is severe. The intertidal zone is virtually inaccessible and was surveyed by boat by Boyd et al. in 1981. The federally threatened Steller seal lion (*Eumetopia jubatus*) is commonly found on offshore rocks which are used as stable haul-out sites. Sea lion pups have been recorded on a few offshore rocks; these sites may be a breeding rookery (RNSP unpublished data).

The next major landmark is False Klamath Cove. False Klamath Cove rock is located on the south end of the cove and is the fifth largest seabird colony in California with up to 30,000 breeding birds, mostly common murres (*Uria aalge*) (Benson 2004b; Sowls et al.

1980). Just south of the cove is a small pocket beach of coarse sand, pebbles and cobbles. A boulder and cobble field extends from near the mouth of Lagoon Creek offshore to a large sea stack. This boulder field is only exposed at low tide and was the site for intertidal inventories and monitoring conducted from July 1974 to June 1976 (Boyd and DeMartini 1977, Boyd et al. 1981), and from June 2004 to November 2005 (Cox et al. 2006). Wave action is severe enough to cause regular movement of the boulders, resulting in prevalence of annual and early successional species on this unstable substrate (Boyd and DeMartini 1977, Boyd et al. 1981, Cox et al. 2006). There are numerous large embedded boulders and rocky benches that support well developed mussel beds and other late successional species at this site (McGary 2005, Cox et al. 2006). A small population of sea palms (*Postelsia palmaeformis*) grows on the north side of the sea stack. Harvest of this alga is prohibited by the California Department of Fish and Game due to recent increase in exploitation. Its habitat specificity and reproductive characteristics indicate that this alga cannot withstand heavy harvesting (Miller 2002, Cox et al. 2006).

The coastline continues to be steep and rocky until Enderts Beach Cove. Most commonly found are cobble or boulder beaches lying at the base of steep cliffs. Damnation Creek is accessible by means of a steep trail and emerges at a rocky bench backed with a very steep cobble beach. Mussel beds and other species capable of handling wave stress are apparent. Damnation Creek empties to this beach, drastically reducing salinity in nearby tidepools after heavy rain. This area was not surveyed by Boyd and DeMartini in the 1970s because it lacked exposed rocky benches at that time and did not seem suitable for rocky intertidal investigations. It seems that much has changed at this site since then. A well formed, extensive rocky bench is now exposed during low tides. Rock weeds (mostly *Fucus gardneri*), numerous red algae, surf grass (*Phyllospadix spp*), mussels, barnacles, and ochre stars (*Pisaster ochraceous*) are now prolific at this site, and it has been established as a site for intertidal monitoring, biodiversity studies, and tidepool fish studies (Cox et al. 2006). Breeding seabirds, mostly Brandt's cormorants (*Phalacrocorax penicillatus*) and pelagic cormorants (*P. auritus*) breed in scattered locations along the cliffs of this area. The offshore rocks known as Three Sisters is also the site of a small seabird breeding colony (Sowls et al. 1980).

Enderts Beach Cove, about 6.5 km (4 mi) south of Crescent City, provides the most popular access to tidepools for RNSP staff and visitors. Geological formations extend from the base of the cliffs and form rocky benches and caves that provide habitat for many sessile intertidal organisms including extensive mussel beds, prolific algae, and rocky trenches that support anemones and sea stars. Intertidal inventories and monitoring occurred from July 1974 to June 1976 (Boyd and DeMartini 1977, Boyd et al. 1981) and from June 2004 to November 2005 (Cox et al. 2006). North of the cove is Enderts Beach, a short stretch of beach with coarse grain sand and a few low intertidal rocky benches. One low rocky bench was the site of tidepool fish studies from March 2004 to September 2005 (Cox et al. 2006) and an intertidal community comparison site for the Crescent City wastewater outfall (Warburton 2005). A rocky outcrop at the north end of Enderts Beach separates Enderts Beach from Crescent Beach.

The northernmost landmark in RNSP is Crescent Beach, a medium to fine sand beach that stretches about 2.6 km (1.6 mi) from a rocky outcrop to the park's northern boundary. This beach is dissipative and quite productive. Sand beach surveys were conducted to census biota at Crescent Beach in 1974-1976 (Boyd and DeMartini 1977) and in 2004-2005 (Cox et al. 2006). Both studies determined that Crescent Beach supports the highest density and greatest diversity of sand beach fauna within RNSP.

B4b. Intertidal

Intertidal habitats along the RNSP coastline are primarily composed of sand beaches of varying grain size, including steep boulder beaches, and rocky outcroppings or benches. These habitats support a diverse array of algae, invertebrates, fish, and shorebirds. The intertidal habitats of RNSP have received minor attention since the park's creation. Most studies have been short-term, and focused on a few accessible sites. General habitat mapping has not been completed. Habitat mapping is vital for managers when attempting to apply site specific data to similar habitats that have not or can not be studied in such detail.

An intertidal habitat inventory is currently underway through an agreement with Humboldt State University. The inventory seeks to describe 42 km (26 mi) of accessible RNSP coastline by delineating segments based on the geomorphology and describing the physical and biological features within. This study is based on protocols developed by Sharman et al. (2006) for Glacier Bay National Park, and by Muchow (2004) at Point Reyes National Seashore and Golden Gate National Recreation Area. Data for each segment will include segment length (based on pedometer and GPS data), geomorphological characteristics (slope and Wentworth substrate type), photographs, biota lists with qualitative abundance estimates, description of streams and cliff seeps, and notes of human objects or impacts (Craig et al. 2006).

A number of site-specific intertidal studies have occurred in RNSP since the mid 1970s. The earliest intertidal inventory and monitoring study in RNSP was conducted from July 1974 through June 1976. This study catalogued the dominant algae and macro-invertebrates, and identified the major physical, chemical, and biological factors that affect the distribution and abundance of intertidal organisms over a seasonal timescale (Boyd and DeMartini 1977, Boyd et al. 1981). The studies focused on three sand beach sites (Crescent Beach, Gold Bluffs Beach, and Redwood Creek Beach) and three rocky intertidal sites (False Klamath Cove, Enderts Beach Cove, and Point Saint George). These sites are located inside RNSP, with the exception of the Point Saint George site, which is north of RNSP and Crescent City. The study included a qualitative description of intertidal habitats and a general account of the intertidal zonation patterns observed along the entire RNSP coastline. The report also included quantitative data for seasonal dynamics in beach slope, sand particle size, water quality, and invertebrate abundance at the three sand beach sites. The study evaluated the effects of vehicle compaction on sand beach invertebrates at the three sand beaches. Monthly inventories were conducted at each of the three rocky intertidal sites using qualitative searches throughout the site, and quantitative searches along transect lines. Photographic stations were also established at these sites to monitor settlement and growth of sessile invertebrates and algae. Inventory lists of algae and macro-invertebrates (from sand beach and rocky intertidal sites) were also compiled.

McGary (2005) compared the composition of sessile species in plots photographed by Boyd and DeMartini in July 1975 and June 1976 to community composition plot photographs taken in June 2005 at False Klamath Cove. This comparison showed substantial change in species composition from early to mid-successional species dominating in 1975 and 1976 to dominance by late and mid- successional species in 2005. The results suggested a decrease in disturbance to rocky intertidal species, likely due to decreased sediment loads (that caused scouring on intertidal rocks), and less coastal debris (e.g., logs and other woody debris) smashing onto intertidal rocks. The study highlighted the need for more integrated management of terrestrial-coastal management and continued intertidal monitoring. Intertidal systems are strongly affected by disturbances, pollutants, and debris of both terrestrial and oceanic origin. Effects of sediment and debris have been studied in RNSP terrestrial watersheds, but this was the first study to consider the indirect effects of logging activities on intertidal systems. Terrestrial and riverine effects are likely very profound along the entire coast of RNSP. Biological monitoring, sediment budgets, and water quality data are crucial for detecting and identifying stressors and natural changes in nearshore environments.

As part of an assessment of coastal and marine resources, a comprehensive inventory and monitoring study was conducted from March 2004 to November 2005 (Cox et al. 2006). This study was focused within the same intertidal sites that were used by Boyd and DeMartini (1977), with the addition of Damnation Creek (rocky intertidal) and the omission of Point Saint George.

Species distribution was examined at a presence/absence scale, and at a finer scales for ecologically important species which involved monitoring in discrete plots and pools. A species list of intertidal algae (124 species), invertebrates (395 species), and fish (29 species) was created and compared with species lists developed by Boyd and DeMartini (1977) and Boyd et al. (1981). Voucher specimens were collected for most algae and invertebrates encountered and are stored in the archives of RNSP in Orick, California. The voucher collection should aid future researchers and park staff in identifying invertebrates and algae.

The sand beach component of the study was conducted in RNSP at Redwood Creek Beach, Gold Bluffs Beach, and Crescent Beach. Abundance and distribution patterns of sand crabs and beach hopper (*Megalorchestia spp*) populations were monitored at all three sand beaches in May and July of 2004 and August of 2005 using protocols developed at Channel Islands National Park (Dugan et al. 1990). Abundance and diversity of sand beach species is known to be highest in late summer and early fall (Boyd and DeMartini 1977). Beach seines were used to inventory fish at Gold Bluffs Beach and Crescent Beach. Seining dates corresponded with sand beach invertebrate monitoring dates.

The study also established a rocky intertidal monitoring program at False Klamath Cove, Enderts Beach Cove, and Damnation Creek. The monitoring program utilized protocols developed by the Multi-Agency Rocky Intertidal Network (MARINe). These protocols are used by state, federal, and local government agencies, universities, and private organizations to monitor rocky intertidal assemblages throughout California. To establish a baseline of seasonal/short term variation, the MARINe protocols were used bi-monthly for the first year and a half (2004-2005). Permanent plots were photographed at each rocky intertidal site and the photographs analyzed to determine the percent cover and seasonal change in marine algae (e.g. *Endocladia muricata*, *Pelvetiopsis limitata*, and *Fucus gardneri*), barnacles (*Cthamalus dalli* and *Balanus glandula*), and mussels (*Mytilus californianus*). In addition, a protocol developed for PISCO's (Partnership for Interdisciplinary Studies of Coastal Oceans) Marine Dynamics Survey group at University of California, Santa Cruz, was used to monitor the abundance and size distribution of mobile invertebrates (including limpets, *Lottia* spp; littorines, *Littorina* spp; black turbans, *Tegula funebralis*; and dogwhelks, *Nucella ostrina* and *N. canaliculata*) within monitoring plots. Both protocols enable scientists to assess the degree to which changes in coastal marine species are mirrored by changes along the Pacific coast or whether changes are unique to the coastline of RNSP. Since November 2005, the three RNSP rocky intertidal sites have been monitored twice a year (in late spring and fall) through a cooperative agreement with the Marine Dynamics Survey team at the University of California, Santa Cruz. Continued biannual monitoring within RNSP should enable the detection of community change due to natural variations, anthropogenic disturbances, invasions, and other ecological factors.

The 2004-2005 project described the biodiversity, abundance and distribution of tidepool fish including sculpins (*Oligocottus maculosus* and *O. snyderi*), monkey-faced pricklebacks (*Cebidichthys violaceus*), juvenile black rockfish and other species (Cox et al. 2006). Tidepools were sampled bi-monthly from March 2004 to September 2005 at all three rocky intertidal sites to determine temporal and spatial fluctuations of intertidal fish. As a result, the abundance, zonation patterns, and size frequency distribution of resident intertidal fish in RNSP's rocky intertidal habitat have been examined over an annual period.

Rocky intertidal habitats along the northern California and Oregon coasts (including RNSP) have recently been determined to serve as nursery grounds for some species of rockfish (Studebaker 2006, Rebecca Studebaker and Karah Cox, Graduate Students, Humboldt State University, personal communication). Black and blue rock fish (*Sebastes melanops* and *S. mystinus*), which are important commercial and recreational species have been observed utilizing rocky intertidal habitats within RNSP. Black rockfish were the most abundant fish sampled in tidepools within RNSP. The sampling was part of a larger study which looked at juvenile rockfish abundance in rocky intertidal areas throughout northern California and Oregon. For the 2005 recruitment year, abundance of juvenile rockfish was lower than those observed in southern and central Oregon, but higher than sites sampled south of RNSP.

A mark and recapture study in the summer of 2004 found black rockfish remained in the rocky intertidal area (False Klamath Cove and Enderts Beach) for up to three months, and showed site fidelity to individual rocky intertidal pools (Lomeli 2004, Cox et al. 2006). These types of studies provide essential information for managers to better protect and enhance habitats within RNSP boundaries. These studies in particular may also be significant in light of a recent study which suggests that black rockfish populations are not as healthy as once thought (O'Farrell and Botsford 2006). Further studies of rocky intertidal use by juvenile rockfish will aid managers in understanding the role of these habitats in early life history of rockfish. Federal managers are required to protect these habitats as mandated by the Magnuson-Stevens Fishery Conservation and Management Act. This act mandates the conservation of essential fish habitat, defined as "...those waters and substrate necessary for spawning, breeding, feeding, or growth to maturity" (Studebaker 2006).

B4c. Subtidal and Offshore

Subtidal surveys are extremely difficult to conduct in RNSP as the coastline of RNSP is highly exposed, water currents are very strong and turbidity is high. What is known about subtidal habitats in RNSP is largely based on SCUBA (Boyd and DeMartini 1977) surveys conducted in July of 1975 and 1976 in rocky habitats just south of Enderts Beach Cove. Surveys were also conducted north of RNSP near Point Saint George. In August 1980, a more extensive area was surveyed, 13 dive sites distributed from the mouth of the Klamath River north to the RNSP border (Boyd et al. 1981). Four different habitat types were distinguished in RNSP north of the Klamath River: rocky habitat influenced by sand, rocky habitats not influenced by sand, rocky habitat influenced by fine sediment, and sandy habitats (Boyd et al. 1981). Of these, rocky habitat influenced by fine sediment was the least common, and only was encountered near the mouth of the Klamath River.

In general, the algal zone extended offshore to a depth of about 6 to 7 m (20 ft), with local bare patches, depending on topography and illumination. The dominant algae were crustose coralline algae and various kelp species. In semi-protected areas, red algae were also common. In regions exposed to northwesterly swell, the invertebrate fauna was dominated by suspension feeders such as sponges, bryozoans, tunicates and the sea cucumber (*Eupentacta quinquesemita*). In more protected rocky habitats, the invertebrate fauna was especially diverse including several species of nudibranchs, hydrozoans, sea anemones, the cup coral (*Balanophyllia elegans*) and the sea star (*Lepasterias hexactis*). Some fish species present included the scalyhead sculpin (*Artedius harringtoni*), brown Irish lord (*Heilepidotus spinosus*), kelp greenling (*Hexagrammos decagrammus*), ling cod (*Ophiodon elongates*) and black rockfish. Some locally abundant species that were rare elsewhere in California, included the sea stars (*Solaster stimpsoni* and *S. dawsoni*). Comparisons made with similar studies in Trinidad Head ASBS and Mendocino Headlands State Underwater Parks conclude that the shallow rocky subtidal biota of RNSP was similar to that of central Humboldt County, but was distinct from that of Mendocino and Sonoma Counties, to the south (Seltenrich 1979).

An ongoing survey of subtidal fish is being conducted by Humboldt State University (Mulligan and Lomeli 2005). Surveys have been conducted in June, July, and September 2005 and January, February, March, May, and December 2006 at three sandy bottom sites off Gold Bluffs Beach, False Klamath Cove, and Enderts Beach; and two rocky reef sites off Damnation and Redwood Creeks. Two replicate 12-minute trawls sample fish at the three sandy bottom sites. Sampling depths ranged from 11 to 30 m (18-50 ft). At rocky reef sites, fish were sampled using hook and line for 1.25 hours at depths ranging from 10-29 m (16-48 ft). Temperature and salinity were also measured at each site. Thirty-four fish species from 16 families were collected in the 2005 surveys. Sandy bottom trawls yielded the highest diversity of fish, with 27 species caught. Eleven fish species were caught over rocky reefs, but may not indicate actual differences in diversity among site types because of differences in sampling technique (Mulligan and Lomeli 2005). This study will provide RNSP with an inventory of subtidal fish species in rocky and sandy bottom habitats, an indication of relative diversity among sites, and a basic understanding of seasonal variations for 2005-2007.

Offshore rocks, also known as sea stacks are numerous along the RNSP coastline. These rocks are important nesting and roosting habitat for numerous seabirds and are used as haulouts by pinnipeds; their nearly vertical surfaces are home to unique intertidal and subtidal biological communities composed of organisms capable of withstanding heavy wave action. The use of these rocks by birds and mammals is discussed below.

The invertebrate and algal communities associated with sea stacks in RNSP have received little attention due to the logistical difficulties of observations. The only known description of sea stack communities in RNSP was done by DeMartini and Pic'l in 1980 (Boyd et al. 1981). In general, invertebrates are sessile, low relief, suspension feeders capable of withstanding a lot of water movement (Boyd et al. 1981). The dominant species that were growing on vertical subtidal sea stack surfaces from 0 to 16 m in depth (0 to 50 ft) are described in this report, as well as several fish species which were observed in the vicinity. Sea stack observations were difficult due to heavy wave action, and poor visibility. However, the water visibility may improve offshore away from sediment sources which would make some subtidal observations on sea stacks more practical than observations on nearshore subtidal surfaces.

B4d. Sea Birds

The coastline and offshore rocks of RNSP are important habitat for a number of sea bird populations. The 95 km (60 mi.) coastline, from Trinidad, California to the Oregon border, supports about 40 percent of the total breeding seabirds along the entire coast of California (Bensen 2005). This stretch of coastline contains four of the five largest seabird colonies in California. An ongoing RNSP study has been monitoring sea bird colonies on False Klamath Rock (the fifth largest seabird colony in California) and White Rock since 2003 to detect natural and human-caused changes in the nearshore environments of RNSP. These rocks provide important nesting and roosting sites for common murres (*Uria aalge*), pigeon guillemots (*Cepphus columba*), double crested cormorants (*Phalacrocorax auritus*), Brant's cormorants (*P. penicillatus*), pelagic cormorants (*P. pelagicus*), and western gulls (*Larus occidentalis*) (Bensen 2004b and

2005). Common murres are ideal for monitoring because they are sensitive to changes in prey availability and have strong site fidelity for breeding (Bensen 2005).

The beaches and nearshore waters and sea stacks of RNSP are used by three threatened and endangered birds: the California brown pelican, marbled murrelet, and western snowy plover. Although, the pelican does not breed within RNSP, White Rock is the largest roosting site for California brown pelicans, with over 1000 birds recorded (Sowls et al. 1980). Data for California brown pelican use of park beaches are collected incidentally during snowy plover and beach carcass surveys (Bensen 2004b). Routine snowy plover surveys detected nests in 2004 and 2005 on Gold Bluffs Beach, the first nests of record in RNSP for this species since the 1980's (Holm 2004). Marbled murrelets nest in the old growth forests of RNSP, but fly to nearshore waters to feed on small fish. Further information about these species can be found in section B4h, below.

B4e. Marine Mammals

Marine mammals found within RNSP include harbor seals (*Phoca vitulina*), Steller sea lions (*Eumetopia jubatus*), California sea lions (*Zalophus californianus*), harbor porpoises (*Phocoena phocoena*), gray whales (*Eschrichtius robustus*), and occasionally humpback whales (*Megaptera novaeangliae*) and northern elephant seals (*Mirounga angustirostris*). These species are protected under the Marine Mammal Protection Act (regulated by NOAA Fisheries), which prohibits the killing of any species of marine mammals. Steller sea lions are present year round and may breed on offshore rocks within the park (RNSP unpublished data). Small populations of gray whales spend the summer in the coastal waters of northern California, potentially feeding on benthic species (primarily crustaceans) within the park. Harbor seals are present in the Klamath River estuary year-round with a peak of about 400 seals in the summer (USDC 1997). Harbor seals are also seasonally present in the Redwood Creek estuary. California sea lions are present in the fall and spring. Both harbor seals and sea lions have been documented feeding on salmonids in this area since the 1960's. Over the past three years, a few individual sightings of elephant seals have been made within RNSP. These animals appear to be resting on RNSP beaches possibly in route to the Castle Rock colony north of Crescent City (Greg Holm, Wildlife Biologist, RNSP, personal communication). Three major haulout sites were recognized along the coast of RNSP at the mouth of the Klamath River, and at two remote rocky coves between the Klamath River mouth and Enderts Beach Cove. Castle Rock, just north of Crescent City and the RNSP boundary, is a major haulout site for California sea lions, harbor seals, and elephant seals (Griswold 1977).

Carcass surveys along the sand beach sections of the RNSP are used to monitor marine mammal mortality. All marine mammal carcasses are identified and the location, cause of death (if it can be determined), and stage of decomposition are recorded. In 2005, three sea lions, four harbor seals, one unknown pinniped, four harbor porpoises, and one fin whale (*Balaenoptera physalus*) washed ashore within the park. In 2000, four gray and one Bairds beaked (*Berardius bairdii*) whale carcasses washed ashore. Live marine mammal sightings are recorded in a RNSP database. Sick and injured animals are reported to the Marine Mammal Center in Crescent City if their injuries appear to be human caused. Other marine mammal monitoring studies on the north coast include Dr. Dawn Goley of Humboldt State University who has been studying the distribution, ecology and behavior of cetaceans and pinnipeds along the northern California coasts of Del Norte and Humboldt County. She rides along on U.S. Coast Guard helicopter patrols of the coastline to observe marine mammals.

B4f. Lagoons, Estuaries, and Freshwaters

Freshwater Lagoon is at the southern boundary of the park. It is separated from the ocean by U.S. Highway 101 and is split north-south by the park boundary. The lagoon no longer naturally breaches nor drains to the ocean through a culvert under US Highway 101. The culvert, its outlet buried by beach sand, is intended to prevent the lagoon from overtopping the adjacent Highway 101 roadbed, not mimic natural processes. The lagoon is isolated from the influx of salt water and remains a freshwater system year round. Its only input is from Owl Creek that enters at the south end of the lagoon (Gergus 1988). Plankton samples taken from the lagoon in a study by Gergus (1988) found an abundance of phytoplankton and zooplankton including *Volvox*, Calanoid copepods, rotifers, and daphnia species. The fish species mentioned as biologically significant in the lagoon were largemouth bass, rainbow trout, threespine stickleback, Japanese pond smelt, prickly sculpin, and others. Historic reports indicate that the California Department of Fish and Game began planting fish in the lagoon in the1930s (Kimsey 1952). Fish planted included rainbow trout, kokanee salmon, Japanese pond smelt, and steelhead. Rainbow trout are still planted by CDFG. Largemouth bass were illegally planted. Lagoon water quality is not ideal for fish health. Elevated pH and low dissolved oxygen concentrations have been recorded as well as temperatures exceeding 21°C (70°F) (USDI 1990, Kimsey 1952). Blooms of the exotic aquatic plant *Egeria densa* have also been a problem due to unknown nutrient sources (USDI 1990). Heavy parasitism by tapeworms and roundworms was noted in 1963 (Day 1963), but no current reports mention this problem.

The Redwood Creek estuary is north of Freshwater Spit and west of Orick at the mouth of Redwood Creek. A sand berm forms in the early summer and allows a lagoon to form, which is a natural holding area for juvenile salmonids. It has been drastically modified from its natural state due to flood control levees completed in 1968. Construction of these levees was prompted by major floods in 1953, 1955 and 1964 (Ricks 1985). These levees cause the accumulation of sediment and impair the use of the estuary by juvenile salmonids. The embayment has consequently become very shallow and true estuarine conditions are not established in the winter and spring (Gregory 1982). Historically the creek supported large runs of Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*), steelhead (O. *mykiss*), and cutthroat trout (O. *clarki*) (Ricks and Feranna 1981). These species are still present, but their runs have been drastically reduced (Anderson 2003). The estuary is important rearing habitat for juvenile salmonids and part of the importance rests on the ability of the estuary to provide an adequate food source. Interspecific competition for food resources in the estuary has been examined (Salamunovich 1987). The study gathered data on the lower 3.5 km (2.2 mi) of the creek, which is lined entirely by levees constructed in 1968 by the U.S. Army Corps of Engineers. Fish food species include *Diptera* larvae and *Corophium spp*. Gammeridean amphipods were the most important food sources for most fish species. Evidence indicated that the juvenile steelhead trout were benthic foragers that relied on aquatic invertebrates for the bulk of their diet. A comprehensive list of invertebrates that make up fish diets in Redwood Creek was made by Salamunovich (1987). Other fish species in Redwood Creek estuary include prickly sculpin, Humboldt sucker, threespine stickleback, staghorn sculpin, starry flounder, surf smelt, and shiner surfperch. A complete list of species observed in the estuary is available in the 2003 Redwood Creek Estuary Monitoring Annual Progress Report (Anderson 2003). Physical and biological processes of Redwood Creek estuary have been monitored continuously since the 1980s by Redwood National Park. Water elevation and temperature, cross-sections, and salmonid population and growth are monitored through spring, summer, and fall. Reports have been written since 1983 and include water quality data, fish counts, invertebrate sampling and other data.

Espa Lagoon (a.k.a. Espau) is a small freshwater lagoon located at the south end of Gold Bluffs Beach. Espa Lagoon supports a small cutthroat trout population (Mulligan and Studebaker 2005). A fish inventory, carried out by RNSP in 1999, caught coastal cutthroat trout and many threespine sticklebacks and northwestern salamanders (Anderson 1999). The lagoon is eutrophic and anoxic in the summer months (Josselyn et al. 1992). Due to the construction of a road across the lagoon mouth and the stabilization of the beach by invasive European beachgrass, the mouth is no longer flushed out and organic matter accumulates and decays in the lagoon, creating low dissolved oxygen and eutrophication. Dredging the lagoon and altering the road has been recommended.

The Klamath River estuary is broadly defined as the lower 6.5 km (4 mi) of river subject to tidal fluctuation. Ten anadromous fish spend portions of their life cycle in the estuary (USFWS 1979a): Chinook salmon, coho salmon, steelhead, cutthroat trout, brown trout (*Salmo trutta*), green sturgeon (*Acipenser medirostris*), white sturgeon (*A. transmontanus*), American shad (*Alosa sapidissima*), Pacific lamprey (*Lampetra tridentata*), and eulachon (*Thaleichthys pacificus*). Chinook salmon runs in the Klamath River occur during the spring, peaking in May, and the fall, peaking in August and September. Spring run fish generally begin river spawning in mid-September while fall-run Chinook salmon begin spawning in October and continue through December. Chinook salmon juveniles generally begin to migrate seaward 90 days after hatching although a few fish remain in fresh water for a year (USFWS 1979a).

In 1985, NOAA launched the Estuarine Living Marine Resources (ELMR) Program to develop a consistent database on the distribution, relative abundance, and life history characteristics of ecologically and economically important fishes and invertebrates in the nation's estuaries. The nationwide ELMR database includes information for 153 species found in 122 estuaries and coastal embayments. The database is divided into five study regions including the West Coast. For each species, five life stages are considered (adults, juveniles, larvae, spawning, and eggs) with some exceptions. Each estuary is subdivided into one to five salinity zones. Relative abundance is ranked by month for each life stage of each species, in each salinity zone of each estuary. The west coast data and life history summary reports include a species list and details for the Klamath River estuary (http://biogeo.nos.noaa.gov/products/elmr/).

There is existing information on the flora, fauna and function of the coastal watersheds within RNSP. Several studies were initiated more than thirty years ago and continue to the present day. The Redwood Creek watershed is one of the most studied watersheds in North America. The U.S. Geological Survey (USGS) began hydrologic and geomorphic studies in 1973 to evaluate land use impacts on park and watershed resources. These studies have been complemented by numerous scientific studies performed by researchers from the National Park Service, Humboldt State University, and the U.S. Forest Service. Park staff have conducted fish population estimates and water quality monitoring for 25 years in the Redwood Creek estuary, and have continued some of the USGS monitoring studies. RNSP performed a watershed analysis for Redwood Creek in 1997. The North Coast Watershed Assessment Program, managed by the California Resources Agency, performed a multi-scale assessment of watershed conditions to determine factors affecting salmonid populations and recommended watershed improvement measures. All previous studies of Redwood Creek recognize timber harvest activities, especially erosion from logging roads, as a major threat to aquatic habitat and water quality. Park staff have cooperatively worked since 1995 with private landowners in the upper Redwood Creek watershed to address potential erosion from logging roads on private lands. Much less is known about the Klamath River and other watersheds effects on coastal park waters.

B4g. Coastal Upland

Freshwater marshes can be found near most ponds and streams within the park. Marshes have been noted around the mouth of Redwood Creek, at Espa Lagoon, at the mouths of Home Creek and Ossagon Creek, the backdunes of Gold Bluffs Beach, around the mouth of the Klamath River, at False Klamath Cove and the backdunes of Crescent Beach.

Coastal strand vegetation occurs on sandy beaches above the highest high tide line. Common species associated with this vegetation type are the invasive European beach grass, beach primrose, sand verbena, and beach morning glory. This vegetation type is common on Crescent Beach and Gold Bluffs Beach, with small patches found near the Redwood Creek and Klamath River estuaries, at False Klamath Cove and on Enderts Beach. Introduced European beach grass is especially problematic at Gold Bluffs Beach and Carruthers Cove. Coastal shrub vegetation is often mixed in with coastal strand and includes species such as twinberry, foxglove, coastal wormwood, and stunted Sitka spruce.

Coastal spruce forest is common at Gold Bluffs beach as well as along Wilson and Nickel Creeks. This forest type is characterized by the salt tolerant Sitka spruce and red alder. Most spruce stands were logged during the 1950s. Coastal grasslands and spruce/redwood forests occur inland of the coastal strand in RNSP. Two threatened plant species have the potential to occur within the coastal zone of RNSP: the western lily (*Lilium occidentale*), and the beach layia. The beach layia only occurs on open sand where there is some level of disturbance that minimizes competing vegetation. Historically, it was never known to occur north of the Little River, which is located approximately 32 km (20 mi) to the south of RNSP. Hence, the population at Freshwater Spit is an anomaly and a range extension for the species. The western lily grows in several coastal habitats including bogs/fens, scrub, grasslands, and forests; but this species has never been recorded in RNSP (Leonel Arguello, Botanist, RNSP, personal communication).

B4h. Threatened and Endangered Species

Thirteen threatened and endangered species are known to occur (or have historically occurred) in the coastal habitats of RNSP (Table 4). Of these, nine species are known to reproduce, at least occasionally, within park boundaries. Brief summaries (below) identify the current status of management strategies for each threatened or endangered species know to occur in RNSP's coastal habitats. These summaries are adapted from species accounts developed by the Fish and Wildlife Branch of RNSP (Sakai 2003, with recent revisions by K. Schmidt). There are three additional threatened and endangered species that occur in the terrestrial habitats of RNSP; the Northern spotted owl (*Strix occidentalis*), fisher (*Martes pennanti*, candidate), and mardon skipper (*Polites mardon,* candidate). Suitable habitat exists within RNSP for 12 additional threatened and endangered species, but these species have not been confirmed within the park. These species include black abalone (*Haliotis cracherodii*), Oregon silver spot butterfly (*Speyeria zerene hippolyta*), short-tailed albatross (*Phoeastris albatrus*), bocaccio rockfish (*Sebastes paucispinis*, candidate), blue whale (*Balaenoptera musculus*), fin whale (*Balaenoptera physalus*), sei whale (*Balaenoptera borealis*), sperm whale (*Physeter macrocephalus*), green sea turtle (*Chelonia mydas*), leatherback sea turtle (*Dermochelys coriacea*), loggerhead sea turtle (*Caretta caretta*), and McDonald's rock-cress (*Arabis macdonaldiana*). These 15 species are not discussed herein.

Table 4. Threatened and endangered species found along the coast of Redwood National and State Parks (from Arcata U.S. Fish and Wildlife Office, Doc. # 376035995-151133).

Common Name	Scientific Name	Federal Status	California Status
American Peregrine Falcon	***Falco peregrinus anatum***	**Delisted (1999)**	**Endangered**
Bald Eagle	***Haliaeetus leucocephalus***	**Threatened**	**Endangered**
California Brown Pelican	***Pelecanus occidentalis***	**Endangered**	**Endangered**
Marbled Murrelet	***Brachyramphus marmoratus***	**Threatened**	**Endangered**
Western Snowy Plover	***Charadrius alexandrinus nivosus***	**Threatened**	
Chinook Salmon	***Oncorhynchus tshawytscha***	**Threatened**	**Endangered**
Coho Salmon	***Oncorhynchus kisutch***	**Threatened**	**Threatened**
Steelhead Trout	***Oncorhynchus mykiss***	**Threatened**	
Tidewater Goby	***Eucyclogobius newberryi***	**Endangered**	
Olive Ridley Sea Turtle	***Lepidochelys olivacea***	**Threatened**	
Humpback Whale	***Megaptera novaengliae***	**Endangered**	
Steller Sea Lion	***Eumetopias jubatus***	**Threatened**	
Beach Layia	***Layia carnosa***	**Endangered**	**Endangered**

American Peregrine Falcon

Suitable habitat occurs in many areas of RNSP. Sea cliffs, beach bluffs, sea stacks, and large bedrock outcrops may all provide potentially suitable nesting habitat for peregrines. However, the only known territories in the park occur along the coast. Peregrine falcons are regularly observed during all times of year at a wide variety of locations throughout RNSP. Although peregrines were observed at a number of locations within the park, the first documented eyrie and reproduction occurred in 1998 on the bluffs above Gold Bluffs Beach (Falvey 1998). Currently there are two confirmed peregrine falcon territories within RNSP, with three nest sites. One territory is centered near Klamath Cove north of Requa, and the two other (most likely alternate nest sites) are near Butler and Home Creeks along Gold Bluffs Beach. The Klamath Cove site is difficult to observe due to its location, and reproduction there has only been confirmed once (Falvey 1999). However, the annual presence of adult birds during the breeding season indicates a high probability of regular nesting at this site (Holm 2002). The pair at Gold Bluffs Beach is very productive, and has produced at least one young each year between 1998 and 2002 (Holm 2002).

Disturbance by human activities remain a threat to reproduction, especially in early spring when disturbance during courtship may result in the abandonment of nest sites or territories (Fyfe and Olendorf 1976). Aerial disturbance from low-flying helicopters and airplanes, a regular activity along the RNSP coast, may be responsible for nest abandonment (USFWS 1982). Known predators include great horned owls, red-tailed hawks, common ravens, coyotes, bobcats, raccoons, and skunks. Areas in RNSP with potential Peregrine Falcon nesting habitat have been surveyed by boat and on land since 1993. Known territories are monitored by park staff throughout the breeding season to determine nesting status.

Bald Eagle

Redwood National and State Parks were identified primarily as winter habitat in the *Recovery Plan for the Pacific Bald Eagle* (USFWS 1986), which forms the basis for management direction and provides recovery goals. Approximately 12,900 ac (5,220 ha) of potential habitat is located within 200 m of streams, lagoons and the ocean. Large trees providing nest sites are located throughout many areas of RNSP. Certain areas in RNSP have been determined as good to excellent habitat potential (Detrich and Garcelon 1986). Areas where bald eagles are annually observed include Redwood Creek, Freshwater Lagoon, along the Smith River, coastal areas near the mouth of the Klamath River, along the entire coastline of Del Norte Coast Redwood State Park, and along Gold Bluffs Beach in Prairie Creek Redwoods State Park.

Nesting habitat, in general, is composed of low elevation, late successional forested stands near permanent lakes and free-flowing rivers. In California, 87 percent of nest sites were within 1.6 km (1 mi) of water (Zeiner et al. 1990). A nest was found along the Klamath River in 1996 outside the park boundary, but close enough for the pair to forage in RNSP. Another nest was found in 1997 on the ridge just south of the town of Orick.

The pair at this nest produced two young in 1999, one young in 2000 and 2001, and two young in 2002 and 2003. This nest will continue to be monitored annually. Nearby Freshwater Lagoon (1.25 miles from the nest) provides suitable foraging habitat, and indeed is used for foraging by bald eagles, most likely including those from this territory. Another territory was discovered on the main stem of Mill Creek in the north end of RNSP in 2003 and appeared to have produced at least one young. Eagles have been seen foraging and soaring repeatedly during the breeding season along Crescent Beach and along the main stem of Mill Creek and are suspected to belong to this second park territory. Historic information indicates that prior to the last few years, successful nesting of bald eagles was not documented in RNSP.

Field surveys to identify potential nesting activities during the breeding season were begun in 1997 and have continued to the present. Known nest sites are monitored annually to determine reproductive status.

California Brown Pelican

Brown pelicans are commonly observed along the entire RNSP coastline in summer and fall, but they can be seen in the park from April until January. Brown pelican habitat is found along the entire coastline of the park. There are approximately 1,631 ac (652 ha) of beach and other coastal mainland habitat available for use by pelicans in RNSP. Offshore rocks large enough to be used for loafing or night roosts cover approximately 11 ha (27 ac) within the park boundary. Groups of 100 or more individuals have been observed with some regularity at the Klamath and Smith River estuaries (Jaques and Strong unpublished data) and at the mouth of Redwood Creek. The largest number of pelicans recorded in one group by RNSP surveyors (an estimated 1,000 individuals) was on the Klamath River spit.

Despite their observed preference for offshore rocks and estuaries, brown pelicans also appear to use sand beaches for loafing night roosting sites, including the beach near the mouth of Redwood Creek, the beach in the vicinity of Home and Boat Creeks near Fern Canyon, and open stretches of beach in the vicinity of Ossagon and Squashan Creeks. Data collected by Jaques and Strong (unpublished), and RNSP staff, indicate that pelicans repeatedly use the same approximate locations on beaches.

Ocean area available for foraging within the park covers approximately 2,291 ha (5,727 ac). Foraging habitat also includes the Klamath River and Redwood Creek estuaries. In RNSP, pelicans have been observed foraging in the surf and in the Klamath River and Redwood Creek estuaries, as well as farther out in the ocean. Foraging locations often appear coincidental with adjacent loafing sites (Jaques et al. 1994). Brown pelicans are monitored incidentally during bi-monthly snowy plover and beach carcass surveys.

Marbled Murrelet

In California, marbled murrelets are restricted to old growth forests in Del Norte, Humboldt, San Mateo, and Santa Cruz Counties, and the associated offshore waters as murrelets must travel to nearshore waters to feed on small fish. RNSP is considered to be the most important murrelet refugium in the region. There are approximately 16,592 ha (41,000 ac) of old growth forest occurring in contiguous stands greater than 0.2 ha (0.5 ac) in size that would presumably be suitable marbled murrelet nesting habitat in RNSP. Old growth stands are fragmented with only a few existing large contiguous blocks of nesting habitat. There also are an additional 146 ha (362 ac) of residual old growth forest (stands with isolated old growth trees surrounded by mature residual trees) occurring within RNSP which may provide lower quality suitable nesting habitat.

Currently the marbled murrelet population in California is estimated to be between 1,650 and 6,500 individuals, 95 percent of which are found along the coastline of Humboldt and Del Norte counties. In 2003, their density in RNSP was estimated to be only 5.93 birds /km^2 (Miller et al. 2003). Ralph et al. (2002) reported a drastic population decline in RNSP over the prior 13 years, despite the fact that during an initial state-wide inventory of potentially suitable marbled murrelet nesting habitat conducted in 1988 a transect along the James Irvine Trail (in RNSP) recorded the highest number of murrelet detections anywhere in the state. A telemetry study in RNSP documented a mean hatching success rate of 46 percent in 2003 and reproductive (fledging) success rate ranging from 13.5 percent to 32.4 percent that included nests with unknown reproductive outcomes (Hebert and Golightly 2003). In 2002-2003, at-sea observations of juvenile: adult ratios, used as an indirect index of breeding success (McShane et al. 2004), indicated a 0.003 to 0.094 juvenile: adult ratio off the RNSP coast, which was far lower than the ratio (>0.15) necessary to stabilize the population (Beissinger 1995). The zone encompassing RNSP has a 100 percent probability of extinction (defined as less than 30 individuals per zone) within 100 years (McShane et al. 2004).

Threats to marbled murrelet populations include nest habitat loss and fragmentation, and predation. Habitat loss and fragmentation is due primarily to commercial logging of coastal old-growth and mature forests, coupled with large wildfires and windthrow (USDI 1992b). The continued timber harvest outside RNSP that results in incidental take of murrelets through reduction of available habitat increases the proportionate effects on park populations of murrelets. Similarly, actions taken by RNSP and CDPR to manage resources and provide for public use and enjoyment that might result in incidental take of murrelets have proportionately greater effects and are subject to more scrutiny.

Nest predation by eight different species, including the Stellers jay (*Cyanocitta stelleri*), common raven (*Corvus corax*), great horned owl (*Bubo virginianus*), sharp-shinned hawk (*Accipiter striatus*), Coopers hawk (*A. cooperii*), Pacific fisher (*Martes pennanti*), Townsend’s chipmunk (*Tamias townsendi*), and Douglas squirrel (*Tamasciurus douglasii*), may be a significant contributor to lowered recruitment (Nelson and Hamer 1995, Marzluff et al. 1996). Corvids (jays, crows, and ravens) have been implicated as the primary predator of murrelet nests (Nelson and Hamer 1995, Raphael et al. 2002). Surveys are currently being conducted by RNSP staff to determine the distribution and abundance of corvids in both developed and non-developed (off trail >400 m (0.25 mi) from trails or roads) areas of old growth redwood. These data will be used to determine how park facilities affect corvid populations, and, indirectly, murrelet populations.

In September 1999, an oil spill in Humboldt Bay, 48 km (30 mi) south of RNSP, killed an unknown percentage of marbled murrelets foraging in oceanic waters off the coast. This disaster reduced the effective population of birds and decreased the chances of complete recovery of the marbled murrelet population in the RNSP region. Legal settlements over the oil spill awarded funds to RNSP which are being used to protect murrelets by studying murrelet populations, and to address problems associated with corvid predation.

The recovery plan for the marbled murrelet outlined a number of recovery objectives that include stabilizing and then increasing population size throughout the range and gathering information necessary for the development of delisting criteria. Recovery actions for the Siskiyou Coast Range Zone (including RNSP) include preventing the loss of occupied nesting habitat, minimizing the loss of unoccupied habitat, and, most pertinent to the park, decreasing the time for development of new suitable habitat. The recovery actions for this zone related to state and national parks call for consideration of the maintenance of high quality habitat when planning for new developments associated with recreation. The recovery plan also describes potential threats associated with increased corvid predation and nest disturbance from facility construction and use (campgrounds, picnic areas, visitor centers, and parking lots), and the importance of proper trash disposal in reducing some of these threats (USFWS 1997).

Western Snowy Plover

RNSP has approximately 412 ha (1,029 ac) of beach habitat that are currently considered potentially suitable for snowy plovers. The draft recovery plan identified Gold Bluffs Beach as providing potential wintering and migration habitat important to the recovery of the species (USFWS 2001). No other RNSP beaches were identified in the draft plan as providing habitat of any sort that should be managed for the population’s recovery, however, the draft recovery plan does state that as new breeding areas are discovered the current list of important breeding habitats should be expanded or refined as appropriate.

RNSP beaches were surveyed in 1977 under the coast wide suitable habitat survey, but did not detect any snowy plovers (Page and Stenzel 1981). Winter surveys (1979 and 1985) detected a few plovers on Gold Bluffs Beach in two out of three winters (Page et al. 1986). In 1993, the year the species was listed, park staff undertook a limited breeding season survey of all accessible beach habitats in RNSP. Beginning in the winter of 1996-97, park staff began thorough surveys of potential habitat in winter and during the breeding season. In January of 2004, snowy plovers were detected on Gold Bluffs Beach for the first time since the mid-1980s. Over the next few months, at least five different individuals (identified by leg bands) were present at one time or another. An adult with two chicks was discovered on 24 May 2004; this family was monitored regularly until one chick fledged on 23 June. Snowy plovers returned to Gold Bluffs Beach in January 2005 and have been observed regularly since then. Based on color-banded individuals and the number of unbanded birds seen at one time, there have been at least 10 different individuals present.

Many reasons have been identified for the decline in western snowy plover numbers and nest sites (USFWS 2001). Threats to snowy plovers include human-caused mortality of adults or young and nest destruction, habitat degradation (human or naturally induced), beach development, invasive exotic plant species in the beach environment, and expanding predator (both native and non-native) populations. Other factors that could affect western snowy plovers in RNSP include the presence of vehicles on the wave slope, dogs running off leash, visitor recreation activities, and predation. Although the abundance of predators using beach habitat in the park is unknown, track and incidental wildlife observations suggest a fairly diverse group of predators inhabit the beach. Eleven vertebrates identified as predators of snowy plover eggs, chicks, or adults are known to occur in beach habitats in RNSP. To a lesser extent, illegal driving (e.g., by unauthorized persons, or above the wave slope), permitted driving by commercial beach fishermen, and firewood cutting/gathering may also impact snowy plovers directly, or indirectly, by reducing habitat quality in some areas.

The quality of beach habitat in RNSP has been reduced in many locations due to extensive invasion by European beach grass (*Ammophila arenoides*). The northern half of Gold Bluffs Beach (including the area where plovers occurred in 2004) probably constitutes the best plover habitat, as it is wide and open and exotic beach grass has not stabilized the dunes to the same degree as elsewhere. Freshwater Spit and the adjacent beach to the north also appear to provide good quality habitat. In this area the dune mat community has been restored through exotic plant management efforts, including the removal of European beach grass. However, this beach receives a high amount of public use along its entire stretch, which may deter plover use. Together Gold Bluffs Beach and Freshwater Spit Beach account for approximately 271 ha (669 ac), or 65 percent of the available beach habitat in RNSP.

Currently, snowy plover surveys are conducted during seven months in the breeding season and three months in winter on all accessible beaches within the parks except Klamath Beach, constituting approximately 347 ha (858 ac; 83 percent) of potentially suitable habitat in RNSP. When plovers are present, survey effort increases and management is guided by *Redwood National and State Parks Staff Responsibilities and Management Strategy for Western Snowy plovers* (RNSP 2005).

Chinook Salmon

Chinook salmon populations have declined along the Pacific coast to the degree that certain evolutionarily significant units (ESUs) were listed as threatened by the NOAA Fisheries under the Endangered Species Act. The California Coastal ESU, those populations from rivers and streams south of the Klamath River to the Russian River, was listed as threatened in 1999 (USDC 1999a) and reaffirmed in June 2005 (USDC-NOAA

2005a) (Figure 31). Chinook salmon are distributed in Redwood Creek, the Klamath River, their numerous tributaries, and the nearshore waters of RNSP, though not listed in the Klamath River and the northern half of the park. Designated critical habitat for California Coastal ESU Chinook Salmon was withdrawn per the Consent Order in the case of National Association of Home Builders v. Evans (April 30, 2002) but designated again in September 2005 (USDC-NOAA 2005b). Suitable habitat for this ESU in RNSP occurs in the Redwood Creek basin and includes all stream and estuarine reaches accessible to the species. Accessible reaches are those within the historical range of the ESU that can still be occupied by any life stage of the species.

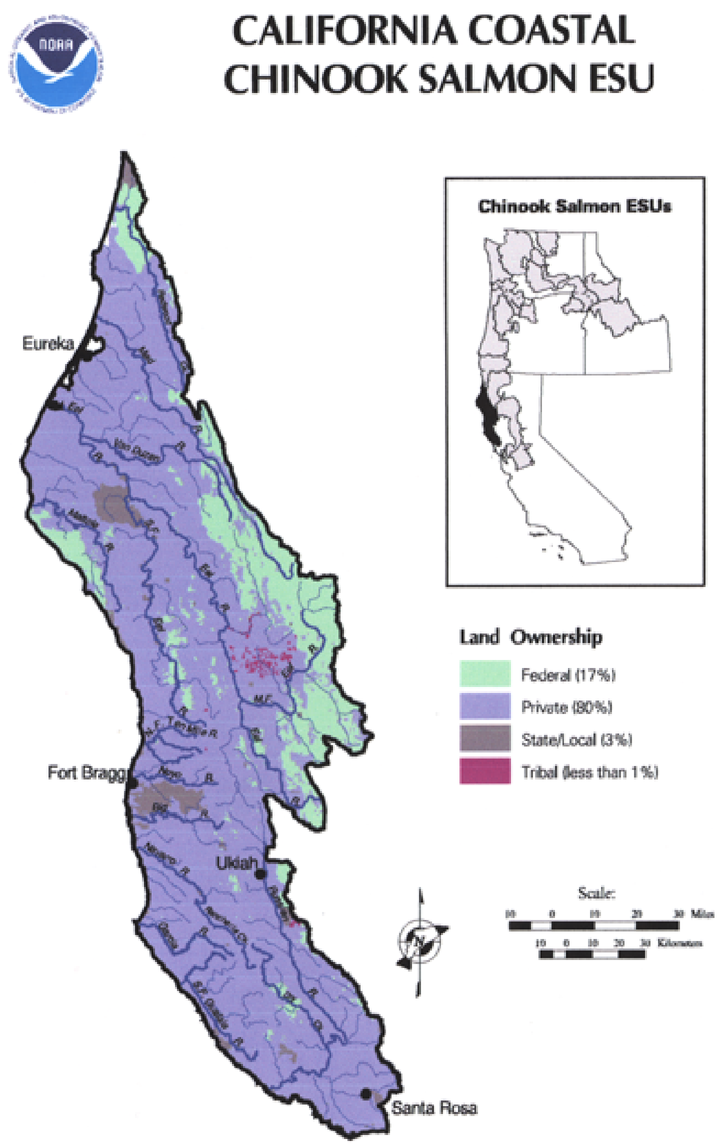


Figure 31. Land ownership in the California Coastal Chinook salmon Evolutionarily Significant Unit (ESU). Redwood Creek can be seen within the borders of federal and state lands within Redwood National and State Parks (from http://www.nwfsc.noaa.gov/trt/maps/map_chincc.pdf).

Winter-run Chinook constitutes the main Chinook runs in Redwood Creek. These fish begin their upstream migration around November, dependent upon the mouth of Redwood Creek being open and river flows sufficient for migration and have spawned and died by the end of January. Adult spring-run Chinook were observed in only one summer since 1981, when the park began summer steelhead surveys, and are not generally considered to use the Redwood Creek watershed. Chinook salmon spawning in RNSP tributaries may be impeded by stream barriers, but they may be able to surmount some barriers that may impede the smaller coho salmon. Juvenile Chinook salmon in Redwood Creek do not spend an extended period of time rearing in upstream areas (Anderson and Brown 1982), but instead migrate downstream and utilize the Redwood Creek estuary. In spring, Chinook salmon fry migrate downstream to rear in the estuary and enter the ocean. Chinook fry downstream migration peaks in upper Redwood Creek in April, May, and June, 97 percent of the migration having occurred by the end of June (Sparkman 2006). After the mouth of the creek closes, fish can not enter the ocean until fall when the mouth breaches. The Redwood Creek estuary is important as the sole extended rearing habitat for this ESU in the park. Park research shows that if given the opportunity, juveniles will spend an extended period to late summer, rearing in the estuary before entering the ocean.

Prior to 1978, most young Chinook salmon were released from Prairie Creek Fish Hatchery in the early spring. These were fish hatched from eggs taken only four or five months earlier. Capturing sufficient numbers of Chinook to obtain their eggs was difficult because of the low numbers of returning adult fish. The low numbers of returning adult Chinook were probably related in part to the conditions in the Redwood Creek estuary. The construction of the flood control project in the estuary resulted in degraded rearing habitat. Winter spawning/carcass counts in RNSP continue to indicate low numbers of returning salmon.

Chinook salmon estuary rearing habitat was degraded when flood control levees that bisect the Redwood Creek estuary were constructed in 1968. The levees altered the physical and biological functions of the estuary and adjacent wetlands and confined the stream channel to a width of 90 m (300 ft). The flood control project reduced the amount of riparian vegetation and tree cover, reduced adjacent wetlands, altered valley drainage patterns, decreased the amount of instream woody debris, and caused decreased pool depths along lower Redwood Creek. The levees bypassed and isolated the last downstream meander of Redwood Creek, reduced circulation into the north and south sloughs, and contributed to 50 percent of the lower estuary between 0 to 1.2 m (0-4 ft) Mean Sea Level filling with sediment or becoming isolated from the embayment (Ricks 1995). Adjacent land uses (e.g., cattle grazing) on the flood plain and uncontrolled breaching of the sand berm (which forms a barrier to the ocean across the mouth), also have contributed to habitat degradation of the estuary.

Juvenile Chinook salmon population and growth are monitored through spring, summer, and fall by RNSP. Population estimates decline to 2,500-3,000 fish by late summer and early fall, indicating a limited carrying capacity in the estuary, but at the same time their length increases. Any recovery efforts for Chinook salmon will rely of restoring the

Redwood Creek estuary, continued road restoration in the watershed, and reducing sediment input.

Coho Salmon

Coho salmon have shown substantial decreases, and even localized extinctions, throughout their range (Konkel and McIntyre 1987, Frissell 1993). Historically the species inhabited most coastal streams in Washington, Oregon, and northern California. In California, including hatchery stocks, the total current population is less than 6 percent of estimates for the period 1940 to 1949, and populations are at least 70 percent lower than during the 1960s (CDFG 1994b). The Southern Oregon/Northern California Coasts ESU for coho salmon, which includes RNSP, were designated as threatened in 1997 (USDI 1997) (Figure 32) and critical habitat (including estuarine areas) was designated in 1999 (USDC 1999b).

Coho salmon are found in Redwood Creek, the Klamath River, several small creeks, and in the nearshore waters of RNSP. Coho occupy 42 km (26 mi) of stream within the lower Redwood Creek basin (RNSP unpub. data); their distribution in the Redwood Creek basin is limited to the mainstem and the larger low gradient tributaries. Park staff conducted general stream surveys of the basin in 1980 and 1981 to describe and characterize the salmonid rearing habitat and distribution of juvenile salmonids (Anderson 1988, Brown 1988). Subsequent surveys in the 1990s have detected coho in streams that did not have coho in 1980-81.

Coho spend two years in the ocean before returning to spawn. After hatching, juvenile coho salmon generally spend one full year rearing in freshwater before entering the ocean. However, Bell (2001) determined 28 percent of Prairie Creek smolts had a two-year freshwater life history component. Downstream migration to the ocean from upstream Redwood Creek rearing areas occurs in early spring (March-April). Survey data from RNSP indicate that these young salmon move directly into the ocean, spending a minimal amount of time in the Redwood Creek estuary (Anderson 1995). Migration through the Redwood Creek estuary is dependent upon the mouth being open to the ocean. Adult coho typically run upstream to spawn from late October to early March depending on access through the estuary (Anderson 1995). Access conditions at the mouth depend on a combination of wave action on the sand berm, the volume of water in the estuary, and stream flow. Recent data suggest the peak of the spawning run begins in late November.

Current fish runs are far below those that occurred 70-80 years ago. News accounts and recollections of longtime residents of the Redwood Creek watershed suggest that both the size and numbers of coho have declined in recent decades (Van Kirk 1994). The total population in the Redwood Creek system in the early 1990s may have numbered more than 2,000 adult coho; most occurred in the Prairie Creek drainage and probably originated from the Prairie Creek Hatchery. Since the closure of the hatchery in 1992 the

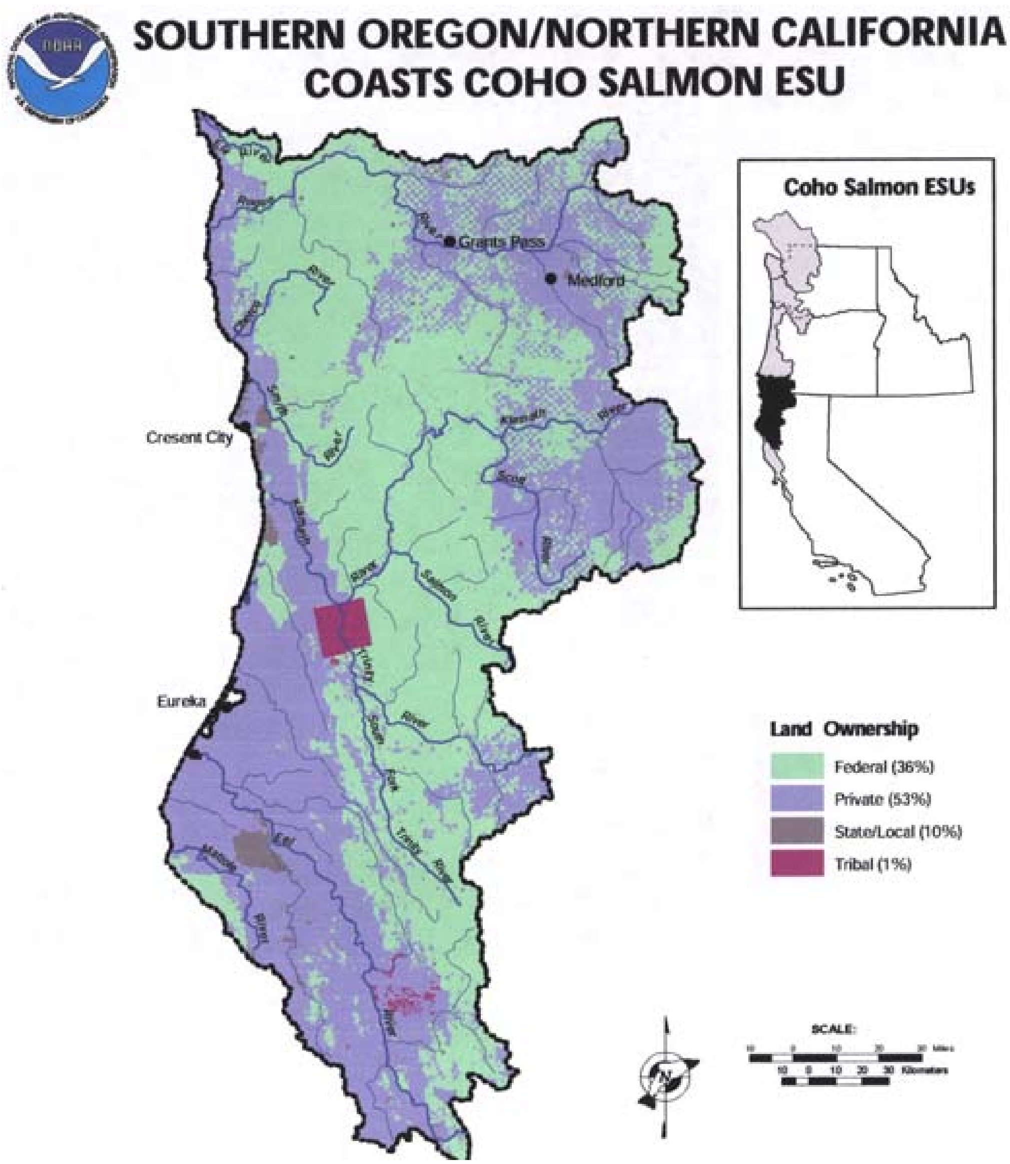


Figure 32. Land ownership in the Southern Oregon/Northern California Coasts coho salmon Evolutionarily Significant Unit (ESU). Redwood Creek and the Klamath Estuary can be seen within the borders of federal and state lands within RNSP. (from http://www.nwfsc.noaa.gov/trt/maps/map_cohsoncc.pdf).

number of coho is probably much lower. Recent water temperature and fish monitoring indicated that an increase of stream temperature may be a factor in restricting juvenile coho to one-fifth of their historical range in mainstem Redwood Creek (Madej et al. 2006).

Park tributaries are systematically surveyed in the summer for juvenile fish, including coho salmon.

Steelhead

Over the past century, over 23 naturally reproducing stocks of steelhead, an anadromous rainbow trout, are believed to have been extirpated, and many more are thought to be in decline in numerous streams in Washington, Oregon, California, and Idaho. Forty-three stocks have been identified as being at moderate or high risk of extinction. Steelhead were listed as endangered in one ESU and threatened in nine ESUs, and proposed as threatened in one ESU. The Northern California ESU, now called a Distinct Population Segment (DPS) (Figure 33), from Redwood Creek south, falls within the boundary of RNSP and was listed as threatened in June 2000 and reaffirmed in 2006 (USDC-NOAA 2006). Critical habitat was designated in 2005 and became effective in 2006 (USDC-NOAA 2005b). Steelhead are found in the estuary, mainstem, and most tributaries including the small order, high gradient tributaries of Redwood Creek.

Steelhead habitat requirements change as they go through different life phases. Adult steelhead need to have access to their natal streams, therefore, it is important that streams are free of barriers to migration, as the majority of spawning occurs in the upper reaches of tributaries. Adults also need clean spawning gravel without heavy sedimentation, adequate flow and cool, clear water. Escape cover for spawning adults also is important. Steelhead eggs and pre-emergent fry require cool water with adequate dissolved oxygen. Fine sediment smothers developing eggs; flow must be free of excessive silt and turbidity. During their first summer, juvenile steelhead are typically found in relatively shallow areas with cobble and boulder bottoms. They reside at the downstream end of shallow pools or in riffles less than two feet deep in areas with woody debris accumulation (logs or tree roots). Cover structures such as boulder clusters and root wads provide both summer and winter rearing habit. Surface turbulence (or white water) provides another source of cover during the summer months. As juvenile steelhead grow, pools become an important habitat component. The best pools for habitat are those with abundant escape cover in the form of large woody debris, undercut banks, root masses, and large boulders. There is an estuary rearing phase where they grow larger before migrating to the ocean.

Winter-run steelhead spawners are the last of the anadromous salmonid species to return to freshwater in the annual cycle, generally between January and April. Juveniles rear in the streams for one to four years before their downstream migration to the ocean. The majority of juvenile steelhead in Redwood Creek spend their second year of life in the estuary and lower part of Redwood Creek (Anderson 1988). They reside in marine waters typically for two or three years prior to returning to the natal stream to spawn. Unlike other Pacific salmon, steelhead are capable of spawning more than one year before they die. They are able to leap above barriers that might impede coho salmon. Whether logjams are barriers to migration depends upon stream dynamics such as the size of the log jam, stream discharge and timing and duration of the steelhead migration. These variables change from year to year. Winter-run steelhead numbers are higher than summer steelhead numbers.

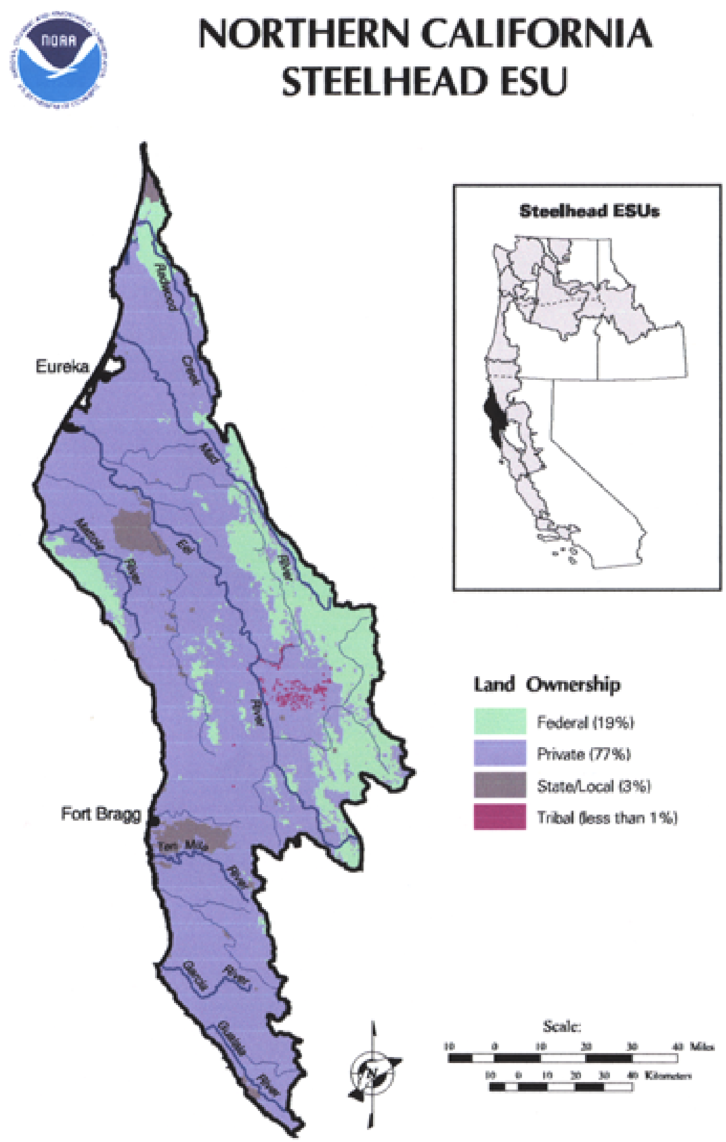


Figure 33. Land ownership in the Northern California steelhead Evolutionarily Significant Unit (ESU). Redwood Creek can be seen within the borders of federal and state lands within Redwood National and State Parks (from http://www.nwfsc.noaa.gov/trt/maps/map_stlhnca.pdf).

Summer steelhead differ from that of the more numerous winter-run steelhead. Adult summer steelhead migrate up the rivers in spring, hold over in deep pools in the summer, and then spawn in winter. Because adult summer steelhead hold in freshwater 8 to 10 months, they are vulnerable to detrimental environmental and human-caused factors including higher water temperatures, low summer flows, decreasing pool depths, and poaching. RNSP Redwood Creek surveys for summer steelhead began in 1981. Survey data indicate a continuous decline since that time. The highest total number of adult fish observed during summer surveys of portions of the mainstem of Redwood Creek was 44 (1984 and 1985). No other park streams in the Redwood Creek basin have been surveyed for summer steelhead; the smaller streams do not have pools large enough to support fish during the warm summer months

Juvenile steelhead are the most common and widely distributed fish in the Redwood Creek basin. During sampling efforts in the summers of 1980 and 1981, steelhead trout occurred in 57 of the 111 tributaries surveyed (Anderson 1988, Brown 1988). Winter stream surveys for adult spawners have been conducted along the mainstem of Redwood Creek (flows permitting), Lost Man Creek, Little Lost Man Creek, Prairie Creek, Mill Creek, and Bridge Creek.

Tidewater Goby

These small 50 mm (2 in) fish are typically found in shallow brackish water, usually less than 1 m (3 ft) deep, in loose aggregations of a few to several hundred individuals. The tidewater goby was listed as endangered in 1994 when it was believed that the species had disappeared from nearly 50 percent of the coastal lagoons within its historic range in California (USDI 1994b). The tidewater goby historically occurred in coastal brackish water habitats throughout California, but is now believed to occupy less than 5 percent of its former habitat (USDI 2002). Populations throughout the range are threatened by a variety of factors, including modification or loss of habitat due to coastal development, channelization, alteration of water flows, exotic fish introductions, and increased sedimentation and effluent caused by grazing (USDI 2002). Suitable habitat for this species includes brackish water at the upper edge of tidal bays near the entrance to freshwater tributaries and coastal lagoons. In RNSP, sites matching this description occur at Boat and Home Creeks near Fern Canyon, where Butler, Ossagon, and Johnson Creeks enter Gold Bluffs Beach, Redwood Creek estuary, and the Klamath River estuary, however, the amount of potential habitat occurring at these sites is unknown.

The current status and distribution of the species throughout all of RNSP are unknown. Presence/absence sampling was conducted annually in the Redwood Creek estuary from 1996 through 2002, and in 1998 in Espa Lagoon (RNSP 1998, Anderson 2002) and none were found. Pilot surveys using a draft protocol were conducted in Home, Butler, Ossagon, and Johnson Creeks at Gold Bluffs Beach in 2004. No gobies were detected during those surveys (Greg Goldsmith, Fishery Biologist, USFWS, personal communication). Outside RNSP, tidewater gobies are known to occur in Stone Lagoon, just south of the RNSP boundary, and in Lake Earl/Lake Tolowa, north of Crescent City. There are historic records of gobies at Freshwater Lagoon from the early 1950s (Swift et al. 1989), and five gobies were collected from the Redwood Creek estuary in 1980 (Terry Hofstra, Resource Management and Science Division Chief, RNSP, personal communication). The Redwood Creek estuary specimens are the last known captures of this species in the parks.

Due to its altered condition, Freshwater Lagoon appears to no longer provide suitable habitat for the tidewater goby. State Route 101 roadbed increased the elevation of the spit 1.5 to 4.5 m (5-15 ft) higher than the original dune crest and precludes salt water, even during storm surges with occasional overwash onto the dunes, from entering the lagoon. In addition to the change in salinity of the lagoon, it has been stocked with predatory fish species such as largemouth bass and rainbow trout. The Redwood Creek estuary was altered in 1968 with the construction of levees for flood control for Orick and surrounding agricultural lands. The levees altered circulation patterns and flow in the estuary, leading to a build-up of sediment and unhealthy estuary water quality conditions (Ricks 1995, Anderson 2002). The location where the gobies were captured in 1980 has filled in with sand and exotic reed canarygrass due to the decreased circulation. It is thought that the tidewater goby will not survive in the estuary until proper habitat has been restored (Anderson 2002). It is unlikely that the species will return to the Redwood Creek estuary without reintroduction and restoration of the estuary to its historical configuration (RNSP 1998).

Olive Ridley Sea Turtle

The Olive Ridley (*Lepidochelys olivacea*) sea turtle is typically restricted to tropical and warm temperate waters along continental margins and rarely off oceanic islands. There is one record of an Olive Ridley sea turtle from RNSP. This animal appeared on a beach near the mouth of Redwood Creek in October 1999 and was subsequently transported to Sea World in San Diego. Personnel at Sea World stated they received Olive Ridleys from as far north as Alaska that year, and suspected that individuals of this tropical species were being transported north in warm water gyres (James Wheeler, Interpreter, RNSP, personal communication).

There is a general lack of information on foraging areas and migratory habits of this species. Likewise it is not known whether the coastal waters within the boundary of RNSP provide suitable habitat, but given the propensity of this species to use warm, tropical ocean areas, it is unlikely. No nesting occurs anywhere in the United States or territories under U.S. jurisdiction (NMFS and USFWS 1998). Off of the U.S. west coast the primary threats are incidental take associated with commercial fisheries, boat collisions, gillnet entanglement, and "cold stunning" in more northern waters (NMFS and USFWS 1998).

Humpback Whale

Humpback whales are found throughout the world's oceans. Humpback whales inhabit coastal, continental shelf waters. Most humpback whales seen off the coast of northern California are likely migrating from off the coasts of Mexico and Central America to southern British Columbia where extensive feeding takes place (Steiger et al. 1991), though some feeding may occur here. Depths in the 0.4 km (0.25 mi) wide nearshore marine environment within RNSP boundaries range from about 3 to 19 m (10-60 ft). This area is probably too shallow for migrating humpbacks but may be very rarely used for feeding. There are six records of humpbacks in the RNSP wildlife observations database, distributed throughout the coastline of the park.

Current populations are a small fraction of original levels, decreased by hunting in the early years of commercial whaling. Hunting is no longer considered a widespread threat because of international protections and some stocks are increasing. Due to their preference for coastal habitat, humpbacks are currently vulnerable to many activities in the near-shore zone such as collisions with vessels, habitat degradation, pollution and entanglement in fishing gear (Carretta et al. 2002).

Steller Sea Lion

The Steller sea lion ranges throughout the North Pacific (Japan to California). Statewide in California, adults and juveniles have declined by over 50 percent between 1927 and 1990 (NMFS 1992). Reasons for the decline are unclear but substantial threats to the species include incidental catch by fisheries, competition with humans for food due to expansion of rockfish, hake, and herring commercial fishing, organochlorine pollutants, and disturbance of rookeries by humans that causes pup abandonment or entire rookeries to be permanently abandoned (NMFS 1992).

In RNSP a small colony of Steller sea lions has been regularly present on a few flat-topped rocks located about 1.6 km (1 mi) north of the Klamath River at Klamath Cove. Stack (1981) studied the Klamath Cove colony in the months of March through June in 1978 and 1979 and indicated the Steller sea lions were using the area for hauling out during “spring migration to the breeding grounds.” Griswold (1985) conducted biweekly counts of pinnipeds in Humboldt and Del Norte Counties between May 1975 and February 1978. The Steller sea lions at Klamath Cove were present in highest numbers in April and May (averaging 50 and 52 animals in each month, respectively). Steller sea lions at this site declined in June and were absent from July through March. In contrast, during those same months animals were present at Castle Rock near Crescent City, where breeding occurred. This rookery produced 10-25 pups between 1980 and 1982; and 124 pups in 1990 (NMFS 1992). In addition, Griswold (1985) reported that Redwood Creek Rock, just north of the mouth of Redwood Creek, was used by Steller sea lions for hauling out.

It now appears the Steller sea lions at Klamath Cove constitute a breeding colony. No complete census or regular surveys of this site have taken place in recent years, but in 2002 it was believed this colony consisted of three territorial males (bulls), and approximately 30 females, plus a number of immature animals (Kristin Schmidt, Wildlife Biologist, RNSP, personal communication). Roughly the same numbers of animals were present when the site was observed in April, June, and September of 2002. In September RNSP documented four females nursing young pups. The only reference alluding to possible breeding at this site in the past was in Sullivan (1980). He reported that “fresh placentas were observed in 1980 on hauling grounds near Klamath Cove…” What is interesting to note is that in other rookeries including Año Nuevo and in Oregon, territorial bulls appear to be gone by mid-late August (Orr and Poulter 1967, Mate 1973). However, in September RNSP noted what appeared to be territorial behavior on the part of the bulls at the Klamath Cove rookery. This colony warrants increased observation in the future.

Terrestrial habitat for Steller sea lions in RNSP may be limited to the area between the Klamath River mouth and False Klamath Cove, a distance of about 6.5 km (4 mi).

Numerous small, secluded beaches adjacent to large off shore rocks occur in this area. Hauling out by Steller sea lions on the Redwood Creek Rock has yet to be confirmed.. A complete assessment of all potentially available habitat (e.g., secluded beaches where human disturbance is minimal) in RNSP has not been conducted.

Beach Layia

Beach layia is a succulent annual herb, belonging to the sunflower family (*Asteraceae*). It occupies sparsely vegetated open areas in semi-stabilized fore dune and coastal scrub communities. The habitat experiences some drifting sand and has other low-growing herbaceous, perennial native species that provide protection from sand movement and erosion. Historically, beach layia occurred in widely scattered, isolated populations within eight dune systems in California (USDI 1992a). Extirpated populations at the mouth of the Little River were thought to represent the northernmost occurrence of the species until a population was discovered on Freshwater Spit in RNSP in July of 1999. After the Freshwater population was discovered, additional surveys for beach layia were conducted in all potentially suitable habitats in RNSP. No additional populations to date have been detected.

The population on Freshwater Spit is monitored and mapped annually. After four years (since its discovery) this population appears to be stable, or slightly increasing, and currently consists of four or five clusters of plants with individual plants scattered in between. Although the plant clusters shift slightly from year to year, there have not been any significant changes in location of this population on the spit since its initial discovery.

Threats to the beach layia include commercial and residential development of fore dune beach habitat. Off-road vehicle use, and trampling by equestrians and hikers may damage the fragile plant communities associated with fore dune habitats. Invasion by European Beach grass (*Ammophila arenaria*) along many beaches has caused stabilization of fore dunes. European beach grass also allows colonization of back dunes by native and nonnative plants that change the nature of the habitat from a dynamic, semi-stable system to a stable system occupied by shrubs such as coyote brush (*Baccharis puluaris*) and trees (e.g., Sitka spruce) (USDI 1992a, RNSP unpublished. data). Stochastic extinction of isolated populations also is of concern (USDI 1992a).

In RNSP, those beaches that remain year round, are not likely to be inundated during high tides, and have a dune complex provide beach layia habitat. The park currently has an estimated 267 ha (669 ac) of beach habitat that meet these criteria. Freshwater Spit and the beach north to the Redwood Creek estuary constitute approximately 31 ha (79 ac) of this habitat. The remaining potentially suitable habitat occurs north of Major Creek to Carruthers Cove along Gold Bluffs Beach, with the best potential habitat at the north end of Gold Bluffs Beach from Ossagon to Carruthers Cove. However, the widespread occurrence of European beach grass on this beach has reduced the quality of the habitat for beach layia. In places where the exotic beach grass was removed from Freshwater spit, beach layia populations have responded favorably by occupying restored areas of the beach (Leonel Arguello, Botanist, RNSP, personal communication). Projects proposed in suitable beach layia habitat are surveyed entirely prior to project implementation.

C. RESOURCE ASSESSMENT

Redwood National and State Parks are located in a relatively unpopulated, rural area, so many of the problems commonly associated with anthropogenic effects are not generally observed along the park coastline. Historically, the coastline of RNSP has been considered pristine, and consequently, an area of low priority for research and management. Much of the coastline is not easily accessible, making monitoring and research difficult, but also keeping direct human impacts low. A comprehensive study done in 1981 found the nearshore, ground and surface waters met or exceeded state water quality standards (Boyd et al. 1981). Building and development along the coastline of the park is minimal. The overall health of the coastline is good, but is influenced by surrounding land uses and human activities.

The most intensely studied coastal areas within RNSP are the two major estuaries that affect the park: the Klamath River and Redwood Creek. Both of these watersheds are of major concern because they provide critical habitat for threatened salmonid species. Both watersheds have been heavily impacted by logging-related or mining runoff. In addition, the Klamath River has been a special source of controversy between different interest groups because of the diversion of river flows for agricultural purposes that are necessary for the health of salmonid populations.

Careful monitoring, ongoing assessment, and discussion and collaboration with other stakeholders in the region are all critical to maintaining the pristine condition of the RNSP coast. Assessment of potential sources of pollutants and stressors to the biological resources of the RNSP coastline will be addressed in this section, as well as relevant regulatory legislation. A final section addressing areas for further research will follow.

C1. Air Quality Issues

In 1977, RNSP was named a Class I air quality area, receiving the highest protection under the Clean Air Act. The park is located in the North Coast Area Air Basin (Figure 34). Its coastal location, combined with prevailing northwesterly winds off the Pacific Ocean, place RNSP in a generally upwind position relative to most emission sources within the air basin. The principal air pollutants of concern are ozone precursors (nitrogen oxides and volatile organic compounds) from mobile sources and particulates from road dust, construction, slash and waste burning, residential fuel combustion, and forest fires. Sulfur dioxide emissions are relatively low in the area. The air quality related values (AQRVs) of RNSP are those resources that are potentially sensitive to air pollution and include visibility, water quality, soils, vegetation, and wildlife.

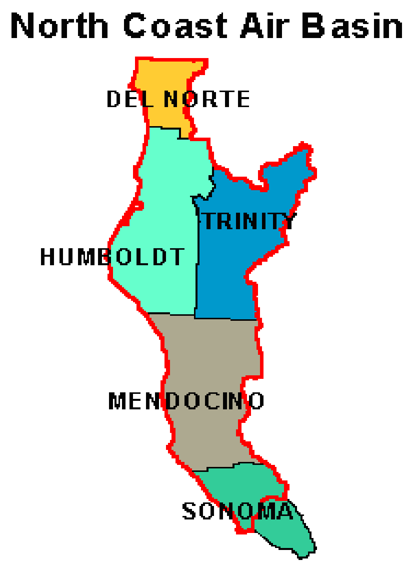


Figure 34. Map outlining the North Coast Air Basin boundaries (from http://www.arb.ca.gov/ei/maps/basins/abncmap.htm).

Visibility is a sensitive AQRV in RNSP, although visibility in the park is still superior to that in many parts of the country. Visibility is sometimes impaired by both natural factors (fog, rain, low clouds, and salt spray haze) and human-caused pollutants (particulates). The U.S. Environmental Protection Agency's Regional Haze regulations require States to establish goals for each Class I air quality area to improve visibility on the haziest days and ensure no degradation occurs on the clearest days. As part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) network, visibility in RNSP has been monitored using an aerosol sampler (1998-present) and an automatic 35mm camera (1987-1995). An Environmental Protection Agency (EPA) analysis of 1988-1997 data indicates that visibility in the park is improving somewhat on both the clearest days and the haziest days (http://www.epa.gov/air/visibility/parks/redw_t.html) (Figure 35).

Estimates of wet atmospheric deposition can be obtained from the NPS Air Atlas website, available at: http://www2.nature.nps.gov/air/maps/AirAtlas/index.htm. These estimates indicate that wet deposition rates for nitrogen and sulfur are relatively low in the park. The California Acid Deposition Monitoring Program operates samplers for wet and dry deposition at Gasquet, 10 km (6 mi) northeast of the park. For the period 1990-1998, deposition rates for nitrogen and non-marine sulfur were low. Several plant species that occur in RNSP, including Jeffrey pine (*Pinus jeffreyi*) and Douglas' sagewort (*Artemisia douglasiana*) are known to be sensitive to ozone. Ozone was monitored with a continuous analyzer from 1987- 1995. Ozone concentrations and cumulative doses were low and unlikely to induce vegetation injury (Sullivan 2001).

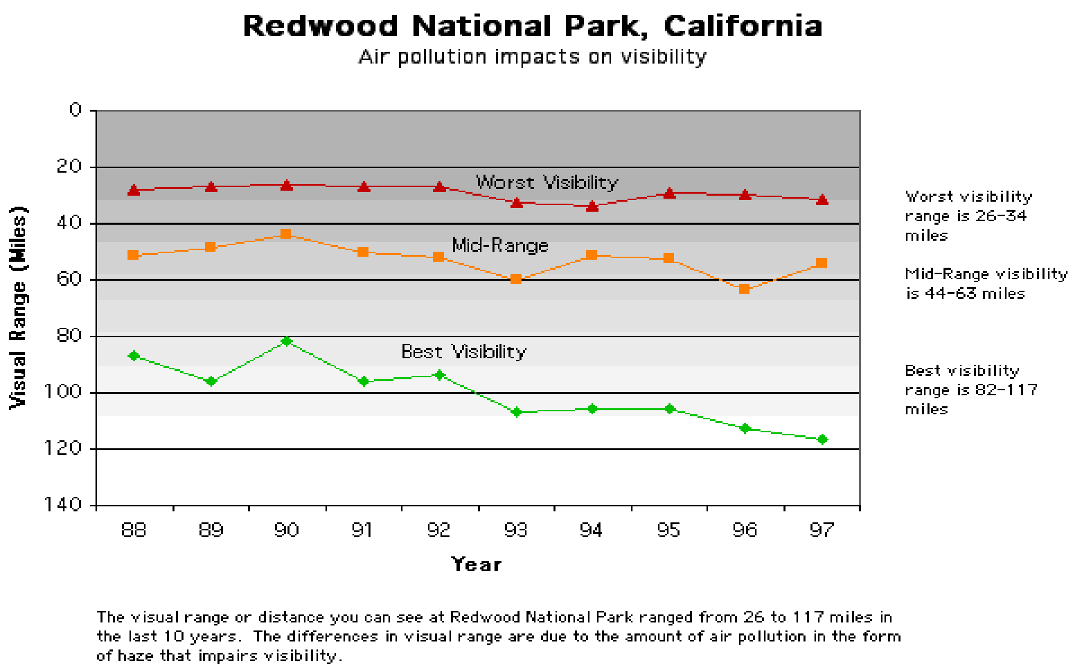


Figure 35. Visibility in RNSP from 1988-1997. Data indicate that the visibility in the parks improved somewhat on both the clearest and haziest days (from http://www.epa.gov/air/visibility/parks/redw_t.html).

It is not known if soils and vegetation in the park are sensitive to nutrient enrichment from nitrogen deposition. In some parts of the country, nitrogen deposition has altered soil nutrient cycling and vegetation species composition; native plants that have evolved under nitrogen-poor conditions have been replaced by invasive species that are able to take advantage of increased nitrogen levels. In many cases, natural inputs of nitrogen from salt spray may be important for coastal plants, such as bush-lupines. Surface waters in RNSP are moderately buffered, and may therefore be less susceptible to nitrogen input from air pollution (Stone et al. 1969).

C2. Water Quality Issues

C2a. Water Quality Monitoring

One of the main issues of concern regarding water quality monitoring is the lack of data and consistency in data collection. Current groundwater withdrawal and surface water usage data are not available through the USGS for Humboldt and Del Norte Counties, although some historical data are available (USGS 2004). Water resources data collected for Redwood Creek in 2004 include current data for sediment levels indicating that the watershed is sediment impaired (USGS 2004). There are no current monitoring data from this station for chemical parameters. Water temperature in Redwood Creek has been monitored by RNSP, in cooperation with the U.S. Geological Survey at seven mainstem sites, including the estuary and selected tributaries (Anderson, 2004). Thermal infrared imaging was conducted in 2003 to evaluate the spatial distribution of summer water temperatures in Redwood Creek (Ozaki and Anderson 2005). Stream temperature monitoring indicates that Redwood Creek is temperature impaired.

The Yurok Tribe Environmental Program developed a Water Quality Control Plan (WQCP) for the Yurok Indian Reservation, encompassing most of the lower mainstem, including the estuary, of the Klamath River. The WQCP sets forth water quality standards for surface, ground and coastal waters of the Reservation, identifies general types of water quality problems which can threaten beneficial uses occurring on the Reservation, and also sets forth an anti-degradation policy requiring existing high water quality levels be maintained. The Yurok Tribe Environmental Program, along with the Fisheries Program, is currently monitoring priority streams on the Reservation. Water reports are available at http://www.yuroktribe.org/departments/ytep/Water.htm.

C2b. Discharges and the California Ocean Plan

RNSP has been designated a State Water Quality Protection Area (SWQPA) by the State Water Resources Control Board (see also a preceding discussion under Area of Special Biological Significance). The California Ocean Plan (SWRCB 2001) prohibits discharges into SWQPAs, including point source run-off and discharge of temperature-elevated wastes.

A recent report identified discharges along the California coast (Southern California Coastal Water Research Project 2003). Discharge is defined as an anthropogenic source or location of discernable volume of water that flows or is released directly into or immediately adjacent to the marine environment of a SWQPA. An outlet is defined as any naturally occurring water body that drains into the marine environment. The RNSP SWQPA report identified 41 discharges, 27 outlets and 5 springs or seeps entering the area, however no assessment of impairment or impact to coastal or marine resources was determined.

Of the 41 discharges, 13 are within the jurisdiction of the National Park Service and the others are either California Department of Transportation (CalTrans) or California Department of Parks and Recreation responsibilities. The NPS submitted an ASBS exception application, dated May 25, 2006, to the State Water Resources Control Board. The application includes a summary of existing information about biological and physical conditions within the ASBS, available discharge data, characterization of watershed areas, treatment processes, pollution controls, and Best Management Practices.

Most of the discharge points are associated with runoff from State Route 101 and other coastal roads. Caltrans conducted end-of-pavement sampling during a storm event in April 2006, at a site located off State Route 101 near Wilson Creek Bridge, approximately 30 m (100 ft) north of mile marker 12.53 in Del Norte County. The data include chemical, bacteriological and toxicological analyses. A summary of the results are included in a letter from NPS to the SWRCB, dated October 26, 2006.

The RNSP Requa wastewater treatment facility was specifically identified by the SWRCB as a point source that is not in compliance with the Ocean Plan. The NPS has sought an exception for Requa given that the facility discharges to land and not to the ocean, flows are significantly reduced from previous levels, and the Requa facility will be closed within a few years when a new maintenance shop is constructed at Aubell.

C2c. Clean Water Act and Impaired Water Bodies in RNSP

Section 303(d) of the federal Clean Water Act requires states to identify waterbodies that do not meet water quality standards and are not supporting their beneficial uses. Each state must submit an updated list, called the 303(d) List of Impaired Waterbodies, to EPA by April of each even-numbered year. In addition to identifying the waterbodies that are not supporting beneficial uses, the list also identifies the pollutant or stressor causing impairment, and establishes a schedule for developing a control plan to address the impairment.

Placement of a water body on the 303(d) list acts as the trigger for developing a pollution control plan, or a Total Maximum Daily Load (TMDL), for each water body and associated pollutant/stressor. The TMDL serves as the means to attain and maintain water quality standards for the impaired water body. During each 303(d) listing cycle the water bodies on the list are prioritized and a schedule is established for completing the TMDLs (SWRCB 2002).

Of the three major rivers in RNSP, Smith River, Redwood Creek and Klamath River, Redwood Creek and Klamath River are listed as impaired. Redwood Creek is listed as sediment and temperature impaired in the current (2002) 303(d) report (Table 5). Multiple causes are listed for the sediment and temperature impairment including logging, road construction, range grazing, erosion, and removal of riparian vegetation. A sediment TMDL for Redwood Creek was signed by EPA in 1998. The temperature TMDL priority for Redwood Creek is listed as low.

The Klamath River has multiple temperature listings for its various reaches, but the lower Klamath reach west of Klamath Glen is listed as impaired due to temperature, low dissolved oxygen, nutrient input, and sedimentation (Table 6). Nutrient sources are from areas outside RNSP’s jurisdiction and include industrial and municipal point sources, agriculture, pasture grazing, and intensive animal feeding. Low dissolved oxygen impairment includes the same causes, as well as upstream impoundment, flow regulation, and removal of water for various reasons, including use in agriculture. Temperature impairment is caused by dam construction, habitat modification, and removal of riparian vegetation, and channel erosion. The TMDL priority is listed as medium. Water quality data for this section of the Klamath River are available in a TMDL report prepared for the EPA in 2004 (Flint et al. 2005)

Table 5. Summary of impairments in the Redwood Creek listed under the 2002 section 303(d) of the Clean Water Act (from http://www.swrcb.ca.gov/tmdl/docs/2002reg1303dlist.pdf).

Region	Type	Name	Pollutant/ Stressor	Potential Sources	TMDL Priority	Estimated Size Affected
1	**R**	**Redwood Creek, Redwood Creek Hydrologic Unit**	**Sedimentation /Siltation**	• Range Grazing- Riparian • Silviculture • Harvesting, Restoration, Residue Management • Logging Road Construction/ Maintenance • Construction/ Land Development • Disturbed Sites (Land Develop.) • Removal of Riparian Vegetation • Streambank Modification/ Destabilization • Erosion/ Siltation • Natural Sources	**Medium**	**332 Miles**
			Temperature	• Logging Road Construction/ Maintenance • Removal of Riparian Vegetation • Streambank Modification/ Destabilization • Erosion/ Siltation • Natural Sources • Nonpoint Source	**Low**	**332 Miles**

Table 6. Summary of impairments in the Lower Klamath River listed under the 2002 section 303(d) of the Clean Water Act (from http://www.swrcb.ca.gov/tmdl/docs/2002reg1303dlist.pdf).

Region	Type	Name	Pollutant/ Stressor	Potential Sources	TMDL Priority	Estimated Size Affected
1	R	Klamath River, Klamath River Hydrologic Unit, Lower HA, Klamath Glen HSA	Nutrients	• Industrial Point Sources • Major Industrial Point Source • Minor Industrial Point Source • Municipal Point Sources • Major Municipal Point Source- dry and/or wet weather discharge • Minor Municipal Point Source- dry and/or wet weather discharge • Agriculture • Irrigated Crop Production • Specialty Crop Production • Pasture Grazing-Riparian and/or Upland • Range Grazing- Riparian • Intensive Animal Feeding Operations • Agriculture- storm runoff • Agriculture- subsurface drainage • Agriculture- irrigation tailwater	Medium	609 Miles
			Organic Enrichment	• Industrial Point Sources • Municipal Point Sources • Agriculture • Irrigated Crop Production • Specialty Crop Production • Range Grazing- Riparian • Agriculture- storm runoff • Agriculture- subsurface drainage • Agriculture- irrigation tailwater • Agriculture- animal • Upstream Impoundment • Flow Regulation/Modification • Out-of-state source	Medium	609 Miles
			Low Dissolved Oxygen	• Temperature • Hydromodification • Dam Construction • Upstream Impoundment • Flow Regulation/ Modification • Water Diversions • Habitat Modification • Removal of Riparian Vegetation • Channel Erosion	Medium	609 Miles

The SWRCB added sedimentation/siltation to the 303(d) list for the lower Klamath Hydrologic Area (HA) in 2006. An exception to the listing is included and states "this approval action applies to all waters in Klamath Glen Hydrologic Subunit Area (HSA) that are under California jurisdiction, including portions of the mainstream Klamath and its tributaries within the HSA, and does not apply to other portions of waters in Klamath Glen HSA that are located in Indian country."

The smaller estuaries and streams within the park boundaries are not large enough to warrant listing under section 303(d) of the Clean Water Act, but they may still be impaired especially by sedimentation due to past logging operations and road construction. It has been recommended that the park set up monitoring protocols for determining water quality in some of these smaller watersheds, in light of evidence of potential impacts on fish, amphibians and reptiles. The NPS Klamath Network is currently finalizing a water quality monitoring protocol for all park water bodies of its six member parks including RNSP.

Public and agency comments on the 2000 General Management Plan (GMP) for Redwood National Park identified the Redwood Creek estuary as a focal point for aquatic restoration efforts in RNSP. The GMP commits the National Park Service to a leadership role in coordinating the efforts of a number of agencies and private landowners who will be involved in management and restoration of the estuary. Park staff have prepared a draft report *Strategies and Opportunities for the Restoration of Redwood Creek Estuary*, which is a revision of the 1983 plan that has guided NPS estuary management. The report outlines issues, resource conditions, and threats to the aquatic resources, and considers a series of long- and short-term actions that can improve the physical and biotic functioning of the estuary. This report presents options and perspectives for the restoration of Redwood Creek estuary, and could be used for consensus planning with other agencies and local private landowners for restoring the estuary.

C2d. Nutrients and Harmful Algal Blooms
Increases in concentrations of limiting nutrients can generate rapid increases in marine phytoplankton populations, or blooms (sometimes referred to as a red, rust, or brown tide). Increased nutrient loads in the coastal ocean may be delivered from anthropogenic sources on land, and from natural oceanographic processes such as coastal upwelling. For example, coastal winds from May through July typically have a northerly component. These winds drive surface waters offshore, allowing colder, deeper, nutrient-rich waters to surface along the coast.

Whether nutrients arrive from anthropogenic sources or natural processes, the resulting phytoplankton blooms can create significant quantities of biotoxins in the water. The problems are particularly significant when filter feeders, like shellfish, accumulate large concentrations of these toxins. Human or animal consumption of these contaminated shellfish, can lead to a variety of poisonings, including paralytic and amnesic shellfish poisoning. Occasionally, substantial fish kills may occur if the blooms are sufficiently dense. In this case, it is usually not the toxins that cause mortality, but fish gills can be clogged by plankton. In other cases, when all available nutrients are consumed by the phytoplankton and a large population die off occurs, marine bacteria consume the dead organic material causing dissolved oxygen (DO) levels to drop substantially. Such low DO levels can potentially harm or kill marine species in the coastal ocean.

The Marine Biotoxin Monitoring Program, conducted by the California Department of Health Services, monitors California's coastal waters for signs of paralytic shellfish poisoning and domoic acid, the cause of amnesic shellfish poisoning. Paralytic shellfish poisoning is caused by a dinoflagellate (*Alexandrium catenella*). These dinoflagellates are consumed by filter feeders such as mussels and clams, which accumulate biotoxins that can reach levels harmful, sometimes fatal to humans if consumed. Domoic acid is a neurotoxin associated with diatom blooms which have become increasingly common over the past 10 years. California's seabird and marine mammal populations can be seriously affected by domoic acid. At toxic levels, domoic acid can cause amnesic shellfish poisoning, which has been known to affect any fish or shellfish feeding on the diatoms. Consumption of these fish or shellfish can lead to death in seabirds and mammals (Langlois 2005).

The Marine Biotoxin prevention plan includes shellfish monitoring, monitoring of commercial shellfish, annual statewide quarantine on sport-harvested mussels, mandatory reporting of disease cases, and public education and outreach. There is one shellfish sampling site for the Marine Biotoxin Monitoring Program located in RNSP at Enderts Beach, and at nearby Clam Beach, Crescent City, and Point Saint George. Sampling includes shellfish and phytoplankton samples. Shellfish samples are analyzed for paralytic shellfish poisoning and domoic acid content. In 2005, a total of 103 shellfish samples were submitted from Humboldt and Del Norte Counties, but none tested positive (Langlois 2005). However, time and space scales of these harmful algal blooms can be sufficiently small such that measurements at these standard sites may not be representative of conditions along the RNSP coastline. Monthly biotoxin reports can be found at www.dhs.ca.gov/ps/environmental/shellfish/default.htm.

C2e. Contaminant Monitoring

The National Status and Trends (NS&T) Mussel Watch Project administered by NOAA, has monitored chemical contaminants in oysters and mussels, and in sediments since 1986. Shellfish can contain high concentrations of contaminants since they are filter feeders and can take up trace pollutants from the surrounding waters. Mussel Watch sites are selected to represent large coastal areas, and to avoid small-scale patches of contamination, or hot spots. For this reason, data can be used to compare contaminant concentrations across space and time to determine which coastal regions are at greatest risk in terms of environmental quality. Mussel Watch sites are designed to describe national and regional distributions of contamination. The data are used for determining the extent and temporal trends of chemical contamination on a nationwide basis, and identifying which coastal areas are at greater risk in terms of environmental quality.

Initially, the NS&T Mussel Watch Project based its suite of measured contaminants on an earlier EPA Mussel Watch Program and reoccupied 50 sites from that program. Presently, over 280 U.S. coastal and estuarine sites are sampled for bivalves biennially and for sediments once every decade. Non-urban sites selected for monitoring are generally 10 to 100 km (6-60 mi) apart. Bivalve and sediment samples are collected from three stations at each site (stations are generally within 100 m (330 ft) of a site center). Tissue contaminant concentrations are measured in several bivalve species. The Mussel Watch Project determines concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyl (PCB) congeners, several pesticides, butyltins, and certain toxic elements in sediment and bivalve samples from the coastal waters of the US.

One site is sampled in RNSP, adjacent to Flint Rock (station code KRFR), a solitary 53-m (175-ft) high rock 3.2 km (2 mi) south of the mouth of the Klamath River (Figure 36). The species sampled is *Mytilus californianus*. The sampling site is on the south side of Flint Rock, which is actually two large rocks. The site center is the eastern point of the northernmost rock. Discrete mussel stations are separate clusters on different sides of the rocks. No sources of contaminants were noted at this site and no analysis was done on these samples; no histology data are available. If contaminants were found in the mussels near Flint Rock, it could indicate the presence of pollution from agricultural or industrial point sources up the Klamath River, or ocean based pollutants.

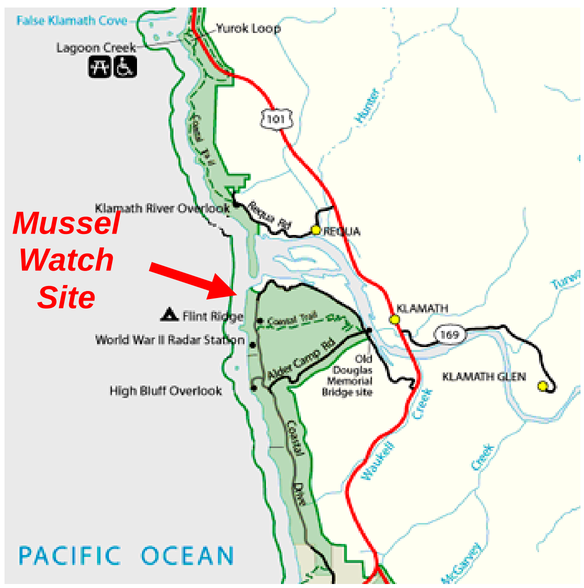


Figure 36. Location of Mussel Watch sampling site at Flint Rock Head, California (station code KRFR) near the Flint Ridge overlook and campsite (modified from RNSP Brochure).

Another site is sampled just north of RNSP, three miles south of Point Saint George. Histology and pathology data are available from 1995-2001 and no elevated contaminants were noted (Center for Coastal Monitoring and Assessment http://ccma.nos.noaa.gov/cit/data/mw_details.html).

The NS&T National Benthic Surveillance Project (NBSP) determined the status of and long-term trends of environmental quality in the nearshore waters of the United States between 1984 and 1993. The primary objective was to determine concentrations of organic and inorganic contaminants in the liver and bile of bottom dwelling fishes, and in associated surficial sediment from coastal and estuarine waters. In addition, the incidence of visible lesions was noted and histopathological examinations of selected liver, kidneys, fins, gills, ovaries, and testes were conducted. In 1987, the NBSP expanded to include measurements of biological effects due to contaminant exposure, as indicated by the prevalence of toxicopathic liver diseases. Measurements of mixed function oxygenase were used as an indicator of exposure to organic compounds and xenobiotics. The presence of DNA adducts was used as an indicator of genetic damage resulting from the interaction of xenobiotic metabolites with DNA (http://ccma.nos.noaa.gov/cit/data/bs_details.html). The closest site to RNSP where benthic surveillance data were collected is Humboldt Bay. No data are available from the Klamath River or Crescent City. It would be advantageous to include RNSP sites in more studies of this type.

C3. Biological Resource Issues

C3a Exotic Species

The term exotic is defined as a species occurring in a given place as a result of direct or indirect, deliberate or accidental actions by humans and is often used synonymously with alien, invasive, non-native and introduced. Exotic species can alter the abundance or distribution of native species, or the ecological relationships of native species. The flora of RNSP includes at least 270 exotic species, all of which entered the park and became established within the past 150 years. There is potential for many more exotic plant species to enter the park in the future, and for present populations to increase in number, area covered and density. European beachgrass, tall oat grass *(Arrhenatherum elatius*), sea fig (*Carpobrotus chilensis*), pampas grass (*Cortaderia jubata*), cape ivy (*Delairea odorata*), french broom (*Genista monspessulana*), english ivy (*Hedera helix*), Klamath weed (*Hypericum perforatum*), yellow bush lupine (*Lupinus arboreus*), garden evening primrose hybrid (*Oenothera glazioviana*), and tansy-ragwort (*Senecio jacobaea*) are all listed as high priority exotic plants for monitoring and removal within RNSP (USDI 1994a).

Removal of exotic plants is generally costly and labor intensive, but it is important to eradicate exotics especially where they affect threatened and endangered species and ecosystem function. The goal of exotic plant management in RNSP is generally eradication, if possible. When eradication is not possible, a confine and contain strategy is used to treat the edges of an infestation. Exotic plants are prioritized for management based on their threat level or invasiveness. Exotic plants that threaten a rare, or threatened and endangered, native species; threaten to hybridize with a native species to create a viable hybrid; or have the potential to seriously alter a vegetation community receive highest priority for control (Leonel Arguello, Botanist, RNSP, personal communication).

European beach grass is especially harmful to native dunemat communities. In RNSP, there are large areas of European beach grass along the beaches that alter the habitat of the federally threatened beach layia population and two sensitive plants, Wolfs evening primrose (*Oenothera wolfii*) and pink sand verbena (*Abronia umbellata* ssp. *breviflora*). After European beach grass was removed from Freshwater Spit, the beach layia population expanded. European beach grass on Gold Bluffs Beach threatens populations and habitat of a sensitive plant, the pink sand verbena. Dense European beach grass stands also eliminate areas of open sand used as nesting sites by the western snowy plover, a federally listed threatened species. From north of Redwood Creek to the southern section of Gold Bluffs Beach, beach grass is not treated because of the high level of disturbance from winter storms. On the central and northern section of Gold Bluffs Beach, removal of beach grass is concentrated at the northern end of the beach with a confine/contain strategy along the edges because of the extensive population of beach grass to the south (Leonel Arguello, Botanist, RNSP, personal communication).

Exotic marine species are not as well known within RNSP boundaries. However, a list of 95 possibly non-indigenous marine species was compiled for Humboldt Bay, 57 km (35.5 mi.) to the south (Boyd et al. 2002). The species identified ranged from vascular plants to fish, most were from various invertebrate groups. Many of the identified species were found to co-occur in both San Francisco Bay, to the south of Humboldt Bay, and in Coos Bay, to the north in Oregon. Comparing this list of non-indigenous species with park inventory lists compiled by Boyd and DeMartini (1977 and Boyd et al. 1981), Cox and McGary (2006), and observations by park staff and visitors, indicate that there is one algal species, *Sargassum muticum*, and 11 invertebrate species found in RNSP that may be exotic (Appendix A). *Sargassum muticum* is native to Japan, but has successfully colonized the Pacific coast from Baja California to British Columbia. This alga was discovered by amateur phycologist Wendell Wood in May 2006. The population seems isolated to a small area north of Wilson Creek in False Klamath Cove. A 2004 survey at Point Saint George to the north, found *S. muticum* cast up on shore (Maloney et al. 2006). It is unlikely that this population will grow quickly due to low sea water temperatures which are not optimal for growth. This population should be considered for eradication before *S. muticum* spreads to other locations in the park. Distribution, growth rates, and potential for invasion by the 12 invertebrate species are unknown at this time.

C3b.Threatened and Endangered Species

As RNSP is home to so many federal and state listed threatened and endangered species, the identification of potential stressors and determining the impact of degraded water quality should both be essential monitoring goals within the park. The Endangered Species Act of 1973 deems that all federally listed endangered and threatened species be restored to the point where they are again viable, self-sustaining members of their ecological communities. Redwood National and State Parks protect threatened and endangered species by minimizing potential disturbance to these species caused by visitor use and park management activities. Hunting is not allowed at any time within RNSP. Fishing is allowed in certain designated watercourses and in nearshore waters within the parks as regulated by the California Fish and Game Commission. Recently, the park closed beaches to off-road vehicle traffic, with the exception of commercial fishermen holding permits, and they are required to drive only on the wave slope (RNP 2000). This action will reduce disturbance to the federally listed western snowy plover and brown pelican, and other shorebirds and marine mammals. Remote areas of the park, including old-growth forest habitat, are off-limits to motorized vehicles and have controlled visitor use. Park management activities are designed to minimize noise and other forms of disturbance to breeding threatened and endangered species by implementing limited operating periods, using hand-tools instead of machinery to conduct park maintenance, and consulting with the US Fish and Wildlife Service and NOAA Fisheries on all projects that have the potential to affect federally threatened or endangered wildlife, fish, or plants.

Restoration efforts help protect, improve and restore threatened and endangered fish and wildlife habitat within RNSP. A watershed-wide erosion control and prevention program exists for abandoned and failing logging roads on both public and private lands in the Redwood Creek watershed. Removing or upgrading roads reduces the threat to water quality, aquatic habitat, and riparian areas by greatly reducing the risk of road failures and sediment delivery to streams during large storms. It also stabilizes stream banks, which allow old-growth redwood trees to remain upright and keep old-growth habitat intact for species such as the northern spotted owl and marbled murrelet. Exotic plant removal (for example, beachgrass, yellow bush lupine, and pampas grass) along beaches enhances habitat for wildlife such as the western snowy plover, which nests and roosts in the back dunes, and plants such as the endangered beach layia that requires open sand dunes to grow.

RNSP fishery and wildlife biologists conduct annual surveys to assess the status and distribution of threatened and endangered species. Specifically, fisheries biologists conduct stream inventories including snorkel surveys, electro-fishing, and seining for anadromous fish, and spawning/carcass surveys in Redwood Creek and its tributaries. Wildlife biologists monitor known northern spotted owl territories, bald eagle nests, and peregrine falcon aeries (nesting sites), and conduct monthly western snowy plover surveys.

C4. Coastal Use and Development Issues

The coastline of RNSP is one of the least developed areas of coast in California. Development is not an issue within the park itself, but adjacent to Crescent City is an active tourist destination and fishing harbor.

C4a. Population

The populations of Humboldt and Del Norte Counties are small. The population of Del Norte County in 2003 was estimated at 27,913, while Humboldt County was 127, 915. Based on census data from 1900 to 2000 (Figure 37), the population of both counties is projected to increase. The population pressures will mainly be centered in the cities of Eureka, Arcata, and Fortuna, and in the unincorporated community of McKinleyville. This might indirectly increase pressures on RNSP through increased local visitor usage. The population of Del Norte County is increasing slowly and increased water usage is unlikely to be an issue on the coast. However, groundwater withdrawals in the upper Klamath basin that occur during drought years can have a significant impact on river flows and overall water usage.

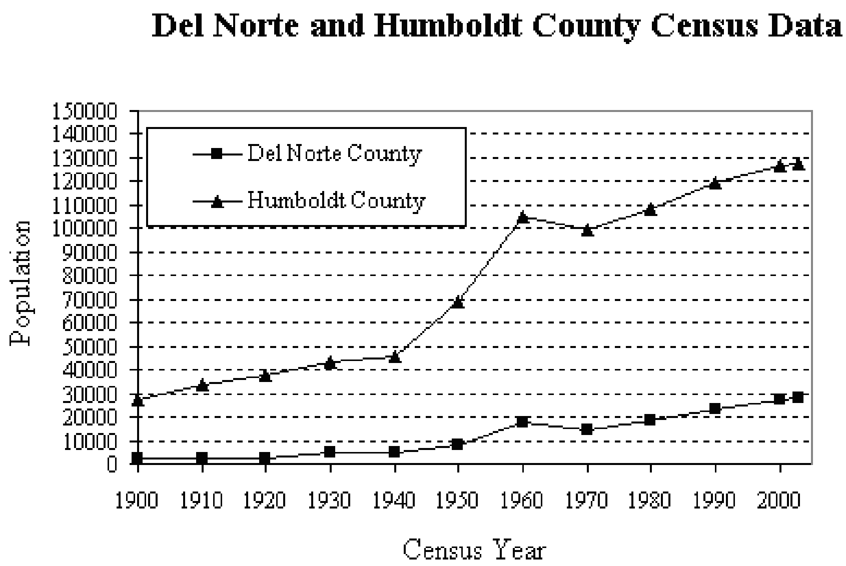


Figure 37. Census data for Del Norte and Humboldt counties from census year 1900 to census year 2000, including the 2003 census estimates (from U.S. Census Bureau http://quickfacts.census.gov/qfd/states/06000lk.html).

C4b. Land Use

Land use issues in Redwood Creek are described in detail in other watershed assessment studies or planning documents (NCWAP 2002, RCWG 2006, US EPA 1998, RNP 2000, RNP 1997). Below is a brief overview of land use issues.

Timber Harvest and Roads

As mentioned earlier, the primary single source of fresh water and sediment to the RNSP coastal zone is the Klamath River. Redwood Creek is the secondary riverine source. The major land use in the Redwood Creek watershed during the past 50 years has been timber production with associated road building. Erodible bedrock, steep terrain and episodic large floods, coupled with ground disturbance from intensive logging and road networks have caused accelerated erosion and sedimentation in Redwood Creek (Kelsey et al. 1995; Madej and Ozaki 1996). RNSP studies have shown the impact of sediment in channels can persist for decades and continues to have a profound effect on the parks' aquatic and riparian resources. While the watershed is recovering from past events, potential sediment threats from roads still exist in the basin (Madej and Ozaki 1996). Similar land use activities have occurred within the Klamath River watershed.

Roads are a major cause of accelerated erosion (Kelsey et al. 1981; Hagans and Weaver 1987; Best 1995). The erosion potential of roads is related to maintenance, location, and design (Janda et al. 1975; Best 1984; Klein 1987). Common erosion problems associated with roads include washouts and stream diversions at stream crossings, mass wasting of unstable fills and over steepened cutbanks, and interception of surface and subsurface water by cutbanks and inboard ditches.

Mining

Mining within the Redwood Creek watershed has been limited to gravel mining within the channel of Redwood Creek and rock quarries and borrow pits used for road construction. Gravel has been mined between the flood control levees, near the mouth of Prairie Creek, at the mouth of Tom McDonald Creek, and near Highway 299 (Janda et al. 1975). Gravel extraction by the Georgia-Pacific Lumber Company between 1951 and 1958 near the Tall Trees Grove totaled between 181,440 to 725,750 metric tons (200,000 and 800,000 tons) (Kelsey et al. 1979). The gravel removal at the Tall Trees Grove was not significant relative to total sediment discharge in Redwood Creek, but may have served to decrease the threat of bank erosion by lowering the channel bed locally (Milestone, J.F., Redwood National Park, written communication, 1979). During State Route 101 Bypass construction, about 317,520 metric tons (350,000 tons) of gravel was removed from lower Redwood Creek channel between the levees near Orick. To maintain levee flood conveyance, gravel is currently mined, up to an allowable 68,810 m^3 (90,000 yd^3) annually, between the flood control levees including the bars upstream of the Prairie Creek confluence.

Livestock Grazing

In other areas of the western United States, livestock grazing has been associated with increased runoff and erosion. Although similar effects may have occurred in Redwood Creek, they are probably less significant in comparison to high natural rates of runoff and erosion and the effects of logging and road building. Cattle grazing adjacent to the estuary and upstream of the park can affect the water quality in Redwood Creek and its estuary; however, both through the introduction of nutrient-rich waste and reduction of riparian shading. An accurate determination of the effects of past and present grazing would require additional research.

Watershed Restoration

The legislation expanding Redwood National Park in 1978 (PL 95-250) authorized a major watershed restoration effort. Congress directed that this work focus on minimizing erosion from past land uses, re-establishing native vegetation, and protecting aquatic and riparian resources along park streams both within and upstream of the park (Spreiter et al. 1995).

Since 1981, removal of former log-haul roads has been the primary focus of the watershed restoration efforts within Redwood National Park. About 280 km (175 mi) of logging roads have been treated since 1978. The total volume of sediment excavated from these roads is roughly 995,000 m^3 (1,300,000 yd^3). Projects have involved correction of stream diversions, excavations of stream crossings, road outsloping, removal of perched debris, road decompaction and water bar construction (Steensen and Spreiter, 1992).

In 2003, a road strategy was completed for park lands in the Redwood Creek area. The road strategy directs restoration and maintenance resources in a manner that provides long-term protection to park resources while allowing access for on-going management support, administrative programs, and research and monitoring. The strategy is an adaptive management tool and the long-term road network will be revised as information and needs change.

Private landowners are currently working cooperatively with RNSP and other agencies to minimize erosion and sedimentation from private lands in the upper basin of Redwood Creek. RNSP signed a Memorandum of Agreement with the largest timber owners who represent about 85 percent of the private lands in the basin, to work cooperatively on erosion control in Redwood Creek. Park staff work on basin-wide initiatives and projects in the upper basin to reduce sediment risks to RNSP downstream aquatic and riparian resources. In the upper basin, park staff worked with land owners to complete a road assessment on private lands. Over 1,700 km (1,100 mi) of roads exist on private lands, of which 1,200 km (725 mi) (about 65 percent) have been evaluated. RNSP is currently seeking implementation funds for road treatment projects in the upper basin.

Surface and Groundwater Withdrawal

A majority of the surface water in the North Coast Hydrographic Region (NCHR) designated by the California Department of Water Resources goes to environmental uses because of the wild and scenic designation of most of the region's rivers. Average annual precipitation ranges from 250 cm (100 in) in the Smith River drainage to 74 cm (29 in) in the Santa Rosa area and about 25 cm (10 in) in the upper Klamath drainage; as a result, drought is likely to affect the Klamath Basin more than other portions of the region. Communities that are not served by the area's surface water projects also tend to experience shortages. Surface water development in the region includes the U.S. Bureau of Reclamation (USBR) Klamath Project, Humboldt Bay Municipal Water District's Ruth Lake, and U.S. Army Corps of Engineer's Russian River Project.

An important factor concerning water demand in the Klamath Project area is water allocation for listed fish species in the upper and lower basin. For example, surface water deliveries for agriculture in 2001, a severe drought year, were only about 20 percent of normal. In 2002, more than 35,000 adult pre-spawning salmon and steelhead died in the Klamath River. Low river levels combined with elevated temperatures and higher than average incoming fish runs stressed the fish and created conditions for an epidemic spread of diseases (USFWS 2003). The September 2002 fish kill was the largest loss of pre-spawning adult salmon ever recorded in the Klamath River. Juvenile fish kills regularly occur on the Klamath River during summer low flows.

Groundwater Development

Groundwater development in the NCHR occurs along the coast, near the mouths of some of the region's major rivers, on the adjacent narrow marine terraces, or in the inland river valleys and basins. Reliability of these supplies varies significantly from area to area.

There are 63 groundwater basins/sub-basins delineated in the region, two of which are shared with the state of Oregon. These basins underlie approximately 4,100 km^2 (1,600 mi^2). Along the coast, most groundwater is developed from shallow wells installed in the sand and gravel beds of several of the region's rivers. Under California law, the water produced in these areas is considered surface water underflow. Water from Ranney collectors installed in the Klamath River, Rowdy Creek, the Smith River, and the Mad River supply the towns of Klamath, Smith River and Crescent City in Del Norte County and most of the Humboldt Bay area in Humboldt County, respectively. Except on the Mad River, which has continuous supply via releases from Ruth Reservoir, these supplies are dependent on adequate precipitation and flows throughout the season. The Orick Community Services District withdrawals 39.5 ac-ft a year (2001-2003 average) from groundwater wells near Redwood Creek in Orick (SHN 2004).

In drought years when streamflows are low, seawater intrusion can occur, causing brackish or saline water to enter these systems. In 1975, the California Department of Water Resources documented severe saltwater intrusion into the groundwater supply near the mouth of the Klamath. This has been a problem in the town of Klamath, which in 1995 had to obtain community water from a private well source. Groundwater supply is limited by the aquifer storage capacity.

Since about 1905, the USBR Klamath Project in the upper Klamath Basin has provided surface water for agricultural use, which in turn has provided water to the wildlife refuges. Since the early 1990s, it has been recognized that surface water in the Klamath Project is over-allocated, but very little groundwater development had occurred. In 2001, a severe drought year, the USBR delivered a total of about 75,000 ac-ft of water to agriculture in California, about 20 percent of normal. In the Klamath River Groundwater Basin this translated to a drought disaster, both for agriculture and wildlife refuges. In addition, there were significant impacts for both coho salmon and sucker populations in the Klamath River watershed. As a result of reduced surface water deliveries, significant groundwater development occurred, and groundwater extraction increased from an estimated 6,000 ac-ft in 1997 to roughly 60,000 ac-ft in 2001. Because of the complexity of the basin's water issues, a long-term Klamath Project operation plan has not yet been finalized. No statewide groundwater management plans are in place for Humboldt or Del Norte Counties (Figure 38).

Groundwater Quality

Groundwater quality characteristics and specific local impairments vary with regional setting within the NCHR. In general, seawater intrusion and nitrates in shallow aquifers are problems in the coastal groundwater basins. Seawater intrusions have been a problem near the Klamath Estuary. From 1994 through 2000, 584 public supply water wells were sampled in 32 of the 63 basins and sub-basins in the NCHR. Analyzed samples indicate that 553 wells, or 95 percent, met the state primary Maximum Contaminant Levels (MCL) for drinking water. Thirty-one wells, or 5 percent, sampled had constituents that exceeded one or more MCL.

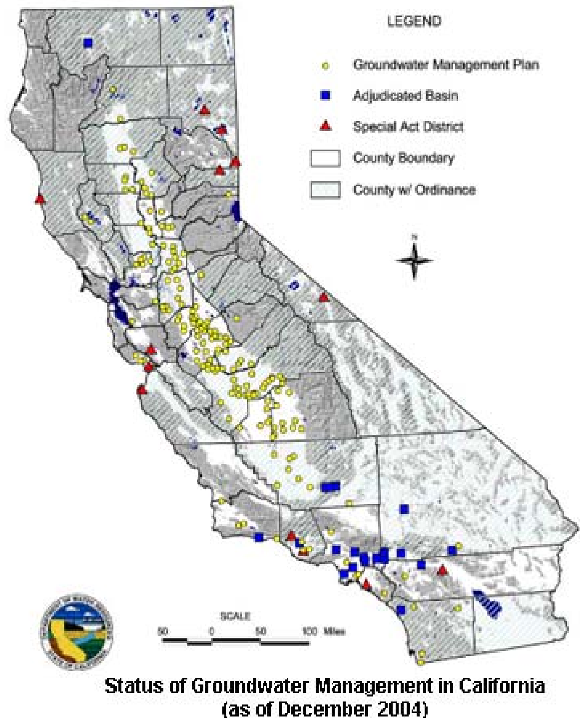


Figure 38. The status of groundwater management in California. Groundwater management plans are not in place for Humboldt or Del Norte Counties (California Department of Water Resources 2003; from http://www.groundwater.water.ca.gov/bulletin118/docs/CAgwMgmt10jan05-final.pdf).

C4c. Fishing

Recreational and commercial fishing occurs offshore, nearshore, and from the beaches of Redwood National and State Parks. The California Fish and Game Commission promulgates fishing regulations and the California Department of Fish and Game enforces all fishing regulations for sport and commercial fishing and manages the fisheries.

American Indian Fishing

The Klamath Estuary has historically been a major contributor of Chinook salmon and other economically important fish to the northern California and southern Oregon ocean salmon fishery (USFWS 1979a). Ocean and river fisheries were not being harvested sustainably at that point in time. The 1979 annual report estimated that, on average, 8.6 salmon were caught for every one that returned to the Klamath River. In 1977, the economic value of salmon and steelhead runs was reported to be $21.5 million. The passage of the Magnuson Fishery Conservation Management Act of 1976, and the establishment of the first set of federal fishing regulations, 16 U.S.C. 1801-1882, marked the beginning of American Indian fishing regulations on the Yurok Indian Reservation and the Hoopa Valley Indian Reservation in 1977. Since that time, considerable attention has focused on the ocean troll and Indian gill-net fisheries on the Klamath and Trinity

Rivers. In 1985, the Klamath River Salmon Management Group was formed to provide recommendations for the management of the combined fisheries operating on Klamath River Chinook stocks. The Yurok Tribe conducts a gill net fishery for Chinook adults within the Klamath River estuary. Klamath salmon are allocated 50:50 between the tribal share (Yurok and Hoopa Tribes) and non-tribal share (ocean commercial and recreational, and river recreation fisheries) (Pierce 1998). The fall Chinook salmon run was especially important to the Yurok and Hoopa tribes because low river flows and ample large fish contribute to high fishing returns.

Recreational Fishing

Most recreational fishing occurs on the Klamath River and its estuary, the Smith River, and Redwood Creek and is focused on salmonid species during their adult migration to upstream spawning grounds in the fall and winter. Although the fishery in Redwood Creek has been severely degraded it still supports catch and release sport fishing in the estuary and lowest reaches. Anglers can catch steelhead, Chinook salmon and coastal cutthroat trout.

Sport fishing focused on the marine environment occurs mainly from the sandy beaches near roads such as Freshwater Spit north to Redwood Creek and Gold Bluffs Beach. Hook-and-line fishing for redtail surfperch, and smelt (night smelt and surf fish) caught in A-frame dip nets or cast nets (Hawaiian throw nets) in the surf are the targeted fish. The A-frame dip net was originally used by American Indians. The sport limit for redtail perch is five with a minimum size of 27 cm (10.5 in) total length, and for surf smelt, 11 kg (25 lbs) in combination. Recreational fishing for any of the RCG Complex, referring to all species of rockfish, cabezon, and greenlings is restricted for boat-based anglers, the season closed from January to April. Shore-based anglers can fish year round. There are also seasonal and daily bag limits restrictions for lingcod.

Commercial Fishing

Historically, salmon canneries operated in the Klamath River estuary prior to 1892 and reached their peak production from 1910-1915. It is estimated that 300,000 - 400,000 salmon were harvested annually during the period from 1915-1928 (Moffett and Smith 1950). Commercial fishing was banned on the river in 1933.

There are no port facilities within RNSP boundaries. The two major commercial fishing ports north and south of RNSP boundaries, are Crescent City, 2 km (1.24 mi) to the north and Eureka, 58 km (36 mi) to the south. Trinidad, a smaller harbor without the infrastructure usually associated with a fishing port (i.e. processing plant) is 27 km (17 mi) south of RNSP. Three commercial fisheries occur within or adjacent to the quarter mile offshore boundary of RNSP; crab, commercial beach fishing for surf smelt/night smelt and redtail surfperch, and live rockfish fishery.

The area between Eureka and Crescent City, which encompasses RNSP, is considered the prime area in California for the Dungeness crab (*Cancer magister*) fishery (CDFG 2001).

Only males 16 cm (6.25 in) or larger are kept. Females are released. Fishing is conducted using baited crab pots which fish on the bottom; pots are periodically retrieved and emptied of crabs. Most crabs are caught within 5 km (3 mi) of shore in 18 – 73 m (60 – 240 ft) depth waters, but fishing also occurs in shallower waters. The commercial season begins on December 1 and ends on July 15. The season opening is sometimes delayed if the crabs are not market quality (i.e. low percentage of meat versus total weight) or the fishermen and processors have not agreed on a wholesale price per pound. It has been estimated that 80-90 percent of all available legal sized male crabs are caught. Eighty percent of the landings are made in December. Management of the fishery is based upon sex taken, length of season, and size of crab. The fishery experiences a 10-11 year cycle in population size but is considered healthy based on relatively constant landings the past 30 years (CDFG 2001). Between 2001 and 2005, landings for area ports ranged from about 764,000 kg to 8,100,000 kg (1,680,162 to 17,826,757 lbs), the majority each year landed in Crescent City (Table 7).

Within RNSP, the commercial beach fishery occurs primarily on Gold Bluffs Beach and Freshwater Spit to Mussel Point. Similar to the recreational fishery for night smelt (*Spirinchus starksi*) and surf smelt (*Hypomesus pretiosus*) (also known as day fish), the smelt are caught in A-frame dip nets in the surfzone. To find the fish, fishermen drive their trucks along the beach looking for gull and pelican feeding activity.

Night smelt are caught at night on the receding high tide while spawning on the gravel substrate. Surf smelt are larger than night smelt. They favor coarse sand and gravel for spawning and are associated with areas of freshwater seepage through the sand. In the 1990s, smelt landings at area ports averaged 360,000 kg per year (800,000 lbs per year), 550,000 kg (1.2 million lbs) between 1994 and 1996. Little is known about the status of either population, but because of their short life cycles, any excessive fishery has the potential to cause the population to plummet in two to three years (CDFG 2001). Combined smelt landings for area ports for 2001 to 2005 ranged from 128,000 kg (218,043 lbs) in 2005 to 178,000 kg (390,720 lbs) in 2003 (Table 7). Price per pound ranged from 25 to 35 cents. In 2005 the Eureka/Crescent City area commercial beach fishery accounted 99.1 percent of the night and surf smelt landed in California.

Redtail surfperch (*Amphistichus rhodoterus*) are also caught from the beaches, but with hook-and-line. The commercial fishery is open from August 1 to April 30. Ninety-nine percent of the state landings are landed between Eureka and Crescent City. There are no estimates of stock size. The commercial catch decreased from the 1970s to the 1990s; average fish weight decreased over 30 years suggesting a decrease in the population (CDFG 2001). The recreational catch declined 78 percent between 1981-1989 and 1993-2001 (CDFG 2004a). Redtail landings for Eureka area ports for 2001 to 2005 ranged from 7,100 kg (15,676 lbs) in 2001 to 12,500 kg (27,480 lbs) in 2002. For the same period the redtail surf fishery accounted an average of 98.7 percent of the redtail surfperch landed in California (Table 7).

Black rockfish (*Sebastes melanops*) are a commercially important nearshore fish. Prior to the recent fishing restrictions imposed because of low population numbers, 88,000 kg

(192,728 lbs) of black rockfish were landed in 2002 at ports (Eureka, Trinidad, and Crescent City) located north and south of RNSP. The black rockfish landed accounted for 95 percent of all black rockfish landed in the state of California. The live black rockfish fishery, fish caught in shallow nearshore waters and transported live to be sold in the Asian markets of the San Francisco Bay Area, occurs in the area. The extent of this fishery within the park's boundary is not known. The park was not aware of the full significance of the nearshore finfish fishery until a truck that originated in Crescent City and destined for San Francisco went off the road in the park. The truck was loaded with a ton of live rockfish (which died). The driver told park personnel they made several trips a week to supply the live-fish market in the Bay Area.

Table 7. North coast commercial landings (pounds) for years 2001 through 2005 of Dungeness crab, night smelt, surf smelt, and redtail perch at the ports of Crescent City, Trinidad, and Eureka, and combined for all Eureka Area Ports. The percentage of the Eureka Area Ports landings compared to all landings in California for each particular species is also listed (from CDFG 2004).

North Coast Commercial Crab and Fish Landings (Pounds)					
Port/Year	**2001**	**2002**	**2003**	**2004**	**2005**
Dungeness Crab					
Crescent City	1,112,953	1,635,003	9,445,871	10,936,678	2,844,169
Trinidad	216,316	311,754	1,763,985	1,704,624	618,249
Eureka	336,559	795,493	5,212,670	5,117,780	1,675,575
All Eureka Area Ports	**1,680,162**	**2,822,421**	**16,672,145**	**17,826,757**	**5,157,001**
Eureka Area/CA %	47.5%	38.7%	74.7%	71.7%	48.0%
Night Smelt					
Crescent City	68,998	36,356	67,141	11,848	4,371
Trinidad	0	1	0	57	0
Eureka	114,161	139,388	153,934	213,264	164,243
All Eureka Area Ports	**183,159**	**182,337**	**221,075**	**225,167**	**168,614**
Eureka Ports/CA %	94.2%	92.8%	98.1%	97.1%	98.9%
Surf Smelt					
Crescent City	2,136	0	71,978	916	1,214
Orick (2004 only)	-	-	-	7,148	-
Trinidad	8,645	0	0	0	0
Eureka	116,501	129,528	97,667	104,316	48,015
All Eureka Area Ports	**127,282**	**131,738**	**169,645**	**112,380**	**49,429**
Eureka Ports/CA %	93.6%	98.4%	99.4%	98.2%	99.8%
Total Smelt					
Eureka Area Ports	**310,441**	**314,075**	**390,720**	**337,547**	**218,043**
Redtail Surfperch					
Crescent City	2,938	2,297	19,916	658	29
Trinidad	8	0	0	0	0
Eureka	12,080	24,610	8,821	22,398	27,191
All Eureka Area Ports	15,676	27,480	26,737	23,195	27,176
Eureka Ports/CA %	96.4%	98.5%	99.4%	99.4%	99.8%

C4d. Marine Protected Areas

Marine Protected Areas (MPA) are being established throughout the United States since Presidential Executive Order 13158 was signed in May 2000. The legislation mandates that federal agencies work closely with states to create a national system of MPAs (MPA 2005; http://www.mpa.gov/). The National Marine Protected Areas Center was established within the US Department of Commerce's National Oceanic and Atmospheric Administration. The National MPA Center coordinates closely with the National Park Service, Minerals Management Service, US Geological Survey and the US Fish and Wildlife Service. A marine managed areas inventory (MMA) is being compiled to develop a comprehensive picture of the nation's marine managed areas. The MMA inventory will be used as a resource to find sites that will be considered for placement on a list of MPAs. Redwood National and State Parks has been included in the MMA inventory as well as Pacific Whiting Klamath River Salmon Conservation Zone (Figure 4) which is located offshore of RNSP, and Castle Rock, a small island off the coast north of RNSP. The proposed MPA listing of RNSP is still in a preliminary stage and does not have direct effect on current management plans within the park, although it will probably result in more emphasis being placed on marine monitoring in the future.

In response to dwindling West Coast rockfish populations, state and federal agencies have instituted restrictions and quotas. To protect and manage what is left of the populations, the California State Legislature in 1999 passed the Marine Life Protection Act and the Marine Life Management Act; laws designed to ecologically and economically sustain marine resources.

The Marine Life Protection Act directed the state to standardize and redesign the present state marine protected areas system. It will set aside part of California's coastal waters as MPAs to help rebuild depleted marine populations and to conserve and sustain marine populations and ecosystems. One of their functions is to protect dwindling stocks of rockfish. There are three types of MPAs: reserves (no-take), marine parks (recreational fishing only), and conservation areas (restricted recreational and commercial fishing). In the initial draft, several areas adjacent to and partially within the parks were proposed. Since then, CDFG has elected a regional approach in the process to setting aside areas. Marine protected areas have been set aside in Channel Islands National Park and along the Central Coast of California. In 2006, CDFG announced the next region to be assessed is the North Central Coast, from Pigeon Point to Point Arena, a reach encompassing south and north of the San Francisco Bay Area. The last region assessed will be the North Coast. Marine protected areas are a very contentious issue among commercial and recreational stakeholders; they suggest that the present myriad of regulations for various species that restrict seasons and areas, bag and trip limits, size limits, and equipment already act as *defacto* marine protected areas.

The Marine Life Management Act applies not only to fish and shellfish taken by commercial and recreational fishermen, but to all marine wildlife. It is meant to protect marine fish populations and ensure sustainable fisheries. The first fishery management plan to be developed was the Nearshore Fishery Management Plan to regulate fishing for 19 nearshore finfish species, including 13 rockfish. The plan manages the fishery through harvest control rules that include regional management, restricted access, allocation between the commercial and recreational sectors, and MPAs.

The long-term impact of the fishing industry to the parks' nearshore fishery resources is unknown, but designated MPAs and implementation of the Nearshore Fishery Management Plan should help to protect these resources from overexploitation.

C4e. Marine Vessel Impact

There is a considerable amount of commercial ship traffic off the RNSP shoreline. Oil tanker traffic offshore of the parks from Alaska to refineries in California as well as non-tanker vessels carrying bunker fuel; 3,658 vessels passed between July 1998 and June 1999 (Pacific States/British Columbia Oil Spill Task Force 2002). One hundred and sixty of those vessels entered Humboldt Bay. Closer to the park coast, commercial fishing vessels are fishing offshore of the parks. The coastline is also difficult to navigate due to fog and numerous offshore rocks, hence ship wrecks and oil spills are a definite possibility. Most experts agree it is not a question of whether, but rather when, a future spill will occur. In the space of five years, oil spills from two ship accidents occurring in and off of Humboldt Bay, 80 km (50 mi) south of the park, have come ashore on park beaches killing birds. If another oil spill were to occur on the RNSP coast, it would likely injure or kill numerous sea birds and mammals, including threatened and endangered species such as the marbled murrelet and the Steller sea lion. Invertebrate and algal communities would likely be adversely affected as well.

Marbled murrelets are particularly at risk from an oil spill occurring in RNSP. The park is home to a significant portion of California's marbled murrelets. These birds spend considerable time foraging in the nearshore waters of the park. Contact with floating oil would coat feathers and skin. As a result, birds may also ingest oil during preening and inhale fumes. Oil spills would likely lower already declining populations (McShane et al. 2004).

Currently, monthly carcass surveys are being conducted by RNSP staff, in part to search for oiled birds or mammals. These surveys aid managers in assessing the mortality that might be caused by an oil spill and contrast the oil-caused mortality with background mortality rates. RNSP beach carcass surveys noted oil contamination in 1997, but oil has not been found on specimens for several years (Holm 1997-2001). Beach carcass surveys are conducted at least 8 times per year (usually once per month) and have been ongoing since 1997 along Gold Bluffs Beach and other beaches within RNSP. These surveys act as a good indication of background levels of contaminants. Ongoing intertidal monitoring is an important method for managers to use for assessment of the damage and recovery status of these communities if an oil spill were to occur. Potential sources of pollution within the park are limited, however nearby industrial sources, highway tanker accidents, as well as the Klamath River are potential sources of pollutants that could negatively affect marine birds and mammals. As was discussed previously, the Klamath River is on the list of 303(d) impaired waterbodies.

C5. Status of Klamath River and Redwood Creek Estuaries

C5a. Water Quality of the Klamath River Estuary

Although the western part of the Klamath River estuary is within RNSP boundaries, it is also within reservation boundaries of the Yurok tribe. The most current water quality and fish stock management data were prepared in a report by the Yurok Tribal Fisheries program for the California Department of Fish and Game in 2004. The California Department of Fish and Game and the US Fish and Wildlife Service also have a role in monitoring activities in the estuary.

This area experiences tidal fluctuation of up to 2 m (6.5 ft) and brackish water 15-30 ppt is present along the bottom May through October. A layer of freshwater 1 to 2 m (3-6 ft) thick is found along the surface of the water column throughout the entire estuary.

The completion of the Trinity River Division of the Central Valley Project in 1963 resulted in an annual diversion of about 1,279,000 ac-ft of Trinity River water. This water is diverted for use in the Sacramento and San Joaquin valleys. About 10 percent of the annual mean runoff for fisheries use was left in the post-project Trinity River. Due to high rainfall this did not immediately significantly affect flows in the lower Klamath River, but it did result in the loss of 59 miles of Chinook salmon spawning and nursery habitat and earlier and more rapid warming of downstream waters during the summer months.

In 2002, approximately 35,000 Klamath River adult fish died because of the fish pathogens, Ich (*Ichthyophthirius multifiliis)* and Columnaris (*Flexibacter collumnare*), of which 97.1 percent were fall-run Chinook salmon. This outbreak of disease has been attributed to low water flows and warmer than normal waters, resulting in crowding and transmission of disease (USFWS 2003).

C5b. Population Trends in Anadromous Klamath River Species

Federal and state governments have recognized the importance of protecting and enhancing fishery resources of these rivers by enacting legislation. In 1984, Congress passed the Trinity River Basin Fish and Wildlife Management Act, P.L. 98-541. The intent of this act was to restore anadromous fish populations of the Trinity River system. The program, which was originally authorized for 10 years, has been reauthorized for several additional years. Concomitant to P.L. 98-541, Congress enacted P.L. 99-552, the Klamath River Basin Fishery Resources Restoration Act, on October 27, 1986. This action authorized the Secretary of the Interior to restore the anadromous fish populations to optimum levels, in both the Klamath and Trinity Rivers, through a 20-year habitat restoration program. AFWO conducts fishery related studies through the auspices of both restoration acts in the Klamath River Basin through an annual proposal process. These efforts focus on the monitoring and evaluation of wild and hatchery anadromous stocks and their habitats.

From 1998-2003, the Natural Stocks Assessment program run by the California Department of Fish and Game looked at hatchery to natural fish ratios and relative size of salmon runs as well as flow conditions and the incidence of disease. Chinook salmon of natural origin ranged from 34-87 percent of the annual catch, coho salmon were mainly from the Trinity River hatchery and steelhead were over 90 percent natural in origin. In 2001, rearing conditions were poor and Chinook and coho runs were quite small.

The following section provides a brief synopsis of the population trends for coho and Chinook salmon, steelhead, coastal cutthroat trout, green (and white) Sturgeon, eulachon and pacific lamprey within the Klamath River Basin.

Coho Salmon

At present, west coast coho populations are substantially lower than historical population levels at the turn of the century and are listed as threatened under the ESA. NOAA Fisheries estimated that at least 33 populations are at moderate to high risk of extinction. Coho populations within the Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU), which includes the Klamath River Basin (Figure 32), are severely depressed: within the California portion of the ESU, approximately 36 percent of coho streams no longer have spawning runs (NMFS 1998). In 1983 annual spawning escapement to the Klamath River system was estimated to range from 15,400 to 20,000. These estimates, which include hatchery stocks, could be less than 6 percent of their abundance in the 1940s and populations have experienced at least a 70 percent decline in numbers since the 1960s (CDFG 1994a). Coho returns monitored at the Iron Gate Hatchery have ranged from zero fish in 1964 to 2,893 fish in 1987 and are highly variable. Based on limited monitoring data from the Shasta River, coho returns have been variable since 1934 and show a great decrease in returns for the past seven years.

Chinook Salmon

The total annual catch and escapement of Klamath River Chinook salmon in the period between 1915 and 1928 was estimated at between 300,000 and 400,000 (Adair et al 1982). The annual average Chinook runs reported in 1960 ranged from 100,000-125,000 adults (USFWS 1960, 1979b). In 1976, the California Department of Fish and Game conducted a beach seining and tagging effort to determine size of returning sea-run fish populations to the Klamath River system. The 1976 fall Chinook salmon run was estimated at 194,000 but the 1978 run was unusually small, just 101,000 fish based on tagging data. Between 1978 and 1995 the average annual fall Chinook escapement, including hatchery-produced fish was 58,820 with a low of 18,133 (CDFG 1996). Overall, fall Chinook numbers declined drastically within the Klamath Basin during the 20th century. Spring Chinook runs appear to be in remnant numbers within the Klamath River Basin and have been completely extirpated from some of their historically most productive waters, such as the Shasta River (Klamath River Task Force [KRTF] 1991).

Steelhead

Run sizes prior to the 1900s are difficult to ascertain, but were likely to have exceeded several million fish. This is based on the descriptions of salmon runs near the turn of the century provided in Snyder (1931). Monitoring of adult steelhead returns to the Iron

Gate Hatchery has shown wide variations since monitoring began in 1963. However, estimates during the 1991 through 1995 period were extremely low and averaged only 166 fish per year compared to an average of 1,935 fish per year from 1963 through 1990 (Hiser 1994). In 1996, only 12 steelhead returned to Iron Gate Hatchery. NMFS considered that based on available information, Klamath Mountain Province steelhead populations were not self-sustaining and if present trends continue, there is a significant probability of endangerment (NMFS 2002). However, steelhead were not listed under the ESA.

Coastal Cutthroat Trout

Coastal cutthroat trout are known to be distributed throughout the lower Klamath River tributaries but their population status and distributions are poorly known. It is believed that coastal cutthroat trout enter the Klamath River November through March and spawn in the spring. Juveniles may rear for up to two years in either streams or the estuary before migrating to the ocean. Collections from the estuary, lower tributaries, and Hunter Creek are documented (KRTF 1991).

Green (and White) Sturgeon

Both white and green sturgeons are found in the Klamath River; the green sturgeon the more abundant of the two. The white sturgeon periodically migrate up the Klamath River (KRTF 1991). Green sturgeon typically enter the Klamath River in late February and may continue to do so through late July. Although sturgeon have been observed as far upstream as Iron Gate Dam they typically do not migrate above Ishi Pishi Falls on the main stem Klamath. Migrating sturgeon also utilize the Trinity, South Fork Trinity, and lower Salmon River. Spawning typically occurs during March to July with peak spawning occurring during April, May to mid-June. Emigration of post spawning adults generally occurs throughout the summer and fall with peaks in August and September. Out migration of sturgeon juveniles may occur when they are less than one year old or as mature as two years old. Out migration begins in the upper reaches of the basin as early as July while peaking in September in downstream areas.

The northern distinct population segment (DPS), those green sturgeon populations of the Eel River and north, were not warranted for listing in 2006, but remain a species of concern and will be reviewed every five years. Sport angling is prohibited on green sturgeon.

Eulachon (Candlefish)

Eulachon are thought to be extremely rare or extirpated in the Klamath River. Historical data suggest they spawned in the lower 8 - 11 km (5 - 7 mi) of the Klamath River during March and April. Eggs incubated for approximately two to three weeks and the larvae then migrated back to the ocean (KRTF 1991).

Pacific Lamprey

The distribution of lamprey in the Klamath River is very poorly known. Nothing is known about the abundance of this species, nor of other lampreys endemic to the upper Klamath River drainage (CDFG 2006). Lamprey have been observed on salmon at the Klamath River Racks (a weir five miles below what is now Iron Gate Dam) and they have been collected from Cottonwood Creek near Hornbrook. They may represent a non-anadromous form in the Klamath Basin. Lamprey have also been observed in the Trinity River and dwarfed landlocked forms have also been reported from the Klamath River above Iron Gate Dam and in Upper Klamath Lake. Lamprey are also suspected of utilizing the Scott, Shasta, and Salmon Rivers (KRTF 1991).

Current Anadromous Salmonid Distribution

At present, habitat of anadromous salmonids is limited in the Klamath River Basin to the main stem and tributaries downstream of Iron Gate Dam. Upstream distribution in several of the tributaries (e.g., Trinity River) has also been limited due to construction of dams and diversions. Access to the Upper Klamath Basin by anadromous species was effectively stopped with the completion of Copco Dam No. 1 in 1917 although reduced access to tributaries in the Upper Klamath Basin likely occurred starting as early as the 1912-1914 period with construction of the Lost River diversion canal and completion of Chiloquin Dam. Access to the upper reaches of the Trinity River and its tributaries were blocked in 1961 with completion of Lewiston Dam. The final reduction in upstream main stem habitat access occurred in 1962 with the completion of Iron Gate Dam downstream of Copco No. 1 and 2 Dams (KRTF 1991).

C5c. Factors Contributing to the Decline of Anadromous Species in the Klamath River

The decline of anadromous species within the Klamath River Basin can be attributed to a variety of factors which include both water diversion and non-flow factors. These include over harvest, affects of land-use practices such as logging, mining, stream habitat alterations, and agriculture (KRTF 1991; Hiner and Brown 2004). Other important factors have included climatic change, flood events, droughts, ENSO events, fires, changes in water quality and temperature, introduced species, reduced genetic integrity from hatchery production, predation, disease, and poaching. Significant effects are also attributed to water allocation practices such as construction of dams that blocked substantial areas from upstream migration and altered flows in the timing, magnitude, duration and frequency in many stream segments (KRTF 1991).

The Klamath basin has two major mitigation hatcheries operated by the CDFG, which release between 5 and 10 million juvenile Chinook annually. The hatchery fish may compete with the wild fish for food and resources. It is possible that the carrying capacity of the estuary can be reached in terms of food availability and that large hatchery releases could exacerbate the problem.

Water quality monitoring in the estuary was conducted by the California Department of Fish and Game from 1991-1994. Detailed results are available but, in general, dissolved oxygen concentrations were adequate to support salmonids but water temperatures were elevated June through August. Water quality was monitored by Yurok tribe fisheries employees (Hiner and Brown 2004).

C5d. Modifications to Redwood Creek Estuary and Effects on Salmonids

Redwood Creek estuary and lower river has been the subject of several modifications that have impacted its role as anadromous salmonid habitat. The construction of flood-control levees and the removal of riparian vegetation have had dramatic effects on the morphology and function of the estuary. The flood-control levees are 5.1 km (3.4 mi) long, stretching from about 2 km (1 mi) upstream of the town of Orick, downstream to about 305 m (1000 ft) from the beach. The earthen embankments on both sides of the river are armored with rip-rap, with some limited thickets of willow and alder along the waters edge. A few gravel bars have developed between the levees that also support stands of vegetation (Anderson 1988, 2003).

Historically, the estuary was quite different than its current condition; the channel was deeper and wider and much more diverse and complex. The levees cut off the last meander of Redwood Creek, now called the South Slough, and isolated the North Slough, reduced the size of the estuary and changed the circulation patterns. One result was that the fish rearing area of the estuary was reduced by as much as 50-75 percent (Ricks 1983). The reduction in size also reduced the tidal prism. In the isolated sloughs, water quality is poor and is marginal for salmonids.

The removal of riparian vegetation also resulted in less in-stream shelter and shade to help keep water cool and coupled with the changes in circulation have produced generally higher water temperatures. These changes along with the general reduction in habitat area, complexity and cover significantly reduced the capacity of Redwood Creek estuary to support juvenile salmonids (Anderson 2003). The limited capacity for juvenile Chinook in the Redwood Creek estuary is a limiting factor for the recovery of the species.

A number of recent studies have been conducted by RNSP staff to develop a set of alternatives to improve the conditions in the estuary. The current state of the issue is documented in the Redwood Creek Integrated Watershed Strategy Report (RCWG 2006).

C5e.Population Trends in Anadromous Redwood Creek Species

Redwood Creek Chinook and coho salmon, steelhead, and coastal cutthroat trout are present but in low numbers when compared with historical accounts (See section B4H for further discussion). The most recent data show some declines and increases in salmonid numbers in Redwood Creek. Data from downstream migrant trapping of juvenile salmonids (2000 to 2006) on Redwood Creek show a negative trend in numbers and is statistically significant for year old steelhead smolts (Michael Sparkman, Fishery Biologist, CDFG, personal communication). On Prairie Creek, Chinook salmon have declined from over 400 adults in early 2000, to 10 to 15 adults the past two years (2005-2006), but coho salmon adults have increased from fewer than 60 in the late 1990s to about 450 adults at present (Walt Duffy, Fishery Biologist, California Cooperative Fish Research Unit at Humboldt State University, personal communication).

Resident coastal cutthroat trout are present in the mainstem and tributaries. Another life cycle component, those cutthroat that migrate to the estuary as adults are present in small numbers. RNSP fisheries monitoring which began in 1980 have not detected eulachon, though historically they were once abundant and spawned several kilometers upstream of the mouth.

C5f. Factors Contributing to the Decline of Anadromous Species in the Redwood Creek.

Present aquatic habitat and riparian problems observed in Redwood Creek are typical of many north coast streams. Unlike the Klamath River, there are no dams or major water diversions on Redwood Creek, but landuse activities are similar. Legacy effects from past floods and landuse have severely altered the instream habitat utilized by anadromous salmonids. Excess sediment delivered to Redwood Creek have aggraded channels, caused streambank erosion, channel widening, loss of pools and habitat diversity, loss of riparian shade, and increased stream temperature (NCWAP 2002). Past harvest of streamside trees coupled with streamside landslides and bank erosion have also resulted in low recruitment potential of large woody debris to Redwood Creek, and it appears that there is a deficit of large woody debris for channel maintenance, instream fish cover and nutrient cycles in the near term (NCWAP 2002). While Redwood Creek is recovering from past events, channel studies have shown that even moderate floods (recurrence interval < 10 years) have set back channel recovery trends (Mary Ann Madej, Research Geologist, USGS, personal communication). Channel response and impacts to aquatic habitat from the next large flood remains uncertain.

Summer water temperatures in Redwood Creek are recovering and maximum water temperatures are lower than the extremely high temperatures recorded in the mid to late 1970s (maximum water temperatures higher than 30°C). However, summer water temperatures are not optimal for rearing juvenile salmonids and adult summer steelhead. A juvenile steelhead fish kill associated with extremely high summer water temperatures was observed in 2006 (Michael Sparkman, Fishery Biologist, CDFG, personal communication). High summer water temperatures also appear to be a factor in restricting juvenile coho to one-fifth of their historical range in mainstem Redwood Creek (Madej et al. 2006).

High sediment loads and high stream temperatures continue to affect anadromous salmonids species spawning and rearing in the creek. As a result, Redwood Creek remains listed as sediment and temperature impaired under the Clean Water Act 303 d list. In addition, the loss of a naturally functioning estuary, poor habitat conditions and water quality significantly reduces the carrying capacity of the estuary which continues to impede salmonid production in the Redwood Creek basin (NCWAP 2002).

Another factor affecting anadromous salmonids in Redwood Creek includes hatchery influences. The Prairie Creek hatchery closed in 1992 and ended over a hundred years of some type of hatchery operations in the watershed.

All these factors have affected salmon and steelhead populations in Redwood Creek and contributed to the decline and resultant federal listing of three out of four salmonid species.

D. Conclusions and Recommendations

D1. Current Level of Knowledge and Identification of Data Gaps

The current state of knowledge for the coastal and marine resources within RNSP has been summarized above. The remote nature of much of the marine parklands has resulted in limited use of much of the coastal section of RNSP. Concomitantly, the remoteness has also resulted in limiting the amount of comprehensive research that has been conducted addressing the parks' marine resources.

After examining the climatic, hydrologic and physical settings of the northern California coast, it is apparent that a number of threats exist for the potential impairment of coastal water resources in RNSP. The sporadic nature of the research that has been conducted in the RNSP coastal ocean makes it difficult, in many cases, to assess the potential threats. We have summarized the primary threats that have been identified and used our best judgment to rank the potential threats. Table 8 characterizes the potential threats using the information summarized above (current stressors are in red).

Many of the recommendations that follow focus on the need for more comprehensive baseline information. In a number of cases, the recommendations rely on more intensive research that has been conducted either north or south of the Park. The timing of the current considerations for future work is quite good, as a number of marine monitoring efforts are currently being considered for the U.S. Pacific coastal ocean that includes the RNSP coastline. These opportunities are identified below.

D1a. Physical Oceanographic Processes Directly Influencing the RNSP Coast

Much of our understanding of coastal ocean conditions and flows near RNSP is based primarily on knowledge of the general ocean circulation of the coastal eastern Pacific. There is currently a fair understanding of the basic oceanographic processes that occur offshore of the study area. These processes have been better studied to the north, and to the south of RNSP. It is fairly well understood that coastal circulation is greatly influenced by local and regional wind fields and circulation is variable over seasonal time scales. The impact of longer-term variability, including El Niño/La Niña events and the Pacific Decadal Oscillation (PDO) is much less understood. These events have been observed to have a direct impact on the coastal biological community in areas to both the north and south and they undoubtedly have an impact on the RNSP marine resources as well.

Included among the effects that result from El Niño, La Niña and the PDO are the variations in wave climate that impact the coast as a result of the shifting storm patterns. The wave heights, wave periods and the direction of wave approach have been observed to change during these events and much of the coastal erosion and modification appear to be correlated with these events. The direct impact of coastal erosion on intertidal and subtidal communities has been observed elsewhere, but the impact within RNSP has not been examined in detail. It is important to understand these processes because these are the mechanisms which will cause change in biological systems, move stressors from place to place, and change habitats. Included among the range of potential effects are events such as the hypoxic (low oxygen) water conditions that were observed off coastal Oregon, which resulted in massive die-offs of fish and invertebrates.

Table 8. Summary of current and potential stressors and their effects on the nearshore/ estuary/coastal environments of Redwoods National & State Parks.

Indicator	Nearshore	Klamath River Estuary	Redwood Creek Estuary	Coastal Zone (Upland)	Coastal Lagoons
WATER QUALITY					
Temperature	**OK**	**EP**	**EP**	N/A	**OK**
Dissolved oxygen	**PP**	**EP**	**EP**	N/A	**EP**
Nutrients	**OK**	**EP**	**OK**	N/A	**EP**
Suspended Sediment	**OK**	**OK**	**EP**	N/A	**OK**
Contaminants	**OK**	**OK**	**OK**	N/A	**OK**
Pathogens	**OK**	**IP**	**OK**	N/A	**OK**
WATER QUANTITY					
Altered Flow	N/A	**EP**	**OK**	**OK**	**OK**
Hyperpycnal Plume	**IP**	N/A	N/A	N/A	N/A
HABITAT DISRUPTION					
Development / Land Use	**OK**	**EP**	**EP**	**OK**	**OK**
Erosion / Sedimentation	**OK**	**EP**	**EP**	**OK**	**ID**
Salmonid spawning habitat degradation	N/A	**EP**	**EP**	N/A	N/A
Channel Modifications	N/A	**EP**	**EP**	N/A	**EP**
BIOLOGICAL					
Salmonid Population Decline	**EP**	**EP**	**EP**	N/A	N/A
Harmful Algal Blooms	**IP or ID** See below	N/A	N/A	N/A	**ID**
Invasive Species	**PP**	**PP**	**PP**	**EP**	**EP**
OTHER					
Climate Change	**PP**	**PP**	**PP**	**PP**	**PP**

Legend: OK = low or no problem IP = intermittent problem EP = existing problem
PP = potential problem ID = insufficient data to evaluate N/A = not applicable
Shading indicates judgment was made on limited data

D1b. Riverine Influences on Marine Resources

The influence of large sources of fresh water on marine systems has been examined in a number of locations nationwide. However, a comprehensive study examining the influence of fresh water input on RNSP marine resources has not yet been conducted. The Klamath River is the largest river in RNSP. It discharges to the coast in the approximate center of the RNSP coastline. The second largest freshwater source is Redwood Creek. Its watershed has been studied in much greater detail; many of the impacts of modifications to the watershed have been documented. The numerous smaller creeks and streams draining to the coast have not been examined and the influence of these sources on the coastal system is not known.

Although no detailed investigation has been conducted on the impact of these freshwater sources on the coastal ecosystems, a few effects can be surmised. The discharge is highly seasonal, as is coastal circulation. During the winter, the river discharges will be directed to the north and toward the coast. If the sediment concentrations in the plume are high enough, then the plume may become hyperpycnal and flow offshore along the sea floor. During late spring and summer, the river discharges will be directed southward and offshore. One likely consequence is that the intertidal areas to the north and to the south of the river mouth will have very different fresh water influences and resulting impacts.

Lowered and variable salinity at river mouths is a likely stressor to the intertidal and possibly to the subtidal communities, and is likely to have variable influence to the north versus to the south of the river mouth. Smaller freshwater discharges, such as creeks and seeps, may have a profound localized effect on intertidal organisms. Variations in coastal water quality have also not been examined in detail which makes any consideration of the impacts of variations in water chemistry even more speculative.

D1c. Coastal Morphology and Habitats in RNSP

The coastal character of RNSP varies from south to north along the coast in direct response to variations in the underlying geology. The relationship between coastal morphology and marine biota has not been established in detail at RNSP. As noted above, physical processes vary over seasonal, annual and decadal cycles. These variations also drive changes in coastal morphology, especially on the sandy sections of the coast. In a one year study, three beaches in RNSP were observed to change seasonally (Boyd and DeMartini 1977); other beaches within RNSP must respond similarly, but have never been studied in detail. Since the study duration was only one year, interannual variation and general seasonal trends in sediment transport cannot be surmised for beaches along the RNSP coast.

The entrances to the local rivers and streams change seasonally as well. Redwood Creek seals from direct connection with the ocean each year, typically in May or June and remains closed until October or November. The Klamath River has also sealed from direct connection with the sea, albeit much less often. Whether such closure is coupled with the seasonal beach response has not been investigated, but the effects of such closure on the estuarine fish populations in Redwood Creek has been documented.

No comprehensive mapping of marine habitat types and locations has been conducted along the RNSP coast. Overall, there is a very poor understanding of the distribution of intertidal and subtidal habitats in RNSP. An inventory of intertidal habitats and a rough-scale biological inventory has recently been initiated. These data will be most useful if it is combined with aerial mapping and GIS. There is very little known about the subtidal resources in RNSP as well. Assessing subtidal resources will be difficult because of poor visibility and rough seas. A baseline inventory of the subtidal resources in RNSP should start with a mapping effort as well.

D1d. Coastal and Submerged Cultural Resources

Many of the local American Indians and the RNSP staff have been working to identify cultural resources in the local area, including the coastal and estuarine areas. The offshore sections of RNSP have not been examined in detail to determine if, and where submerged cultural resources may be located.

D1e. Distribution and Abundance of Coastal Biological Resources

Marine Mammals

Past and current work has identified a number of haulout and feeding sites. Carcass surveys have monitored marine mammal mortality. However, baseline data for the species' life history, distribution, abundance and breeding sites in RNSP is poorly understood. Future efforts should prioritize Steller sea lions and determine the status of potential breeding sites in RNSP.

Seabirds

Most of the species, distribution of breeding sites and abundance of seabirds have been examined. Some recent and past monitoring data and aerial photographs are available from the CDFG, but have not yet been analyzed. It has also been suggested that this monitoring may be ceasing soon. RNSP is currently monitoring two seabird colonies at False Klamath Cove Rock and White Rock. Seabirds, including California brown pelicans, are also monitored incidentally during carcass and western snowy plover surveys along the sand beach stretches in RNSP.

Fish

The fish species that live within RNSP are known, more so for freshwater species than marine species, but the distribution of many marine species is not. In addition, little is known about the abundance of most species beyond gross catch data provided by commercial fishermen to CDFG. Nearshore fish sampling by HSU of the park coastline is ongoing, but it is only the first step of any marine fish research.

Intertidal Communities

Intertidal communities have been intensively studied both in the 1970s and more recently in 2004-2005. Both of these studies contributed to our knowledge of the abundance and distribution of algae and invertebrates at three rocky intertidal sites, macro-invertebrates at three sand beaches, and an inventory of algae and invertebrates at all six sites. Recent studies also described the distribution and abundance of tidepool sculpins and juvenile black rockfish at three rocky intertidal sites. Rocky intertidal habitats in RNSP were found to provide nursery habitat for black rockfish, an important commercial and recreational fish.

Intertidal habitats in RNSP are home to a diverse array of species, and are uniquely affected by both marine and terrestrial factors. Comparisons between photographs taken in 1975 and 1976 to those taken in 2005 of the same rocky intertidal areas indicate a change in the successional regime of rocky intertidal communities in RNSP. During the 1970s, rocky intertidal communities were dominated by early successional species. This was a result of an increase in the frequency and severity of disturbance during this period, likely due to large sediment loads and drift wood arriving from impaired watersheds such as Redwood Creek and the Klamath River throughout the 1960s and 1970s (McGary 2005). While this study indicated some level of recovery in the rocky intertidal habitats of RNSP, it also highlights the sensitivities of intertidal habitats to degradation from terrestrial activities. North coast river mouths deliver variable amounts of sediment and freshwater that alters nearshore environments, but very little is known about quantity, variability, or deposition. Understanding these factors is imperative for managers to distinguish natural and anthropogenic effects in intertidal habitats and ameliorate threats to the species that inhabit them.

Similarly, oceanographic processes are poorly known along the coastline. Processes such as the ENSO, PDO, and global warming can have strong effects on biological communities inhabiting nearshore environments. Increased water temperatures and ocean transport anomalies can result in alterations of community composition and relative abundances, and species range expansion and introduction. The current intertidal monitoring effort for invertebrates and algae is an important tool for monitoring changes in the biological communities, but a fuller picture could be gained with the addition of oceanographic data (mapping of nearshore currents, sediment budgets, etc.). Monitoring of tidepool fish every 3-5 years could also contribute to our knowledge of longer-term processes such as PDO and global warming. Studies have shown that fish assemblages remain similar over short term, but species shifts can become apparent over decade or longer term time scale.

All intertidal studies in RNSP have focused on a limited number of sites and in only two habitat types (stable rocky substrate, and medium-fine sand beaches). Development of detailed habitat maps of the entire coastline delineating geomorphology and habitat types should be a priority. Without such a mapping effort, it is difficult to use data from existing studies for anything more than managing the study sites themselves. Habitat mapping and geomorphological descriptions will allow managers to scale up, by applying what is known about a few sites to other sections of coastline sharing the same characteristics.

Intertidal monitoring and mapping may become increasingly important if RNSP is ever designated as a Marine Protected Area (MPA). Any proposed MPA listing of RNSP does not have a direct effect on current management plans within the park, although it will probably result in more emphasis being placed on marine communities in the future.

Thirteen possibly non-indigenous species have been identified in the intertidal habitats of RNSP, however the distribution and ecological effects of these species is not known. Monitoring efforts should be developed to determine the abundance and distribution of these non-indigenous species. Future inventories should focus on identifying exotic species.

Subtidal Communities

Much more is known about intertidal habitats as compared to subtidal habitats. There have been only two subtidal studies within RNSP (Boyd and DeMartini 1977, Boyd et al. 1981). Both of these were qualitative descriptions and observation reports. Boyd et al. (1981) identified four habitat types in the northern half of RNSP, but the data are not sufficient to determine the distribution of these habitat types. This study also suggested that the communities in RNSP were similar to those found at Trinidad Head in central Humboldt County. However, comparisons made with similar studies in Mendocino Headlands State Underwater Parks concluded that the shallow rocky subtidal biota of Humboldt and Del Norte Counties was distinct from that of Mendocino and Sonoma Counties to the south (Seltenrich 1979, Boyd et al. 1981).

Recently subtidal fish inventories were conducted at five sites off the RNSP coast (Mulligan and Lomeli 2005). When completed, the study will provide an inventory of subtidal fish species, information about their abundance, distribution and variation in numbers and diversity. Future subtidal studies should include bathymetry, substrate, and vegetation mapping. These data are necessary for determining habitat types. Data about physical characteristics can be combined with site specific biological data to give managers an idea of how species are distributed on the RNSP coastline. This inferential data are especially important in RNSP where visibility limitations make it difficult to make direct observations in the subtidal habitats. Future subtidal observations will be important contributions to the limited subtidal observations available which are needed for ground-truthing habitat maps and determining habitat availability for subtidal species.

D2. Recommendations

Most of the recommendations below center on the need for baseline information in the study area. Such data will be necessary to conduct any future and more detailed examination of the RNSP marine resources.

We recommend:

- **Conduct basic mapping of the coastal and nearshore environment to classify habitats and investigate the possible existence of submerged cultural resources within RNSP boundaries.**

  We recommend RNSP develop a collaborative partnership with colleagues in CICORE (California Center for Integrative Coastal Observation, Research and Education). CICORE is a coastal ocean monitoring program supported by NOAA and conducted by several marine-related institutions of the California State University system, including Humboldt State University. As a part of the CICORE program, key remote sensing measurements are being made along the California coastline using both hyperspectral overflights and marine acoustic swath-mapping to characterize coastal habitats, among other tasks. In October 2004, a preliminary hyperspectral study was undertaken in Humboldt Bay and north to Trinidad Head. Future overflights or acoustic mapping may be able to include RNSP.

- **Conduct longer-term measurements of important water characteristics in the nearshore RNSP. Such measurements would be key for determining the influence of seasonal and longer term climatic variations on the marine resources of RNSP.**

  CICORE is also invested in real-time, automated, *in situ* measurements of key water characteristics (e.g., temperature, salinity, dissolved oxygen, turbidity, pH, chlorophyll concentration, and water level) using standardized instrumentation. We recommend that RNSP collaborate with CICORE to investigate the possibility of establishing and maintaining similar measurement systems along the RNSP shoreline. Ideally, in order to capture the undoubtedly significant influence of the Klamath River plume along the shoreline (and the influence of coastal currents on the plume itself), measurements should be made at two sites: one site north and one site south of the Klamath River mouth.

- **Characterize the coastal and nearshore currents along the RNSP coastline.**

  We recommend RNSP develop a collaborative partnership with the Coastal Ocean Current Monitoring Program (COCMP). This program, supported by the California Coastal Conservancy, is designed to provide measurements and model predictions of coastal ocean currents, which play an important role in the transport and mixing of many properties (e.g., fresh water, sediments, nutrients, and pollutants) along the park shoreline. At present, a single surface current radar (SCR) system is sited on the coast in Crescent City and is operated by Oregon State University. As the regional representative of COCMP, Humboldt State University intends to establish up to four more SCRs along the north coast of California to measure and generate hourly maps of ocean surface currents across the continental shelf. The proposed SCR systems would provide roughly 5 km (3.1 mi) resolution. In order to support detailed understanding, monitoring, and prediction of flows closer to the shoreline, higher resolution observations in the park region will likely be needed, either on a temporary or permanent basis. Such measurements would also likely support the development of improved predictive models. A collaborative partnership with COCMP would improve the prospects for justification of such a high-resolution current monitoring system.

- **Characterize the erosional and depositional environments along the RNSP coastline, including the rates of erosion and deposition.**

  Shoreline change data are scheduled to be collected every three years using LIDAR mapping techniques on USGS overflights. Data currently are not analyzed for the RNSP section of the coast. Perhaps a cooperative agreement could be developed to broaden the current area of analysis to include the RNSP coastline.

- **Identify the beach littoral cells and develop a beach sediment budget for the RNSP coast.**

  Hapke et al. (2006) have indicated that much of the coastline of RNSP is accreting which is in contrast to much of the Oregon and California coastline. Willis and Griggs (2003) have suggested that these same beaches may be sediment impaired with respect to the supply of riverine sediments. This apparent contradiction clearly indicates the need for a closer examination of the sources and sinks of sediment along the RNSP coast. We suggest that the development of a littoral cell sediment budget would be the most direct method to work toward a better understanding of local coastal processes and responses.

- **Conduct a baseline inventory of the intertidal and subtidal habitats and associated biological communities within RNSP.**

  Biological inventories of algae, invertebrates, and fish occurring in select rocky intertidal and sand beach habitats were conducted in 2005 as part of the Marine Resources Survey. Biological inventories of intertidal fish, invertebrates, and algae should continue to occur approximately every 3 to 5 years. Standardized protocols should be favored as they would have more power to detect and identify change and make comparisons with other coastal regions. Intertidal habitat inventories were begun in the summer of 2005 to identify and describe variations in geology, beach morphology, and biological communities along the entire RNSP coastline. These data should be used to develop a GIS dataset and layers for the coastline. Subtidal inventories consist only of qualitative data gathered in the mid to late 1970s and ongoing subtidal fish surveys. Subtidal surveys are very difficult in RNSP because of poor water visibility attributed to rough water and runoff. Remote sensing options should be explored for identifying subtidal habitats and vegetation types. All subtidal and intertidal inventories would be greatly enhanced by a mapping effort (hyperspectral overflights and marine acoustic swath-mapping; see recommendation 1).

- **Continue long term intertidal monitoring at regular intervals.**

  Long term monitoring allows managers to understand and predict how environmental change, including human impacts affect biological communities. Initial intertidal monitoring data collected by the Marine Resource Survey (bi-monthly June 2004 – November 2005) provides a baseline of natural dynamics in RNSP, but continued monitoring is necessary for tracking long-term changes. Monitoring is now being conducted in late spring and fall through a cooperative agreement with the University of California, Santa Cruz. It is extremely important to continue biannual monitoring. These data can be used to detect and document the occurrence and extent of change due to natural catastrophes, temperature changes, biological invasions, and anthropogenic disturbances such as oil spills. Monitoring of tidepool fish abundance and diversity should be considered for integration into current rocky intertidal monitoring activities to broaden the range of organisms monitored, and provide managers with more insight to this complex ecosystem.

- **Establish a comprehensive monitoring program for marine invasive species.**

  There are 12 possibly non-indigenous species known to occur in the park's intertidal habitats. It is recommended that a comprehensive monitoring program for marine invasive species be put in place for RNSP. This monitoring program could be conducted in conjunction with inventory and monitoring efforts. The first step for detection would be to compile a list of non-indigenous species with potential to occur in RNSP. This list should also provide information about what habitat types each species occurs in, and indicate if a particular species is invasive elsewhere. This list should be cross checked with all species found in past and future inventories. Detecting exotic species could be achieved through routine inventories at select sites, or through observations conducted during regular intertidal monitoring events. The most cost and time effective way to monitor the RNSP coast for invasive species would be to determine which species are known to be invasive, and routinely search the habitats with which they associate. Once detected, the abundance of non-indigenous populations should be eradicated or monitored regularly to determine if the population is increasing. Species that are known invasives should be targeted for eradication or monitored most frequently.

Literature Cited

Adair, R., W. Harper, G. Rankel, and J. Smith. 1982. Annual report, Klamath River fisheries investigation program. U.S. Fish Wildlife Service, Fisheries Assistance Office, Arcata, California. pp. 89-122.

Adelman K. and G. Adelman. 2002-2004. California Coastal Records Project. Available at: www.californiacoastline.org

Allen, G.H. 1964. An oceanographic study between the points of Trinidad Head and the Eel River. The Resources Agency of California, State of California, Sacramento, California. Publication No. 25. 135 pp.

Anderson, D.G. 1988. Juvenile salmonid habitat of the Redwood Creek basin, Humboldt County, California. M.S. Thesis, Humboldt State University, Arcata, CA. 99 pp.

Anderson, D.G. 1995. Biological supplement to Redwood National and State Parks US Army Corps of Engineers application: coho salmon utilization of Redwood Creek estuary. Unpub. Report on file at Redwood National and State Parks, Orick, CA. 13 pp.

Anderson, D.G. 1999. Espa Lagoon Fish Inventory, 1999 Activities. Prepared for Fish and Wildlife Branch, Redwood National and State Parks. Unpub Report on file at Redwood National and State Parks, Orick, CA.

Anderson, D.G. 2002. Tidewater Goby Annual Report. Prepared for Redwood National and State Parks.

Anderson, D.G. 2003. Estuary Annual Monitoring Report. Prepared for Redwood National and State Parks.

Anderson, D.G. 2004. 2004 Redwood Creek summer steelhead trout survey. Unpub. Report of file at RNSP. 18 pp.

Anderson, D.G. 2005. Estuary Annual Monitoring Report. Prepared for Redwood National and State Parks.

Anderson, D.G. and R.A. Brown. 1982. Anadromous salmonid nursery habitat in Redwood Creek watershed. In: Proceedings of the first biennial conference of research in California National Parks. University of California, Davis.

Atwater, B.T. 1970. Implications of plate tectonics for the Cenozoic evolution of western North America. Geological Society of America Bulletin. 81: 3513-3536.

Bakun, A. 1973. Coastal upwelling indices, west coast of North America, 1946-71. U.S. Dept. of Commerce, NOAA Technical Report no. NMFS SSRF-671.

Bakun, A. 1996. Patterns in the ocean: Ocean processes and marine population dynamics. California Sea Grant College System. La Jolla, CA.

Barnes, C.A., A.C. Duxbury, and B.A. Morse. 1972. Circulation and selected properties of the Columbia River effluent at sea. In: Pruter, A.T. and D.L. Alverson (eds.). The Columbia River estuary and adjacent ocean waters. University of Washington Press, Seattle. pp. 41-80.

Barnes, R.K., L.M. Alvis, C. Buck, B. David, J. Dorrance, J.A. Fero, G.J. Gregory, T.S. Jenkins, E.A. Kamp, J. Montoya, J.W. Weaver, G.C. Woods, G.B. Crawford, and J.C. Borgeld. 2002. Identification and characterization of the Klamath River plume under low wind and low discharge conditions. Humboldt State University, Department of Oceanography. Senior Field Cruise report. 26 pp.

Barth, J.A., S.D. Pierce, and T.J. Cowles. 2005. Mesoscale structure and its seasonal evolution in the northern California Current System. Deep-Sea Res. II, 52: 5-28.

Beamish, R.J. 1993. Pacific Salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Sciences 50: 1002-1016.

Beardsley, R.C. and S.J. Lentz. 1987. The Coastal Ocean Dynamics Experiment collection, an introduction. Journal of Geophysical Research 92: 1455-1463.

Beissinger, S. 1995. Population trends of the marbled murrelet projected from demographic analysis. In: Ecology and Conservation of the Marbled Murrelet in North America. C.J. Ralph, G.L. Hunt, M.G. Raphael, and J.F. Piatt (eds.) Gen. Tech. Report PSW-GTR-152. USFS, Albany, CA.

Bell, E. 2001. Survival, growth, and movement of juvenile coho salmon, *Oncorhynchus kisutch*, over-wintering in alcoves, backwaters, and main channel pools in Prairie Creek, California. M.S. Thesis. Humboldt State University, Arcata, CA. 75 pp.

Bensen, K. 2004a. Bald eagle inventory monitoring. RNSP. Annual Progress Report. Unpub. Report on file at RNSP, Orick, CA. 4 pp.

Bensen, K. 2004b. 2003 and 2004 seabird colony monitoring, RNSP. Annual Progress Report. Unpub. Report on file at RNSP, Orick, CA. 7 pp.

Bensen, K. 2005. Sea Bird Colony Monitoring, Annual Progress Report. Report on file at Redwood National and State Parks, Orick, CA. 9 pp.

Best, D.W. 1984. Land use of the Redwood Creek basin. Redwood National Park Research and Development Technical Report 9. 24 pp.

Best, D.W. 1995. History of timber harvest in the Redwood Creek basin, Northwestern California. In: Nolan, K.M., H.M. Kelsey and D.C. Marron (eds.), Geomorphic processes and aquatic habit at in the Redwood Creek basin, Northwestern California. U.S. Geological Survey Professional Paper 1454, pp. C1-C7.

Borgeld, J.C. 1985. Holocene stratigraphy and sedimentation on the northern California continental shelf. PhD dissertation. University of Washington. 177 pp.

Bowen, A.J. and D.L. Inman. 1966. Budget of littoral sands in the vicinity of Point Arguello, California. U.S. Army Coastal Engineering Research Center Technical Memo. No. 19, 56 pp.

Boyd, M. and J.D. DeMartini. 1977. Intertidal and Subtidal Biota of Redwood National Park. A report to the U.S. Department of the Interior, National Park Service Contract No. CX8480-4-0665. Humboldt State University, Arcata, CA. 162 pp.

Boyd, M., J.D. DeMartini, and G. Pic'l. 1981. Reconnaissance Study of Redwood National Park Areas of Special Biological Significance. A report to the California Department of Fish and Game and the California State Water Resources Control Board. Humboldt State University, Arcata, CA.

Boyd, M.J., T.J. Mulligan, and F.J. Shaughnessy. 2002. Non-indigenous marine species of Humboldt Bay, California. Report to California Department of Fish and Game. 118 pp.

Brown, R. 1988. Physical rearing habitat for anadromous salmonids in the Redwood Creek basin, Humboldt County, California. M.S. Thesis. Humboldt State University, Arcata, California. 132 pp.

Brown, W.M. 1973. Streamflow, Sediment and Turbidity in the Mad River Basin. Department of the Interior, U.S. Army Corps of Engineers. Water Resources Investigation #36-73.

Brown, W.M. 1975. Sediment Transport, Turbidity, Channel Configuration and Possible Effects of Impoundment of the Mad River, Humboldt County. California. Department of the Interior, Army Corps of Engineers. Water Resources Investigation #26-75.

Brown, W.M. and J.R. Ritter. 1971. Sediment Transport and Turbidity in the Eel River Basin, California. U.S. Geological Survey Water-Supply Paper 1986. 70 pp.

Bureau of Land Management Website, Updated 2003. Available at: http://www.ca.blm.gov/caso/rocks_islands.html.

California Coastal Sediment Management Workgroup. 2006. California Coastal Sediment Master Plan Status Report. Draft. 32pp. + Appendices

California Department of Fish and Game. 1994a. Length of residency of juvenile Chinook salmon in the Klamath River estuary. Annual Performance Report. Federal Aid in Sport Fish Restoration Act. Project Number F-51-R-6. Project No. 32. Job No. 4. 11 pp.

California Department of Fish and Game. 1994b. Petition to the Board of Forestry to list coho salmon as a sensitive species. Calif. Dept. Fish and Game Rep. 35 pp + appendices.

California Department of Fish and Game. 1996. Length of Residency of juvenile Chinook salmon in the Klamath River estuary. Annual Performance Report. Federal Aid in Sport Fish Restoration Act. Project Number F-51-R-6. Project No. 32. Job No. 4.

California Department of Fish and Game. 2001. California living marine resources: a status report. The Resources Agency, California Department of Fish and Game. 593 p.

California Department of Fish and Game. 2004a. Annual status of the fisheries- report through 2003. The Resources Agency, California Department of Fish and Game. 182 pp.

California Department of Fish Game. 2004b. Commercial landings website. http://www.dfg.ca.gov/mrd/education.html

California Department of Fish and Game. 2006. Habitat Conservation Planning Branch. (http://www.dfg.ca.gov/hcpb/cgi-bin/more_info.asp?idKey=ssc_tespp&specy=fish&query=Lampetra%20similis).

California Department of Water Resources. 2003. Bulletin 118: California's Groundwater 2003 Update. Available at: http://www.groundwater.water.ca.gov/bulletin118/update2003/index.cfm.

Carretta, J.V., J. Barlow, K. A. Forney, M.M. Muto, and J. Baker. 2002. Humpback Whale (*Megaptera novaeangliae*), Eastern North Pacific Stock. U.S. Pacific Marine Mammal Stock Assessments: 2001. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC-317. pp. 68-75.

Center for Coastal Monitoring and Assessment – NOAA. Mussel Watch Program Website. Data Available at: http://ccma.nos.noaa.gov/cit/data/mw_details.html

Chavez, F.P. 1996. Forcing and biological impact of onset of the 1992 El Niño in central California. Geophyscial Research Letters 23: 265-268.

Chelton, D.B. 1984. Seasonal variability of along-shelf geostrophic velocity off central California. Journal of Physical Oceanography 12: 757-784.

Clarke, S.H., Jr. 1992. Geology of the Eel River Basin and adjacent region: implications for late Cenozoic tectonics of the southern Cascadia Subduction Zone and Mendocino Triple Junction. American Association of Petroleum Geologists Bulletin 76: 199-224.

Clarke, S.H., Jr and G.A.Carver. 1992. Late Holocene tectonics and paleo-seismicity of the southern Cascadia subduction zone, northwestern California: Science, v. 255, p. 188-192.

Corson, W.D., C.E. Abel, R.M. Brooks, P D. Farrar, B.J. Groves, J.B. Payne, D.S. McAreny, and BA. Tracy. 1987. Pacific coast hindcast phase II, Wave Information Study. U.S. Army Corps of Engineers, Coastal Engineering Research Center, WIS Report 16.

Cox, K.N. , C.L. McGary, T. Mulligan, and S. Craig. 2006. Marine Resources of Redwood National and State Parks. Comprehensive Report (2004-2005). A report to the U.S. Department of the Interior, National Park Service. February 2006. 161 pp.

Craig, S.F., K. Colridge, and P. Reath. 2006. Redwood National and State Parks Coastal Inventory Protocol IV. and First Annual Report. On file at Redwood National and State Parks, Orick, Ca.

Curray, J.R. 1965. Late Quaternary history, continental shelves of the United States. In: Wright, H.G. Jr. and D.G. Frey (eds). The Quaternary of the United States. Princeton University Press, pp. 723-735.

David, B. 2003. Sequential, two-dimensional morphologic beach profiles compared with empirically based models for predicting storm-induced beach erosion and post-storm accretion at Trinidad State Beach, California. B.S. senior thesis. Humboldt State University, Arcata, California, USA.

Day, J.S. 1963, Freshwater Lagoon, Humboldt County, a summary report. California Department of Fish and Game. 4pp.

Dean, J.M. and A.E.S. Kemp. 2004. A 2100 year BP record of the Pacific Decadal Oscillation, El Niño Southern Oscillation and Quasi-Biennial Oscillation in marine production and fluvial input from Saanich Inlet, British Columbia. Palaeogeography, Palaeoclimatology, Palaeoecology 213: 207-229.

Detrich, P.J. and D.K. Garcelon. 1986. Criteria and habitat evaluation for bald eagle reintroduction in coastal California. Prepared for Calif. Dept. Fish and Game. Institute for Wildlife Studies, Arcata, CA.

Dugan, JD, M. Hubbard, and G. Davis. 1999. Sand Beach and Coastal Lagoon Monitoring Handbook, Channel Islands National Park, California. National Park Service, Channel Islands National Park, Ventura, California.

EG&G. 1988, 1989a, b, 1991. Northern California Coastal Circulation Study (NCCCS);San Francisco to Oregon;1986-1989.

Falvey, B. 1998. Peregrine Falcon inventory and monitoring- 1998, Redwood National and State Parks (RNSP). Unpub. Rep. on file at Redwood National and State Parks, Orick, CA. 10 pp.

Falvey, B. 1999. Peregrine Falcon inventory and monitoring - 1999, Redwood National and State Parks (RNSP). Unpub. Rep. on file at Redwood National and State Parks, Orick, CA. 7 pp.

Flint, L.E., A.L. Flint, D.S. Curry, S.A. Rounds, and M.C. Doyle. 2005. Water-Quality Data from 2002 to 2003 and Analysis of Data Gaps for Development of Total Maximum Daily Loads in the Lower Klamath River Basin, California. U.S. Geological Survey Scientific Investigations Report 2004-5255, 77 pp. http://water.usgs.gov/pubs/sir/2004/5255/pdf/sir_2004-5255.pdf.

Francis, R.C., K. Aydin, R.L. Merrick, and S. Bollens. 1999. Modeling and management of the Bering Sea ecosystem. In: Dynamics of the Bering Sea: A summary of physical, chemical, and biological characteristics and a synopsis of research on the Bering Sea. Loughlin, T.R. and Ohtani, K. (eds.) University of Alaska Sea Grant College Program Report, AK-SG-99-03. Chap. 20: 409-433.

Freitag, H.P. and D. Halpern. 1981. Hydrographic observations off northern California during May 1977. Journal of Geophysical Research 86: 4248-4252.

Frissell, C.A. 1993. Topology of extinction and decline of native fishes in the Pacific Northwest and California. Conserv. Biol. 7: 342-354.

Fyfe, R.W. and R.E. Olendorff. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service, Occ. Paper No. 23. 12 pp.

Garvine, R.W. 1999. Penetration of a buoyant coastal discharge onto the continental shelf, a numerical modeling experiment. Journal of Physical Oceanography 29: 1892-1909.

Gergus, E. 1988. An ecological overview of Freshwater Lagoon in Humboldt County, California. Compiled for Freshwater Fish Ecology Class, Dr. Terry Roelofs, Humboldt State University.

Gershunov, A. and T.P. Barnett. 1998. Interdecadal modulation of ENSO teleconnections. Bulletin of the American Meteorological Society 79: 2715-2726.

Geyer W.R., P. Hill, T. Milligan, and P. Traykovski. 2000. The structure of the Eel River plume during floods. Continental Shelf Research 20: 2067-2093.

Glogoczowski, M. and P. Wilde. 1971. River Mouth and Beach Sediments, Russian River, California to Rogue River, Oregon, Part A Introduction and Grain Size Analyses. University of California, Berkeley, Hydraulic Eng. HEL, 2-36, 73pp.

Graham, N.E. 1994. Decadal-scale climate variability in the 1970s and 1980s, observations and model results. Climate Dynamics 10: 135-159.

Grantham, B.A., F. Chan, K.J. Nielsen, D.S. Fox, J.A. Barth, A. Huyer, J. Lubchenco and B.A. Menge. 2004. Upwelling-driven nearshore hypoxia signals ecosystem and oceanographic changes in the Northeast Pacific. Nature 429: 749-754.

Gregory, R. 1982. Physical and chemical parameters of Redwood Creek estuary. Department of Oceanography, Humboldt State University. 43pp.

Griffin B.J. 2003. Scoping Comments on California Coastal National Monument. U.S. Department of the Interior, Bureau of Land Management California Coastal National Monument, The Marine Mammal Center, October 25, 2003.

Grimes, C.B. and M.J. Kingsford. 1996. How do riverine plumes of different sizes influence fish larvae, do they enhance recruitment? Marine and Freshwater Research 47: 191-208.

Griswold, M.D. 1977. Location and use of pinniped haulouts in Del Norte County, California. On file at RNSP, Orick, CA.

Griswold, M.D. 1985. Distribution and movements of pinnipeds in Humboldt and Del Norte Counties, California. M.A. Thesis. Humboldt State University, Arcata, CA. 108 pp.

Hagans, D.K. and W.E. Weaver. 1987. Magnitude, cause and basin response to fluvial erosion, Redwood Creek basin, northern California. In: Beschta, R.L., T. Blinn, G.E. Grant, E.J. Swanson and G.G. Ice (eds.), Erosion and sedimentation in the Pacific Rim, International Association of Hydrological Sciences Publication 165: 419-428.

Hapke, C.J., Reid, D., Richmond, B.M., Ruggiero, P., and J. List. 2006. National assessment of shoreline change Part 3: Historical shoreline change and associated coastal land loss along sandy shorelins of the California Coastal USGS Open-File Report 2006-1219. 72 p.

Harris, C.K., P.A. Traykovski, and R.W. Geyer. 2005. Flood dispersal and deposition by near-bed gravitational flows and oceanographic transport: a numerical modeling study of the Eel River shelf, northern California. Journal of Geophysical Research, 110: 2004JC002727.

Hebert, P.N. and R.T. Golightly. 2003. Breeding biology and human-caused disturbance to nesting of marbled murrelets (*Brachyramphus marmoratus*) in northern California. Unpub. Progress Report Humboldt State University, Dept of Wildlife, Arcata, CA.

Hickey, B.M. 1979. The California current system: hypotheses and facts. Progress in Oceanography 8: 191-279.

Hickey, B.M. and N.E. Pola. 1983. The seasonal along-shelf pressure gradient on the west coast of the United States. Journal of Geophysical Research, 88: 7623-7633.

Hiner, M. and A. Brown. 2004. Monitoring and evaluation of current and historical physical habitat conditions, water quality and juvenile salmon use of the Klamath River estuary. Prepared for the California Department of Fish and Game.

Hiser, C. A. 1994. Annual Report, Iron Gate salmon and steelhead hatchery, 1991-1992. Calif. Dep. Fish Game, Inland Fish. Branch Admin. Report 93-2, 14 p.

Holden, B. 2003. Fish Distribution Survey Report. Unpublished Report on file at Redwood National and State Parks, Orick, CA. 13 pp.

Holm, G. 1997-2001. Annual reports. Beach Carcass Survey Summaries. Unpublished Report on file at Redwood National and State Parks, Orick, CA.

Holm, G. 2002. Peregrine Falcon inventory and monitoring annual progress report. Unpub. Report on file at Redwood National and State Parks, Orick, CA. 12 pp.

Holm, G. 2004. Western snowy plover winter (2003-2004) and 2004 breeding season surveys – Annual Progress Report. Unpub. Report on file at RNSP, Orick, CA. 22 pp.

Huyer, A. 1983. Coastal upwelling in the California current system. Progress in Oceanography 12: 259-284.

Huyer, A., R.L. Smith, and E.J.C. Sobey. 1978. Seasonal difference in low-frequency current fluctuations over the Oregon continental shelf. Journal of Geophysical Research 83: 5071-5089.

Huyer, A., P.M. Kosro, J. Fleischbein, S.R. Ramp, T. Stanton, L. Washburn, F.P. Chavez, T.J. Cowles, S.D. Pierce, and R.L. Smith. 1991. Currents and water masses of the coastal transition zone off northern California, June to August 1988. Journal of Geophysical Research 96: 14809-14831.

Huyer, A. 2003. Preface to special section on enhanced subarctic influence in the California Current, 2002. Geophysical Research Letters 30: 8019.

Janda, R.J., K.M. Nolan, D.R. Harden, and S.M. Colman. 1975. Watershed conditions in the drainage basin of Redwood Creek, Humboldt County, California. U.S. Geological Survey Open-File Report 75-568, 266 pp.

Jaques, D.L., R.L. Lowe, and D.W. Anderson. 1994. Brown pelican range expansion in the eastern North Pacific: roles of tradition and climate change. *In* Jaques, D.L. 1994. Range expansion and roosting ecology of non-breeding California brown pelicans. Unpub. M.S. Thesis. University of California, Davis. 133 pp.

Jensen, R.E., J.M. Hubertz, and J.B. Payne. 1989. Pacific Coast Hindcast Phase III, Wave Information. U. S. Army Corps of Engineers, Coastal Engineering Research Center, WIS Report 17.

Johnson, J.W., J.T. Moore, and E.B. Orret. 1971. Summary of Annual Wave Power for Ten Deep Water Stations along the California, Oregon and Washington coasts. University of California Hydraulic Engineering Laboratory Technical Report HEL-24-9.

Josselyn, M., A. Fiorillo, and M. LosHeurtos. 1992. Espa Lagoon Enhancement Plan. Prepared for Renee Pasquinelli, Department of Parks and Recreation.

Kelsey, H.M., M. Coghlan, J. Pitlick, and D. Best. 1979. Geomorphic analysis of streamside landsliding in the Redwood Creek basin. In: Nolan, K.M., H.M. Kelsey, H.M., and D.C. Marron (eds.), Geomorphic processes and aquatic habit at in the Redwood Creek basin, Northwestern California, U.S. Geological Survey Professional Paper 1454, p. J1-J12.

Kelsey, H.M., M.A. Madej, J. Pitlick, P. Stroud, and M. Coghlan. 1981. Major sediment sources and limits to the effectiveness of erosion control techniques in the highly erosive watersheds of north coastal California. In: Davies, T.R.H. and A.J. Pearce (eds.), Erosion and sediment transport in Pacific Rim steeplands, International Association of Hydrological Sciences Publication No. 132: 493-509.

Kelsey, H.M., M. Coghlan, J. Pitlick, and D. Best. 1995. Geomorphic analysis of streamside landslides in the Redwood Creek Basin, northwestern California. Chapter J In: Nolan, K.M., H. M. Kelsey, and D. C. Marron, (eds.), Geomorphic processes and aquatic habitat in the Redwood Creek Basin, northwestern California. U.S. Geological Survey Professional Paper 1454.

Kimsey, J.B. 1952. A survey of Freshwater Lagoon, Humboldt County. Unpublished report prepared for the CA Department of Fish and Game.

Klamath River Task Force [KRTF]. 1991. Long range plan for the Klamath River basin conservation area fishery restoration program. U.S. Fish and Wildlife Service. Yreka, California.

Klein, R.D. 1987. Stream channel adjustments following logging road removal in Redwood National Park. Redwood National Park Research and Development Technical Report Number 23, 38 pp.

Klein, R. 1993. Topographic monitoring on Freshwater Beach, Redwood National Park. Prepared for California Department of Fish and Game.

Komar, P.D. 1986. The 1982–83 El Niño and erosion on the coast of Oregon. Shore and Beach 54: 3-12.

Komar, P.D. 1998. Beach processes and sedimentation. 2nd edition, Prentice Hall, 544 pp.

Konkel, G.W. and J.D. McIntyre. 1987. Trends in spawning populations of Pacific anadromous salmonids. USDI Fish and Wildlife Service Wildl. Tech. Rep. 9, Washington DC. 25 pp.

Kosro, P.M., A. Huyer, S.R. Ramp, R.L. Smith, F.P. Chavez, T.J. Cowles, M.R. Abbott, P.T. Strub, R.T. Barber, P. Jessen, and L.F. Small. 1991. Structure of the transition zone between coastal waters and the open ocean off northern California, winter and spring 1987. Journal of Geophysical Research 96: 14707-14730.

Langlois, G.W. 2005. Marine Biotoxin Monitoring Program Annual Report. Submitted to California Department of Fish and Game by California Department of Health and Human Services, Division of Drinking Water and Environmental Management. www.dhs.ca.gov/ps/environmenta/shellfish/default.htm

Largier, J.L., B.A. Magnell, and C.D. Winant. 1993. Subtidal circulation over the northern California shelf. Journal of Geophysical Research 98: 147-179.

Lillie, Robert, J. 2005. Parks and Plates: The geology of our national parks, monuments, and seashores. W.W. Norton and Company. 298 pp.

Lohrenz, S.E., G.L. Fahnenstiel, D.G. Redalje, G.A. Lang, M.J. Dagg, T.E. Whitledge, and Q. Dortch. 1999. Nutrients, irradiance, and mixing as factors regulating primary production in coastal waters impacted by the Mississippi River plume. Continental Shelf Research 19: 1113-1141.

Lomeli, M. 2004. Site fidelity by young-of-year black rockfish (Sebastes melanops) within tidepools at False Klamath Cove and Enderts Beach, Redwood National and State Parks. Paper in progress as part of NSF-supported Research Experiences for Undergraduates project, Humboldt State University, Arcata, CA.

Madej, M. A. and V. Ozaki. 1996. Channel response to sediment wave propagation and movement, Redwood Creek, California, USA. Earth Surface Processes and Landforms, Vol. 21: 911-927.

Madej, M. A., C. Currens, V. Ozaki, J. Yee, and D. G. Anderson. 2006. Assessing the possible thermal rearing restrictions for juvenile coho salmon (*Oncorhynchus kisutch*) through termal infrared imaging and in-stream monitoring, Redwood Creek, California. Can. J. Fish. Aquat. Sci. 63: 1384-1396.

Malcolm, M. 1994. Living in a well-ordered world: Indian people of northwestern California. Redwood National Park. Heydey Books, Berkeley, California. 16 pp.

Maloney, E., Fairey, R., Lyman, A., Reynolds, K., and Sigala, M. 2006. Introduced Aquatic Species in California Open Coastal Waters. Final Report. California Department of Fish and Game, Office of Spill Prevention and Response. Sacramento, CA. 93 pp.

Mantua, N.J., S.R. Hare, Y. Zhang, J.M. Wallace, and R.C. Francis. 1997. A Pacific interdecadal climate oscillation with impacts on salmon production. Bulletin of the American Meteorological Society 78: 1069-1079.

Marine Protected Areas Website. Managed by the US Department of Commerce/NOAA. Updated 2005. Available at: http://mpa.gov/.

Marzluff, J.M., J.M. Luginbuhl, M.G. Raphael, D.M. Evans, D.E. Varland, L.S. Young, S.P. Horton, and S.P. Courtney. 1996. The influence of stand structure, proximity to human activity, and forest fragmentation on the risk of predation to nests of marbled murrelets on the Olympic Peninsula. Unpublished Report submitted to the USFWS. 63 pp.

Mate, B.R. 1973. Population kinetics and related ecology of the northern sea lion, *Eumatopias jubatus,* and the California sea lion, *Zalphus californianus*, along the Oregon coast. Ph.D. Thesis, University of Oregon, Eugene OR. 94 pp.

Maughan, W.D., W.J. Miller, L.L. Mitchell, C.M. Bard, L. Walker, and C.L. Whitney. 1979. Areas of Special Biological Significance. State Water Resources Control Board. Available at: http://www.swrcb.ca.gov/general/publications/docs/areas_special_biological_significance_july1976.pdf

McGary, C. 2005. A Long-Term Comparison of High Rocky Intertidal Communities in Redwood National and State Parks. M.S. Thesis. Humboldt State University, Arcata, CA. 93 pp.

McPherson, R.C. 1992. Style of faulting at the southern end of the Cascadia subduction zone. In: Pacific Cell, Friends of the Pleistocene Guidbook for the Field Trip to northern California, June 5-7 1992. p. 97-111.

McShane, C., T. Hamer, H. Carter, G. Swartzman, V. Friesen, D. Ainley, R. Tressler, K. Nelson, A. Burger, L. Spear, T. Mohagen, R. Martin, L. Henkel, K. Prindle, C. Strong, and J. Keany. 2004. Evaluation report for the 5-year status review of the marbled murrelet in Washington, Oregon, and California. Unpub. Rept. EDAW, Inc. Seattle, WA. Prepared for the U.S. Fish and Wildlife Service, Region1, Portland, OR.

Miller, K.A., revised by John O'Brien. 2002. Annual Status of the Fisheries Report Through 2003. California Fish and Game Report.

Miller, S.L., C.J. Ralph, W. Mellberg, and L. Long. 2003. Abundance, distribution, and productivity of marbled murrelets along the coast of northern California and southern Oregon in 2003. Annual Report to the Pacific Lumber Company.

Moffett, J.W. and S.H. Smith. 1950. Biological investigations of the fishery resources of Trinity River, California. US Fish and Wildlife Service-Special Scientific Report Fisheries No. 12. Washington, DC.

Moley, K. and L. Dengler. 1992. Geology and ground shaking northern California. Humboldt Earthquake Education Center, Department of Geology, Humboldt State University, Arcata, CA.

Montoya, J.A. 2003. Tidal modulation of river gauge at Klamath, CA during summer low flow conditions July-September 2003. Department of Oceanography, Humboldt State University, Arcata, CA.

Muchow, R. S. 2004. Point Reyes National Seahore/ GoldenGate National Recreation Area Coastal Inventory Protocol, Draft.

Mulligan, T. and M. Lomeli. 2005. Redwood National and State Parks Subtidal Fish Survey. Progress Report on file at RNSP, Orick, Ca.

Mulligan, T. and R. Studebaker. 2005. Fishes of Espa Lagoon and East Creek, Prairie Creek Redwood State parks, Humboldt County, CA. Department of Fisheries Biology, Humboldt State University, Arcata, CA. 24pp.

Munchow, A. and R.W. Garvine. 1993. Dynamical properties of a buoyancy-driven coastal current. Journal of Geophysical Research. 10: 20063-20078.

National Center for Atmospheric Research & UCAR Office of Programs. Climate Indices Website. http://www.cgd.ucar.edu/cas/catalog/climind/soi4.gif

National Marine Fisheries Service. 1992. Recovery plan for the Steller sea lion (*Eumatopias jubatus*). Prepared by the Steller Sea Lion Recovery Team for the National Marine Fisheries Service, Silver Spring, MD. 92 pp.

National Marine Fisheries Service. 1998. Endangered and threatened species: Proposed endangered status for two chinook salmon ESUs and proposed threatened status for five chinook salmon ESUs; proposed redefinition, threatened status, and revision of critical habitat for one chinook salmon ESU; proposed designation of chinook salmon critical habitat in California, Oregon, Washington, Idaho. Federal Register 63 (45): 11482-11520. March 9, 1998.

National Marine Fisheries Service. 2002. Biological Opinion: Klamath Project Operations. Available at: (http://swr.nmfs.noaa.gov/psd/klamath/KpopBO2002finalMay31.PDF)

National Marine Fisheries Service and US Fish and Wildlife Service. 1998. Recovery plan for U.S. Pacific populations of the olive ridley turtle (*Lepidochelys olivaca*). National Marine Fisheries Service, Silver Spring, MD.

National Oceanic and Atmospheric Administration (NOAA) National Ocean Services (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) water levels website. (http://co-ops.nos.noaa.gov/cgi-bin/station_info.cgi?stn=9419750+Crescent+City,+CA)

Nelson, S.K. and T.E. Hamer. 1995. Nest success and the effects of predation on marbled murrelets. Pages 57-67 In: C.J. Ralph, G.L. Hunt, M.G. Raphael, and J.F. Piatt (Tech. eds.). Ecology and conservation of the marbled murrelet. Gen. Tech. Rept. PSW-GTR-152. U.S. Dept. of Agriculture, Forest Service, Albany, CA.

Nerem, R.S. and G.T. Mitchum. 2000. Observations of Sea Level Change from Satellite Altimetry, In: Sea Level Rise: History and Consequences, edited by B.C. Douglas, M.S. Kearney, and S.P. Leatherman, pp. 121-163, Academic Press.

Nigam, S., M. Barlow, and E.H. Berbery. 1999. Pacific decadal SST variability, Impact on U.S. drought and streamflow. EOS Transactions, American Geophysical Union 80: 621-25.

Nilsen, T.H. and S.H. Clarke, Jr. 1987. Geological evolution of the late Cenozoic basins of northern California. In: Schymiczek, H. and R. Suchland (eds.). Tectonics, Sedimentation and Evolution of the Eel River and Other Coastal Basins of Northern California. San Joaquin Geological Society, CA. pp. 15-29.

Nittrouer, C.A. 1999. STRATAFORM, overview of its design and synthesis of its results. Marine Geology 154: 3-12.

North Coast Watershed Assessment Program (NCWAP). 2002. Draft Redwood Creek watershed synthesis report. California Resource Agency. 524 pp.

O'Farrell, M. and L. Botsford. 2006. Estimating the status of nearshore rockfish (*Sebastes spp.*) populations with length-frequency data. Ecological Applications 16(8):977-986.

Ogston, A.S., D.A. Cacchione, R.W. Sternberg, and G.C. Kineke. 2000. Observations of storm and river flood-driven sediment transport on the northern California continental shelf. Continental Shelf Research 20: 2141-2162.

Orr, R.T. and T.C. Poulter. 1967. Some observations on reproduction, growth, and social behavior in the Steller sea lion. Proc. Calif. Acad. Sci. 37: 381-394.

Overland, J.E., J.M. Adams, and H.O. Mofjeld. 2000. Chaos in the north Pacific: spatial modes and temporal irregularity. Progress in Oceanography 47: 337–354.

Ozaki, V. and D.G. Anderson. 2005. Evaluation of stream temperature regimes for juvenile coho salmon in Redwood Creek using thermal infrared. Water Resources Division Technical Report/NPS/NRRWRD/NRTR-2005/33. 23 pp.

Pacific States/British Columbia Oil Spill Task Force. 2002. West Coast Offshore Vessel Traffic Risk Management Project.

Page, G.W. and L.E. Stenzel, (eds). 1981. The breeding status of the snowy plover in California. Western Birds. 12: 1-40.

Page, G.W., F.C. Bidstrup, R.J. Ramer, and L.E. Stenzel. 1986. Distribution of wintering snowy plovers in California and adjacent states. Western Birds. 17(4): 145-170.

Peterson, W.T. and F.B. Schwing. 2003. A new climate regime in northeast pacific ecosystems. Geophysical Research Letters 30: 1896.

Pierce, R. M. 1998. Klamath Salmon: understanding allocation. 34pp.

Pullen, J.D. and J.S. Allen. 2000. Modeling studies of the coastal circulation off northern California, shelf response to a major Eel River flood event. Continental Shelf Research 20: 2213-2238.

Pullen, J.D. and J.S. Allen. 2001. Modeling studies of the coastal circulation off northern California: statistics and patterns of wintertime flow. Journal of Geophysical Research 106: 26959-26984.

Ralph, C.J., S.L. Miller, K. Hollinger, B. Hogoboom, R.I. Frey, L. Long, T. Matsumoto, and H.Stauffer. 2002. 2001 Annual report – marbled murrelet monitoring in northwestern California and Oregon – marbled murrelet research. Redwood Sciences Laboratory, Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture. Internet publication. 5 pp.

Ramp, S.R., L.K. Rosenfeld, T.D. Tisch, and M.R. Hicks. 1997. Moored observations of the current and temperature structure over the continental slope off central California 1, a basic description of the variability. Journal of Geophysical Research 102: 877-902.

Raphael, M.G., D. Evans Mack, J. M. Marzluff, and J.M. Luginbuhl. 2002. Effects of fragmentation on populations of the marbled murrelet. Studies in Avian Biol. 25: 221-235.

Redwood Creek Watershed Group (RCWG). 2006. Redwood Creek Integrated Watershed Strategy, 102 pp. (http://www.co.humboldt.ca.us/planning/Prop50/01_RWC_IWS%20Final.pdf).

Redwood National Park. 1997. Redwood creek watershed analysis. Redwood National and State Parks. 100 p.

Redwood National and State Parks. 1998. Tidewater goby annual report, Fish and Wildlife Branch. Unpub. Report. on file at Redwood National and State Parks, Orick, CA.

Redwood National and State Parks. 2000. General Management Plan/General Plan. USDI National Park Service and California Department of Parks and Recreation. 111 pp.

Redwood National and State Parks. 2005. Redwood National and State Parks staff responsibilities and management strategy for western snowy plovers. Unpub. document on file at South Operations Center, Orick, CA.

Reid, J.L. and R.S. Arthur. 1975. Interpretation of maps of geopotential anomaly for the deep Pacific Ocean. Journal of. Marine Research 33: 37-52.

Ricks, C. 1983. Flood history and sedimentation at the mouth of Redwood Creek, Humboldt County, California. MS Thesis. Oregon State University, Corvallis, Oregon. 166 pp.

Ricks, C.L. 1985. Flood history and sedimentation at the mouth of Redwood Creek, Humboldt County, California. National Park Service, Arcata, California. Technical Report 15.

Ricks, C.L. 1995. Effects of channelization on sediment distribution and aquatic habitat at the mouth of Redwood Creek, Northwestern California, In: Nolan, K.M., Kelsey, H.M., and Marron, D.C. (eds.), Geomorphic processes and aquatic habit at in the Redwood Creek basin, Northwestern California. U.S. Geological Survey Professional Paper 1454, p. Q1-Q17.

Ricks, C.L. and R. Feranna. 1981. The historic fisheries of Redwood Creek recorded from interviews and photographs provided by the people of Orick, California. Unpublished report. on file at Redwood National Park.

Rosati, J.D. and N.C. Kraus. 1999. Sediment Budget Analysis System (SBAS). U.S. Army Corps of Engineers, Coastal Engineering Technical Note IV-20.

Ryan, H.F. and M. Noble. 2002. Sea level response to ENSO along the central California coast: how the 1997 -1998 event compares with the historic record. Progress in Oceanography 54: 149-169.

Sakai, H. 2003. A conservation strategy for managing threatened and endangered species in Redwood National and State Parks. Redwood National and State Parks. 116pp.

Salamunovich T. 1987. Fish Food Habits and their Interrelationships in Lower Redwood Creek. M.S. Thesis. Humboldt State University, Arcata, CA.

Sauer, M., B. Fahning, A. Feit, J. Golnik, J. Hill, C. Oberlander, C. Sedlacek, J.C. Borgeld, and G.B. Crawford. 1998. Hydrography, nutrients, and phytoplankton off northern California during low winds in June 1998. Department of Oceanography, Humboldt State University, Arcata, CA.

Seltenrich, C.P. 1979. The development of interpretive materials and of a preliminary resource management plan for Mendocino Headlands and Salt Point Underwater Parks. M.S. Thesis, Humboldt State University, Arcata, CA. 232 pp.

Sharman, L., P.Vanselow, and W. Eichenlaub. 2006. Mapping coastal resouces in Alaska's National Parks. National Parks Service, U.S. Department of the Interior at http://www.nps.gov/glba/InDepth/learn/preserve/projects/coastal/

SHN. 2004. Feasibility study – wastewater collection, treatment, and disposal for the unicorporated community of Orick. SHN Consulting Engineers and Geologists, Inc. Eureka, California. 122 pp.

Smith, R.L., A. Huyer, and J. Fleischbein. 2001. The coastal ocean off Oregon from 1961 to 2000: is there evidence of climate change or only of Los Niños? Progress in Oceanography 49: 63-93.

Smith, S.J. 1978. Coastal slope stability along 35 miles of northern California coast: Orick to Crescent City. Prepared for Redwood National Park, Orick, CA.

Snyder, J. O. 1931. Salmon of the Klamath River, California. Fish Bulletin. 34. Sacramento: State of California Department of Natural Resources, Division of Fish and Game, Bureau of Marine Fisheries.

Southern California Coastal Water Research Project. 2003. Final Report: discharge into state water quality protection areas. Final Report to the State Water Resources Control Board. Contract 01-187-250. 27 pp.

Sowls, A.L., A.R. Degange, J.W. Nelson, and G.S. Lester. 1980. Catalog of California seabird colonies. U.S. Department of Interior, Fish and Wildlife Service, Biological Services Program. FWS/OBS 37/80. 371 pp.

Sparkman, M.D. 2006. Upper Redwood Creek juvenile salmonid downstream migration study, a five-year summary report (2000-2004). CDFG AFRAM Annual Report 2.4. 84 pp.

Spreiter, T.A., J.F. Franke, and D.L. Steensen. 1995. Disturbed lands restoration: the redwood experience: Eighth Biennial Conference on Research and Resource Management in Parks and Public Lands, April 17-21, 1995, Portland, OR.: George Wright Society, Hancock, MI. p 238.

Stack, J.D. 1981. Diurnal activity patterns of nonbreeding *Zalophus californianus* and *Eumatopias jubatus* at Klamath Cove, California. M.A. Thesis, Humboldt State University, Arcata, CA. 78 pp.

State Water Resources Control Board. 2001. California ocean plan, ocean waters of California. State Water Resources Control Board, Sacramento, 39 pp. Available at: http://www.waterboards.ca.gov/plnspols/docs/oplans/cop2001.pdf.

State Water Resources Control Board. 2002. Available at : http://www.swrcb.ca.gov/rwqcb1/programs/tmdl/303d/303d.html

Steensen, D.L., and T.A. Spreiter. 1992. Watershed rehabilitation in Redwood National Park. Paper presented at the 1992 National Meeting of the American Society for Surface Mining and Reclamation, Duluth, MN., June 14-18, 1992.

Steiger, G.H., J. Calambokidis, R. Sears, K.C. Balcomb, and J.C. Cubbage. 1991. Movement of humpback whales between California and Costa Rica. Marine Mammal Science. 7: 306-310.

Stone, E.C., R.F. Grah, and P.J. Zinke. 1969. An analysis of the buffers and the watershed management required to preserve the redwood forest and associated streams in the Redwood National Park. Stone and Associates, Vegetation Management Consultants, 105 pp.

Storlazzi, C.D. and G.B. Griggs. 2000. The influence of El Niño-southern oscillation (ENSO) events on the evolution of central California's shoreline. Geological Society of America Bulletin 112: 236-249.

Strand, R.G. 1962. Geologic map of California, Redding sheet. California Division of Mines and Geology.

Strand, R.G. 1963. Geologic map of California, Weed sheet. California Division of Mines and Geology.

Strub, P.T., J.S. Allen, A. Huyer, and R.L. Smith. 1987a. Large-scale structure of the spring transition in the coastal ocean off western North America. Journal of Geophysical Research 92: 1527-1544.

Strub, P.T., J.S. Allen, A. Huyer, R.L. Smith, and R.C. Beardsley. 1987b. Seasonal cycles of currents, temperatures, winds, and sea level over the Northeast Pacific continental shelf: 35°N to 48°N. Journal of Geophysical Research 92: 1507-1526.

Studebaker, R.S. 2006. Use of Rocky Intertidal Areas by Juvenile *Sebastes* in Northern California. M.S. Thesis, Humboldt State University, Arcata, CA. 100 pp.

Sullivan, R.M. 1980. Seasonal occurrence and haul-out use in pinnipeds along Humboldt County, California. Journal of Mammalogy. 61(4): 754-760.

Sullivan, T. 2001. Assessment of Air Quality and Air Pollutant Impacts in Class National Parks of California. National Park Service, Denver, CO.

Swift, C.L., J.L. Nelson, C. Maslow, and T. Stein. 1989. Biology and distribution of the tidewater goby, *Eucyclogobius newberryi* (Pisces: Gobiidae) of California. Contributions in Science No. 404. Natural History Museum of Los Angeles County. Los Angeles, CA. 19 pp.

Tillotson, K. and P.D. Komar. 1997. The wave climate of the Pacific Northwest, Oregon and Washington, a comparison of data sources. Journal of Coastal Research 13: 440-452.

Traykovski, P., W.R. Geyer, J.D. Irish, and J.F. Lynch. 2000. The role of density driven fluid mud flows for cross shelf transport on the Eel River continental shelf. Continental Shelf Research 20: 2113-2140.

Trenberth, K.E. 1990. Recent observed interdecadal climate changes in the Northern Hemisphere. Bulletin of the American Meteorological Society 71: 988-993.

Trenberth, K.E. 1997. The definition of El Niño. Bulletin of the American Meteorological Society 78, 2771-2778.

Trenberth, K. E. and J. W. Hurrell. 1995. Decadal coupled atmosphere-ocean variations in the North Pacific Ocean. In: R. J. Beamish (ed.), Climate change and northern fish populations. Can. Spec. Pub. Fisheries Aquatic Sciences. 121: 15-24.

Trexler, J.H. 1989. Ancestral Klamath River deposits at Gold Bluffs, Prairie Creek Redwoods State Park, Humboldt County. California Geology. 42(7): 147-152.

U.S. Army Corps of Engineers. 1984. Shore Protection Manual (SPM). 4th ed., 2 Vols., U.S. Government Printing Office. Washington, DC.

U.S. Census Bureau. State and County QuickFacts. Data derived from Population Estimates, 2000 Census of Population and Housing, 1990 Census of Population and Housing, and Historical Population Counts. Avaliable at: http://quickfacts.census.gov/qfd/states/06000lk.html.

U.S. Department of Commerce. 1997. Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and the Coastal Ecosystems of Washington, Oregon, and California. NOAA Technical Memorandum NMFS-NWFSC-28. Available at: http://research.nwfsc.noaa.gov/publications/techmemos/tm28/tm28.htm

U.S. Department of Commerce. 1999a. Endangered and threatened species; threatened status for two chinook salmon evolutionarily significant units (ESUs) in California. Fed. Reg. 64(179): 50394-50415.

U.S. Department of Commerce. 1999b. Designated critical habitat; central California coast and sourthern Oregon/northern California coasts coho salmon; final rule and correction. Fed. Reg. 64(86): 24049-24062.

U.S. Department of Commerce – National Oceanic and Atmospheric Administration. 2005a. Endangered and threatened species: final listing determinations for 16 ESUs of west coast salmon, and final 4(d) protective regulations for threatened salmonid ESUs. Fed. Reg. 70(123): 37160-37204.

U.S. Department of Commerce – National Oceanic and Atmospheric Administration. 2005b. Endangered and threatened species designation of critical habitat for seven evolutionarily significant units of Pacific salmon and steelhead in California. Fed. Reg. 70(170): 52488-52627.

U.S. Department of Commerce – National Oceanic and Atmospheric Administration. 2006. Endangered and threatened species: final listing determinations for 10 distinct population segments of west coast steelhead. Fed. Reg. 71(3): 834-862.

U.S. Department of the Interior. 1990. Freshwater Lagoon Spit: Environmental Assessment and Proposed Management Plan for Redwood National Park.

U.S. Department of the Interior. 1992a. Endangered and threatened wildlife and plants; six plants and Myrtle's silverspot butterfly from coastal dunes in northern and central California determined to be endangered. Fed. Reg. 57: 27848-27872.

U.S. Department of the Interior. 1992b. Endangered and threatened wildlife and plants; determination of threatened status for the Washington, Oregon, and California population of the marbled murrelet; final rule. Fed. Reg. 57: 45328-45337.

U.S. Department of the Interior. 1994a. Exotic Plant Management Plan and Environmental Assessment for Redwood National and State Parks.

U.S. Department of the Interior. 1994b. Endangered and threatened wildlife and plants; determination of endangered status for the tidewater goby. Fed. Reg. 59: 5494-5499.

U.S. Department of the Interior. 1997. Endangered and threatened species; threatened status for the southern Oregon/northern California coast evolutionarily significant unit coho salmon; final rule. Fed. Reg. 62(117): 33038-33039.

U.S. Department of the Interior. 2002. Endangered and threatened wildlife and plants; withdrawal of proposed rule to remove the northern populations of the tidewater goby from the list of endangered and threatened wildlife. Fed. Reg. 67(216): 67803-67818.

U.S. Environmental Protection Agency. 1998. Total Maximum Daily Load for Sediment, Redwood Creek, California. U.S. Environmental Protection Agency, Region 9. 60 pp.

U. S. Fish and Wildlife Service. 1960. Natural resources of northern California. Report appendix: a preliminary survey of fish and wildlife resources. U.S. Department of the Interior, Pacific Southwest Field Committee.

U.S. Fish and Wildlife Service. 1979a. Annual Report: Klamath River Fisheries Investigation, Progress, Problems and Prospects.

U.S. Fish and Wildlife Service. 1979b. A Review of the History and Status of Anadromous Fish Resources of the Klamath River Basin.

U. S. Fish and Wildlife Service. 1982. The Pacific coast American peregrine falcon recovery plan. 87 pp.

U.S. Fish and Wildlife Service. 1986. Recovery plan for the Pacific bald eagle. Fish and Wildlife Service, Portland, OR. 160 pp.

U. S. Fish and Wildlife Service. 1997. Recovery plan for the threatened Marbled Murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Portland, OR. 203 pp.

U.S. Fish and Wildlife Service. 2001. Western snowy plover (*Charadrius alexandrinus nivosus*) Pacific coast population draft recovery plan. Portland, OR. 630 pp.

U.S. Fish and Wildlife Service. 2003. Klamath River Fish Die-off September 2002: Causative Factors of Mortality. Report Number AFWO-F-02-03.

U.S. Geological Survey. 2001. Coastal Vulnerability to Sea-Level Rise: A Preliminary Database for the U.S. Atlantic, Pacific, and Gulf of Mexico Coasts. DDS-68.

U.S. Geological Survey. 2004. Water Resources Data California Water Year 2004. Volume 2: Pacific Slope Basins from Arroyo Grande to Oregon State Line except Central Valley Water-Data Report CA-04-2.

Van Kirk, S. 1994. Historical Information on Redwood Creek. Prepared for V. Ozaki, Redwood National Park.

Warburton, K. 2005. Effects of a wastewater outfall in a rocky intertidal community. M.S. Thesis. Humboldt State University, Arcata, CA. 58 pp.

Wheatcroft, R.A., C.K. Sommerfield, D.E. Drake, J.C. Borgeld, and C.A. Nittrouer. 1997. Rapid and widespread dispersal of flood sediment on the northern California margin. Geology 25: 163-166.

Wheatcroft, R.A. and J.C. Borgeld. 2000. Oceanic flood layers on the northern California margin, large-scale distribution and small-scale physical properties. Continental Shelf Research 20: 2163-2190.

Willis, C.M. and G.B. Griggs. 2003. Reductions in fluvial sediment discharge by coastal dams in California and implications for beach sustainability. Journal of Geology 111: 167-, 16p.

Wyrtki, K. 1975. Fluctuations of the dynamic topography in the Pacific Ocean. Journal of Physical Oceanography 5: 450-459.

Zeiner, D.C., W.F. Laudenslayer, Jr., K.E. Mayer, and M. White. 1990. California statewide wildlife habitat relationships system. California’s wildlife, 3 volumes. California Department of Fish and Game, Sacramento, CA.

Zhang, Y., J.N. Wallace, and D.S. Battisti. 1997. ENSO-like interdecadal variability 1900-93. Journal of Climate 10: 1004-1020.

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Appendix A: Exotic Marine Species Found in RNSP

HIGHER TAXON	GENUS	SPECIES	COMMON NAME
PHAEOPHYCEAE	SARGASSUM	MUTICUM	Japanese Wireweed
PORIFERA	CLIONA	CELATA	Yellow Boring Sponge
CNIDARIA	AURELIA	AURITA	Moon Jelly
CNIDARIA	OBELIA	DICHOTOMA	Sea Plume
POLYCHAETA	DODECACERIA	CONCHARUM	Small Black U Worm
POLYCHAETA	HARMOTHOE	IMBRICATA	Fifteen-scaled Worm
POLYCHAETA	SERPULA	VERMICULARIS	Red Calcareous Tube Worm
POLYCHAETA	SPIOPHANES	SP.	Bristle Worm
GASTROPODA	CREPIDULA	SP.	Slipper Snail
OPISTHOBRANCHIA	DENDRONOTUS	FRONDOSUS	Busy Backed Sea Slug
BIVALVIA	MYA	ARENARIA	Soft Shelled Clam
TUNICATA	BOTRYLLUS	TUBERATUS	Pacific Star Tunicate

As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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