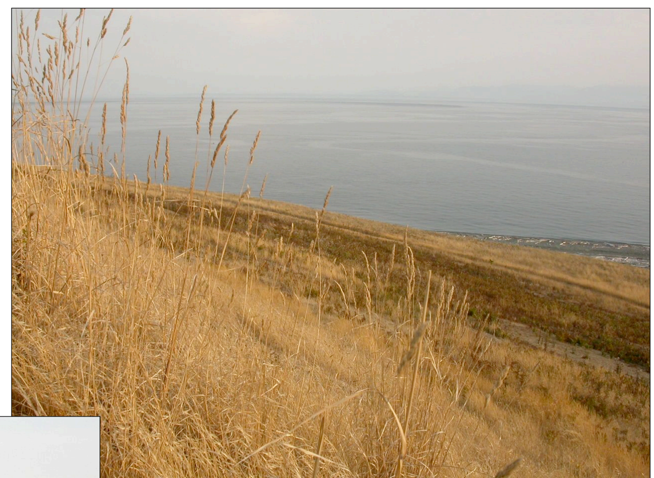
U.S. Department of the Interior

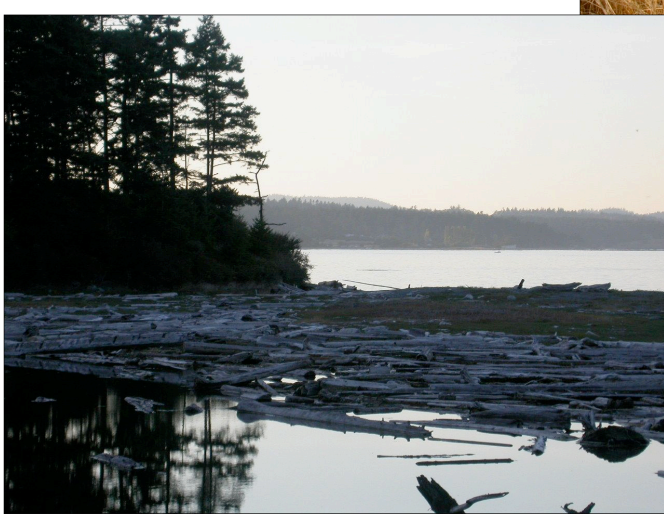
Water Resources Division
Natural Resource Program Center

Technical Report NPS/NRWRD/NRTR-2006/360

ASSESSMENT OF COASTAL WATER RESOURCES AND WATERSHED CONDITIONS AT SAN JUAN ISLAND NATIONAL HISTORICAL PARK

Dr. Terrie Klinger, Dr. David Fluharty, Kirsten Evans and Carrie Byron





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Top Right: American Camp, Terrie Klinger
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December 2006

This report was prepared under Task Order J9W88040014 of the Pacific Northwest Cooperative Ecosystems Study Support Unit (agreement CA9088A0008).

WATER RESOURCES DIVISION

National Park Service - Department of the Interior
Fort Collins - Denver - Washington

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Acknowledgements
We wish to thank the many people and institutions that have assisted us in preparing this report. Leigh Smith, Peter Dederich, Bill Gleason, Steve Fradkin, Kristen Keteles, Cliff McCreedy, and Mark Flora of the National Park Service all have been very helpful in guiding this work. Craig Dalby has generously provided assistance with GIS aspects of the project. For sharing data, we thank numerous state agency personnel, including Deborah Sargeant, Don Melvin, Jerry Borchert of the Washington Department of Health, Jennifer Whitney of Washington Department of Fish and Wildlife, personnel from the Washington Department of Natural Resources and the Washington Department of Ecology. Tina Whitman and others at Friends of the San Juans have been especially helpful in providing data and other information. Megan Dethier of the Friday Harbor Labs, UW, shared important data and information. Jill Coyle and Andrea Repetto provided technical assistance. The San Juan County Planning Department and the San Juan County Marine Resources Committee made files available to us. Others that provided helpful information include Kevin Ranker, San Juan County Commissioner; Jim Slocomb, Laura Arnold, and Jody Kennedy, San Juan County Marine Resources Committee; Rowann Talmon, WSU Extension Beachwatchers Program; Mark Billington, Westcott Bay Sea Farms; Jenny Roberts, FHL Science Outreach Program; Lori Larkin, SJC Conservation District; Vicky Heater, SJC Health Department; Kari Koski, The Whale Museum; and volunteers from the Islands Oil Spill Association.

Commonly used abbreviations

BMP – Best Management Practice
COASST – Coastal Observation and Seabird Survey Team
EPA – Environmental Protection Agency
FDA – United States Food and Drug Administration
FHL – Friday Harbor Laboratories
FHWA – Federal Highway Administration
FOSJ – Friends of the San Juans
GNOME – General NOAA Modeling Environment
HAB – Harmful Algal Bloom
HAZWOPER – Hazardous Waste and Emergency Response
MPN – Most Probable Number
NCDC – National Climate Data Center
NOAA – National Oceanic and Atmospheric Administration
NPS – National Park Service
NPS WRD – National Park Service Water Resources Division
NWFSC – Northwest Fisheries Science Center (National Oceanic and Atmospheric Administration)
PAH – Polyaromatic hydrocarbons
PSAMP – Puget Sound Ambient Monitoring Program
PSAT – Puget Sound Action Team
PSP – Paralytic Shellfish Poisoning
PSWQA – Puget Sound Water Quality Authority (now Puget Sound Action Team)

SAJH – San Juan Island National Historical Park
SMP – Shoreline Master Program
STORET – the Environmental Protection Agency's STOrage and RETrieval database for water quality, biological, and physical data sets contributed by state environmental agencies, EPA and other federal agencies, universities, private citizens, and many others.
TMDL – Total Maximum Daily Loads
USGS – U.S. Geological Survey
UW – University of Washington
WDOE – Washington Department of Ecology
WDFW – Washington Department of Fish and Wildlife
WDNR – Washington Department of Natural Resources
WRIA – Water Resource Inventory Areas
WSF – Washington State Ferries
WSU – Washington State University

Executive Summary

The purpose of this report is to provide a better understanding of the coastal water resources and watershed conditions of San Juan Island National Historical Park (SAJH). We review the existing literature and summarize what is known about the current condition of the coastal water resources of the park and the degree to which they may be affected by natural and anthropogenic factors. We summarize current water resource conditions and assess the current state of knowledge pertaining to specific environmental indicators and stressors. We identify information gaps where data are inadequate to fully assess resource condition, and offer recommendations for future studies both to fill information gaps and to facilitate resource management. While we focus on coastal resources, we consider watershed conditions and surface and groundwater in the adjacent watersheds where relevant.

San Juan Island National Historical Park is located on San Juan Island within the San Juan Archipelago, on the boundary between the United States and Canada in northern Washington State. It consists of two spatially discrete units, American Camp situated on the southeastern end of San Juan Island and English Camp tucked away in Westcott and Garrison Bays on the northwestern end of the island. The park was established by Congress in 1966 in commemoration of the Pig War of 1859 and the American and British occupation of the islands between 1852 and 1872. Congress authorized the National Park Service to acquire property on San Juan Island, “necessary for the purpose of interpreting and preserving the sites of the American and English Camps on the island, and of commemorating the historic events that occurred from 1852-1871 on the island in connection with the final settlement of the Oregon Territory boundary dispute, including the so-called Pig War of 1859” (80 Stat. 737).

The main focus of the NPS management of SAJH is on historic preservation and interpretation, however SAJH’s 1752 acres present geological, archeological, floral, faunal and scenic resources that offer increasingly significant opportunities for study, interpretation and recreation and these also require management (NPS 2004). The park itself consists of two large tracts of land, the English Camp unit of 529 acres fronting on the protected shores of Westcott and Garrison Bays and the American Camp unit of 1223 acres. The marine ecosystems surrounding these units and their 6.1 miles of shoreline are considered to be among the most scenic and intact in the continental United States. The natural assets and the historical significance of the SAJH attract more than 250,000 visitors each year – mostly during the summer months and on weekends. In addition, the park is located on an island that is part of one of the fastest developing counties and regions in the United States. Thus, the demand for preserved landscapes and open space for outdoor recreation is expected to continue to grow along with interest in national history.

Pleistocene glaciation profoundly shaped the onshore and offshore topography, to the extent that the landscape is readily identified by its rounded features and the location of glacial sediments. San Juan Island sits in the rain shadow of the Olympic Mountains and is drier than other areas of western Washington. There is considerable variation in micro-climate even within San Juan Island. This natural variability is reflected in the local vegetation, with grassy prairies in the dry American Camp area and western evergreens

and deciduous trees in the English Camp area. Freshwater areas exist in the form of numerous small wetlands in each area. Marine waters of SAJH include the protected Garrison and Westcott Bays adjacent to English Camp, as well as more exposed shorelines along Griffin Bay and the Strait of Juan de Fuca in American Camp, and three small lagoons on Griffin Bay.

Human occupation of the site dates back 6000 years based on evidence from shell middens at Cattle Point that show utilization lasting until the historic period. Most pre-European usage is thought to have occurred in the summer with fishing and shellfish gathering and processing (drying, smoking) by local tribes and their northern neighbors in present day Canada. The site of English Camp may have been a permanent residence of some Native Americans during the latter part of the period. Many of the U.S. Puget Sound tribes maintain "usual and accustomed" fishing rights under treaties signed with the U.S. government in the mid to late 1850s.

Captain Vancouver was the first explorer to visit the region in 1792. Following his lead, Europeans began settling in the region in the 1830s; by the 1850s it had become hotly contested by the British and the United States. The rate of settlement was slow in the archipelago as there were better lands with more reliable water located closer to markets. Even so, some sheep farmers and agriculturalists were attracted to the area. Limestone mining for cement and salmon fishing and canning were early industries that developed along with technology and access to markets (Johansen and Gates 1957).

Development in the San Juan archipelago was built on agriculture, mining, fishing and shellfish aquaculture. With summer tourism and summer residency, the San Juan Island Archipelago became increasingly popular. For a time, the limited ferry service and remoteness remained a significant barrier. However, with the advent of automobile tourism, greater discretionary income and more leisure time, tourism increased as did seasonal and year-round home building. Fueling the boom at present is the retiring post WW II generation looking for a slower paced lifestyle in an attractive location. These and other trends make SAJH vulnerable to additional recreation pressures and stresses from surrounding development, but also create opportunities to provide interpretation and education about the history, landscape and resources of the park (Flora and Fradkin 2004).

SAJH exists within the larger oceanographic setting of the eastern Strait of Juan de Fuca and the southern Strait of Georgia. The interior waters of the region are characterized by estuarine circulation driven primarily by discharge from the Fraser River through the Strait of Georgia, Haro Strait, and the Strait of Juan de Fuca. Discharge from the Skagit River drainage and Puget Sound provide smaller influences to the system. Semi-diurnal tides create swift tidal currents and these intense tidal flows cause intense vertical mixing, especially at sills. Freshwater resources on San Juan Island are limited by low rainfall and by the limited extend and capacity of local aquifers. Surface water resources in the vicinity of American Camp are minimal. At English Camp, surface water resources include a stream entering Westcott Bay to the north of the park boundary, and another entering Garrison Bay to the south of the park boundary. The Westcott-Garrison Bay

Watershed has been designated a priority watershed; San Juan County has developed but not adopted an action plan for the area.

The shorelines of both American Camp and English Camp are dominated by unconsolidated sediments interrupted by rocky platforms. Within American Camp, the southern shore consists primarily of sand, much of it covered with drift logs. At its southern end, the sandy shore is backed by a steep eroding bluff face. On the northern shore of American Camp, along Griffin Bay, the shore is mostly covered by gravel and cobble. On both shores of American Camp, shallow rocky bedforms are interspersed with soft-sediment areas. Shores within English Camp consist almost exclusively of unconsolidated sediment, mostly mud, some of which has a shallow anoxic horizon.

Biologically, the intertidal and subtidal communities are characteristic of the region. Three lagoons in American Camp comprise salt marsh habitat that is uncommon in the region. Forage fish spawn in some local areas where suitable sediments are found.

In this assessment, the key foci are on water quality data sources, water quality impairment, and sources of pollutants including non-point sources. In addition to water quality assessment, we examine other areas of concern including harmful algal blooms, non-native and invasive species, harvest and collection of organisms, habitat modification, shoreline development and zoning, water withdrawals, erosion, oil spills, land and water-based recreation, tsunami hazard and climate change as they relate to management of SAJH.

In this assessment, we used marine water quality data collected by state and other agencies, assessments of marine water quality drafted by federal, state and local agencies, and three previous assessments of marine water quality. The National Park Service Water Resources Division provided a Baseline Water Quality Inventory Report in 1995. Huxley College performed limited monitoring sufficient to provide an overview of water quality in 2000. The San Juan County Watershed Action Plan offers the results of stream and marine water quality sampling in the late 1990s. The majority of the marine water quality data were obtained from the Washington State Department of Ecology and Washington State Department of Health. The efforts of the Department of Ecology focused on water column profile, chemical contamination and plankton species, and the efforts of the Department of Health primarily focused on ensuring the safety of shellfish harvested for human consumption in commercial operations and recreation activities.

The current condition of the water-related coastal resources within SAJH is based upon an assessment of common ecological indicators and stressors including water quality (e.g., nutrients, dissolved oxygen, fecal bacteria, metals, and toxic contaminants), land use (e.g., development, agricultural activities, aquaculture, etc.), habitat modification (e.g., shoreline modification, coastal erosion, etc.), recreational use (e.g., boating, fishing, shellfish harvesting, collection of marine organisms, etc.), and other concerns such as the introduction of non-native invasive species, harmful algal blooms, and fuel and oil spills.

The condition of water resources in Westcott and Garrison Bays at English Camp is influenced by relatively low rates of flushing, seasonally high use by recreational boaters, and by land use practices in the watershed. These combine to cause potential and actual impairments to water quality in the vicinity of English Camp. Very limited sampling for nitrogen at the Roche Harbor Reservoir outlet stream showed elevated levels of nitrate. Additional inputs of nitrogen from agricultural sources, failing septic systems, and discharge of on-board holding tanks are likely to cause levels of nitrogen to be elevated to an unknown extent. Point estimates of fecal bacteria show that while levels tend to be acceptable under Washington Department of Health (WDOH) standards, they occasionally are highly elevated, causing an intermittent problem. Algal blooms have not been reported; however, highly elevated levels of PSP were detected on four occasions between 1992 and 1997, suggesting that algal blooms have occurred in the past. Algal blooms may be facilitated by relatively low flushing rates and occasional elevated nutrient levels in the Westcott-Garrison Bay system. Existing data are insufficient to determine whether metals currently are or could become problematic with respect to water quality. Toxicants are introduced into Westcott and Garrison Bays from agricultural, residential, boating, and biological sources.

Wastewater in Westcott and Garrison Bays comes from failing residential septic systems and from illegal discharge of holding tanks by recreational boaters and presents a potential source of impairment. Stormwater quality is not monitored in Westcott or Garrison Bay. Stormwater enters the bays from the surrounding watersheds through sheet flow, creek flow, and stream flow, carrying nutrients, fecal bacteria, and suspended solids from agricultural and residential areas and from county roads. One unnamed creek entering Westcott Bay was designated a category 5 polluted water body under state standards due to elevated levels of fecal coliform bacteria. Logging and residential landscaping within the watershed likely have altered natural filtration capacity, and may have increased impacts of stormwater runoff into the bays. In addition, agricultural operations have been identified by San Juan County as a likely source of elevated nutrients, biocides and fecal coliform bacteria in the area. Biocides from agricultural and residential landscaping applications and marine applications (e.g., boating, creosote logs) could present a potential problem in Westcott and Garrison Bays but the extent is not known. Relatively high levels of recreational boating in Westcott and Garrison Bays increase the likelihood that small fuel spills will occur within the bays, and oil from larger spills in Haro Strait could drift into the bays.

Habitat modification from logging and construction of residential homes has affected land cover, forest understory, and shoreline vegetation, all of which are known to affect associated ecological function. We note that shellfish aquaculture may affect water quality in Westcott and Garrison Bays, but we choose not to rate its impact. Shellfish aquaculture can improve water quality through biofiltration, and can reduce water quality through the addition of feces, pseudofeces, and through modification or disturbance to the benthic habitat. Aquaculturists have a strong economic incentive to maintain high water quality in the vicinity of operations and the facilities are monitored regularly. Sharp declines in eelgrass have occurred in Westcott and Garrison Bays since 1998. The cause of the decline has not yet been established, and cannot yet be linked to specific water quality impairments.

Other areas of concern have been identified as harmful algal blooms, non-native and invasive species, harvest and collection of organisms, recreation, shoreline modification and hardening, recreational boating and mooring buoys, shoreline development and zoning, water withdrawals, coastal erosion, marine debris, fuel and oil spills, tsunami hazards, and climate change. These areas of concern are consistent with the findings of 2001 SAJH Vital Signs Workshop.

The presence of harmful algal blooms has been noted for SAJH. It is likely that they present a growing threat to water quality at the regional level. Paralytic shellfish poisoning and domoic acid poisoning are of most concern and there is regular monitoring of shellfish operations and beaches around Puget Sound. Non-native and invasive species have been identified in marine and estuarine environments in the Puget Sound region. The main source is from shellfish growing, ballast water and intentional and unintentional sources. Non-native clams, oysters, mussels and an invasive seaweed, *Sargassum japonica,* are established within SAJH.

Harvest and collection of clams and crabs occurs in Westcott and Garrison Bays within the intertidal area of SAJH (but not in the English Camp historical area). Digging and trampling activities associated with these practices may have affected the abundance of the bent-nose clam. At American Camp there is limited shellfish gathering and crabbing but a commercial crab fishery co-managed by the state and tribes exists in Griffin Bay. Recreational use of the shoreline is popular and may result in trampling, causing declines in the abundance of the rockweed, *Fucus*.

Shoreline modification and hardening in SAJH includes the removal of shoreline vegetation in the parade ground area of English Camp and the existence of a small dock. Outside the boundaries of SAJH, shoreline habitats have been altered by removal of shoreline vegetation and construction of docks, but shoreline hardening is much less frequent than in other areas of Puget Sound. Eelgrass and seaweeds have been lost from areas covered by docks and other overwater structures. A shellfish farming operation covering 23 acres of subtidal bedland uses in-water culturing systems that result in some shading of the seabed.

Recreational boating and mooring buoys present possible problems associated with peak seasonal use. Boating activities can cause impacts to water quality through intentional or accidental introduction of sewage, hydrocarbons, metals, and biocides, increased turbidity and disturbance of benthic habitats in the process of anchoring or mooring.

Shoreline development and zoning can be a benefit to the long-term protection of water quality and water resources in SAJH. San Juan County has prepared a water assessment report and has drafted a marine habitat management plan and watershed management plan for Westcott-Garrison Bay and the County's Shoreline Master Program covers lands within 200 feet of the shore (above ordinary high water). The zone from shore to extreme low tide is a Conservancy Shoreline designation that is intended to protect intertidal resources. To date, the marine habitat and watershed draft plan has not been formally adopted.

Similar regulations apply to areas adjacent to American Camp, which is zoned for large land-use designations in the Griffin Bay area and Cattle Point areas, but where the density of development already exceeds these designations. The shoreline in the vicinity of American Camp lacks Conservancy Shoreline designation. The South Beach area north of American Camp has a five-acre lot size and the shoreline is designated Conservancy or Natural.

Water withdrawals present a difficult issue throughout the San Juan Islands because of the limited extent and capacity of the aquifers, their characteristically slow recharge rates, and their vulnerability to saltwater intrusion. English Camp may be affected somewhat by hydrologic alterations in the Westcott-Garrison Bay watershed. In American Camp, concerns include the vulnerable lagoons on Griffin Bay and the condition of one well within the park. Connections to aquifers serving nearby residential properties are not fully characterized, but residential water use could impact groundwater resources within the park.

To supplement ground water resources, a community adjacent to American Camp operates a desalinization facility for household use on an intermittent basis. The facility is located on Griffin Bay, immediately adjacent to the park boundary. When operating, the facility releases thermally enhanced hypersaline water into nearshore waters. The impacts of this discharge are unknown because no monitoring program exists.

Coastal erosion is a natural process in SAJH but can be accelerated by recreational activities and changes in shoreline uses, even those external to the Park areas. In American Camp the exposure of the county road is of current concern. Relocation of the road on the feeder bluffs could alter erosional processes and impact adjacent shorelines.

Deposition of marine debris is a constant problem but it is poorly documented. Greater concern exists for fuel and oil spills in the major shipping channels on the southern and western shores of San Juan Island. The shores of American Camp are particularly at risk because of 1) their location at the confluence of three significant marine traffic lanes; 2) local ocean circulation patterns that tend to accumulate floating material on the shore of South Beach; 3) circulation patterns that carry buoyant materials into San Juan Channel, where they can be trapped by eddies in southern Griffin Bay; 4) soft-sediment beaches, which will retain oil longer and be more recalcitrant to cleaning than rocky substrates; and 5) prevailing wind, current and wave conditions that make oil spill response logistically difficult. Westcott and Garrison Bays are at risk of small-scale fuel spills from recreational boats, and from larger oil spills that could occur in Haro Strait. Once inside Westcott and Garrison Bays, oil will tend to be trapped and could persist for long periods.

Tsunami hazards have been identified for the Cattle Point area adjacent to American Camp but the San Juan Islands are generally thought to be at low risk due to the high-bank nature of most of the shore. Sea level rise associated with climate change processes over the next 50-100 years could cause inundation of low-lying areas in English and American Camp resulting in the disappearance of the coastal lagoons in Griffin Bay and likely accelerating erosion along South Beach and the cliffs at the eastern end of the beach.

Review of the existing data and information concerning water resources in SAJH leads us to conclude that there are considerable gaps in the data that prevent full assessment of the trends in water quality and water resources. Consequently, our recommendations include suggestions for closing data gaps, especially those pertaining to water resources that could become impaired in the near-to-mid-term. Our recommendations are stated in summary form immediately below. The order in which the recommendations appear does not reflect relative importance or urgency.

Table i. Potential for impairment of SAJH water resources.

Stressor / Environmental Indicator	**English Camp:** Westcott-Garrison Bay	**American Camp:** Griffin Bay	**American Camp:** Strait of Juan de Fuca	**American Camp:** Coastal Lagoons
WATER QUALITY INDICATOR				
Nutrients	**PP**	**PP**	**OK**	**PP**
Dissolved Oxygen	**PP**	**OK**	**OK**	**OK**
Fecal Bacteria	**EP**	**OK**	**OK**	**OK**
Toxic Compounds	**PP**	**OK**	**PP**	**OK**
LAND USE-RELATED STRESSORS				
Septic / Wastewater / Effluent	**PP**	**OK**	**OK**	**PP**
Water Withdrawals	**OK**	**PP**	**PP**	**PP**
Stormwater Runoff	**EP**	**OK**	**OK**	**OK**
Agricultural Runoff	**PP**	**OK**	**OK**	**OK**
Aquaculture	**PP**	**OK**	**OK**	**NA**
HABITAT MODIFICATION				
Shoreline Modification	**PP**	**PP**	**OK**	**OK**
Coastal Erosion	**OK**	**OK**	**PP**	**OK**
RECREATIONAL USAGE				
Boating	**EP**	**PP**	**EP**	**NA**
Fishing	**OK**	**OK**	**OK**	**NA**
Shellfish Harvesting	**PP**	**OK**	**OK**	**NA**
OTHER STRESSORS/INDICATORS				
Non-Native / Invasive Species	**PP**	**PP**	**OK**	**PP**
Harmful Algal Blooms	**PP**	**EP**	**OK**	**PP**
Fuel / Oil Spills	**PP**	**PP**	**PP**	**PP**
Marine Debris	**OK**	**PP**	**PP**	**OK**

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, shaded=limited data

Table ii. Recommendations

English Camp

- Work with San Juan County to encourage adoption and implementation of the Westcott-Garrison Bay Watershed Management Plan
- Pursue partnerships with local and state entities for collaborative management of Westcott-Garrison Bay aquatic resources
- Work with local and state entities to educe impacts of recreational boating in Westcott-Garrison Bay
- Monitor nutrients, dissolved oxygen, and fecal coliform in Westcott-Garrison Bay regularly
- Partner with others to monitor eelgrass declines in Westcott-Garrison Bay; consider eelgrass restoration
- Measure the introduction of fecal bacteria from the English Camp parade ground to Garrison Bay. Consider management options that would reduce fecal loading from the parade ground to the bay if loads exceed NPS, regional, or local standards.

American Camp

- Address groundwater withdrawals and saltwater intrusion in American Camp
- Develop and implement a monitoring program for the coastal lagoons and immediately adjacent areas of Griffin Bay (for example, Fish Creek)
- Partner with others to encourage responsible boating practices and wildlife viewing practices in American Camp, particularly with regard to killer whales
- Work to reduce impacts of road building on the nearshore environment at Cattle Point

Parkwide

- Partner with the Islands Oil Spill Association to update oil spill contingency planning for English and American Camps; track the Washington State oil spill contingency plan rule update process and outcome
- Promote research into issues identified at the NPS Vital Signs workshop
- Encourage basic and applied research by University of Washington and other investigators; develop guidelines for the conduct of scientific research in park areas
- Develop management plans for aquatic invasive species, or partner with local and state agencies to manage aquatic invasives

A. Park and Regional Description

A.1. Background

A.1.a. Setting

San Juan Island National Historical Park (SAJH) was established by Congress in 1966 in commemoration of the Pig War of 1859 and the American and British occupation of the islands between 1853 and 1972. Congress authorized the National Park Service to acquire property on San Juan Island, "necessary for the purpose of interpreting and preserving the sites of the American and English Camps on the island, and of commemorating the historic events that occurred from 1852-1871 on the island in connection with the final settlement of the Oregon Territory boundary dispute, including the so-called Pig War of 1859" (80 Stat. 737). Prior to Congressional action the military portions of the area had been placed on the National Historic Register and had been acquired by the Washington State Parks system. Accordingly, the primary focus of management within SAJH has been historic preservation and interpretation. However, in the face of increasing population growth and suburbanization of the archipelago, the 1752 acres preserved within the park now encompass significant geological, archeological, floral, faunal and scenic resources that are being lost elsewhere. Consequently, park areas offer increasingly significant opportunities for study, interpretation and recreation, and these activities require management that extends beyond historic preservation and interpretation (NPS 2004).

SAJH is located in the San Juan Archipelago situated to the north of Puget Sound, between the eastern Strait of Juan de Fuca and at the southern Strait of Georgia (Figures 1 & 2). This area, sometimes called the Salish Sea or Whulge, is made up of about 800 islets and 370 miles of tidelands (http://www.nps.gov/sajh/naturescience/index.htm).
The park itself consists of two large tracts of land. English Camp occupies 529 acres near the northern end of the island, with shorelines along Westcott Bay and Garrison Bay (also here referred to as Westcott-Garrison Bay). American Camp occupies 1,223 acres at the southern end of the island, bounded to the north by Griffin Bay and to the south by the eastern Strait of Juan de Fuca (Figures 3 & 4). The marine ecosystems surrounding these units and their 6.1 miles of shoreline are highly valued and have historically supported a rich biota. However, the park is embedded within a county and region that are among the fastest growing in the United States. Consequently, the demand for and value of preserved landscapes and open space for outdoor recreation will continue to grow.

The San Juan Islands are heavily influenced by the Pleistocene glaciation with the last event occurring about 16,400 years ago (Haugerud et al. 2003), as evidenced by the sandy soils and the glacier polish on exposed rock outcroppings. Situated in the Puget Sound lowland, the area is also considered seismically active and exposed to potential tsunami hazards. The prevailing climate is coastal and mild with rainfall most abundant in the winter.

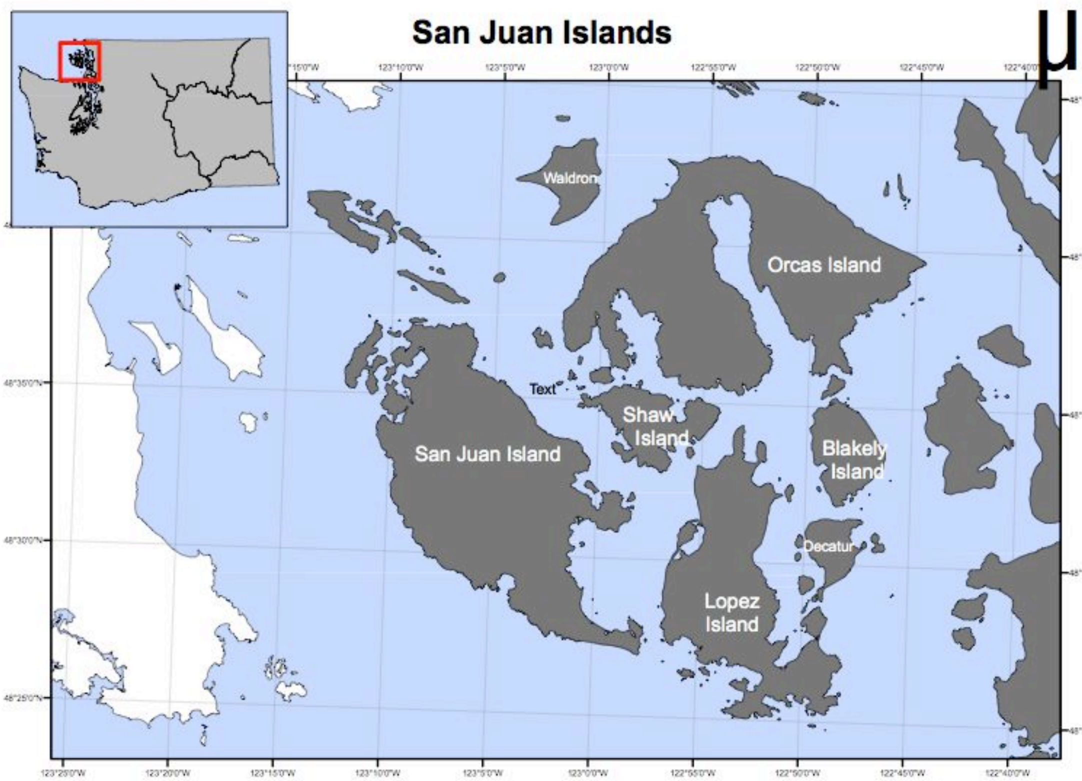


Figure 1. Regional setting of San Juan Island.

Rainfall is lower than the Puget Sound average due to the rain shadow effect of the Olympic Mountains but even local climate can be affected. For example, English Camp records 26-28 inches of rain annually while American Camp is a dry 17 inches annually (Flora and Fradkin 2004). The terrain is varied; high relief and steep slopes are associated Mt. Finlayson in American Camp and Young Hill in English Camp. American Camp consists mostly of grassy prairie although on the western boundary and on the north slope of Mt. Finlayson there are forests. English Camp is mostly forested with second and third growth western evergreens and some large big leaf maples (*Acer macrophyllum*), madrona (*Arbutus menziesii*), and the rare Garry oak (*Quercus garryana*) in areas with suitable conditions.

Surface waters in American Camp are limited to a few springs and 26 wetland areas that together cover about 80 acres. English Camp has nine wetland areas totaling about 13 acres (Holmes 1998). The shorelines along the north shore of American Camp are composed of gravel. Three lagoons occur along Griffin Bay, one of which (Jakle's Lagoon) has good circulation and is relatively high in productivity. The south shore of American Camp is much more exposed to the prevailing winds and consists of jutting headlands and gravel pocket beaches on the west that grade into a long sandy beach toward the east and returns to rocky headlands at Cattle Point. In contrast, English Camp is located along

Garrison and Westcott Bays, characterized by shallow, very protected waters with mostly low relief shorelines with considerable vegetative cover.

Figure 2. San Juan Archipelago and surrounding region.
Source: http://www.gulfislandsnationalpark.com

A.1.b. Site History

Following delineation of the boundary between the United States and Canada (British Territory), settlers occupied San Juan Island and took up residence in many of the former military buildings. It was not until 1904 that special efforts were made to mark the sites for their historic value. In 1935 the NPS surveyed the San Juan Islands for designation as a National Seashore Recreation Area and decided that they were worthy of that designation. Beginning in 1951, the State of Washington began purchasing key historic sites through the

Washington State parks and Recreation Commission. By the late 1950s the Washington Congressional delegation was introducing bills into Congress for recognition of the historic areas as a National Monument under NPS management. The NPS again sent two additional survey teams to assess the merits of these proposals in 1959 and 1961. Washington State firmly supported these proposals. The site was accorded National Historic Landmark status in 1961.

A.1.c. Human Utilization

Shell middens at Cattle Point show evidence of Native American occupation dating back 6000 years and lasting until the historic period. The earliest remains show primary use of terrestrial animals and plants but not marine shells, fish or marine mammals. Use of marine resources apparently came several thousand years later. Evidence exists to indicate that English Camp may have been occupied relatively recently by Native Americans and was possibly the site of a winter village. Guss Island in Garrison Bay is a known sacred and ceremonial site for the Lummi tribe and has been closed to entry by the NPS since SAJH was established. It is likely that Cattle Point, which is more exposed but located close to productive fishing grounds, was a sporadically used seasonal fishing camp (Stein 2000). Throughout the San Juan Archipelago there exist remains of Native American habitation. Most usage is thought to have occurred in the summer, consisting primarily of fishing and shellfish gathering and processing [drying, smoking] by tribes from North Puget Sound and present-day British Columbia. Many of the US tribes maintain "usual and accustomed" fishing rights under treaties signed with the U.S. government in the mid- to late 1850s.

Captain Vancouver in 1792 was the first explorer to visit the region (Johansen and Gates 1957). Already in the 1830s Europeans were settling in the region, the ownership of which became hotly contested by the British and the United States. A boundary delineation in 1846 was intended to resolve the disputes but settlers argued about boundaries with respect to the San Juan Archipelago. By the early 1850s the Hudson Bay Company had established a trading post at what later became known as American Camp where sheep were raised and a large vegetable garden was maintained. United States residents of Oregon Territory were eligible to stake homesteads and under the Donation Land Law, although many simply occupied the land or took over others claims. Uncertainty about land tenure during the so-called Pig War (1859) and the extended joint occupancy of the San Juan Islands that followed slowed but did not stop development. Settlement continued once the boundary issue was settled in favor of the U.S. The rate of settlement in the archipelago was slow because elsewhere there existed better lands with more reliable water and located closer to markets. Even so, some sheep farmers and agriculturalists were attracted to the area. Limestone mining for cement and fishing were early industries that developed along with technology (e.g., fish canning) and access to markets (Johansen and Gates 1957).

The economic base in the San Juan Archipelago was built from agriculture, mining, fishing and shellfish aquaculture. Remoteness and limited accessibility kept the numbers of residents and visitors low for several decades. More recently, seasonal tourism and vacation-residency have become increasingly popular, and now these activities, and the construction trade that accompanies them, account for a major fraction of the local economy. Accompanying growth in tourism and leisure is growth in residency among retirees looking for a slower paced lifestyle in an attractive location. Concomitantly, mining has ceased and it has become increasingly difficult to compete in agriculture. Declines in salmon and other fish stocks and changes in fisheries regulations have sharply reduced commercial fishing within the archipelago. These and other trends expose SAJH to growing recreational use by residents and visitors, while development in surrounding areas render the resources of the park increasingly valuable as areas for interpretation and education (Flora and Fradkin 2004).

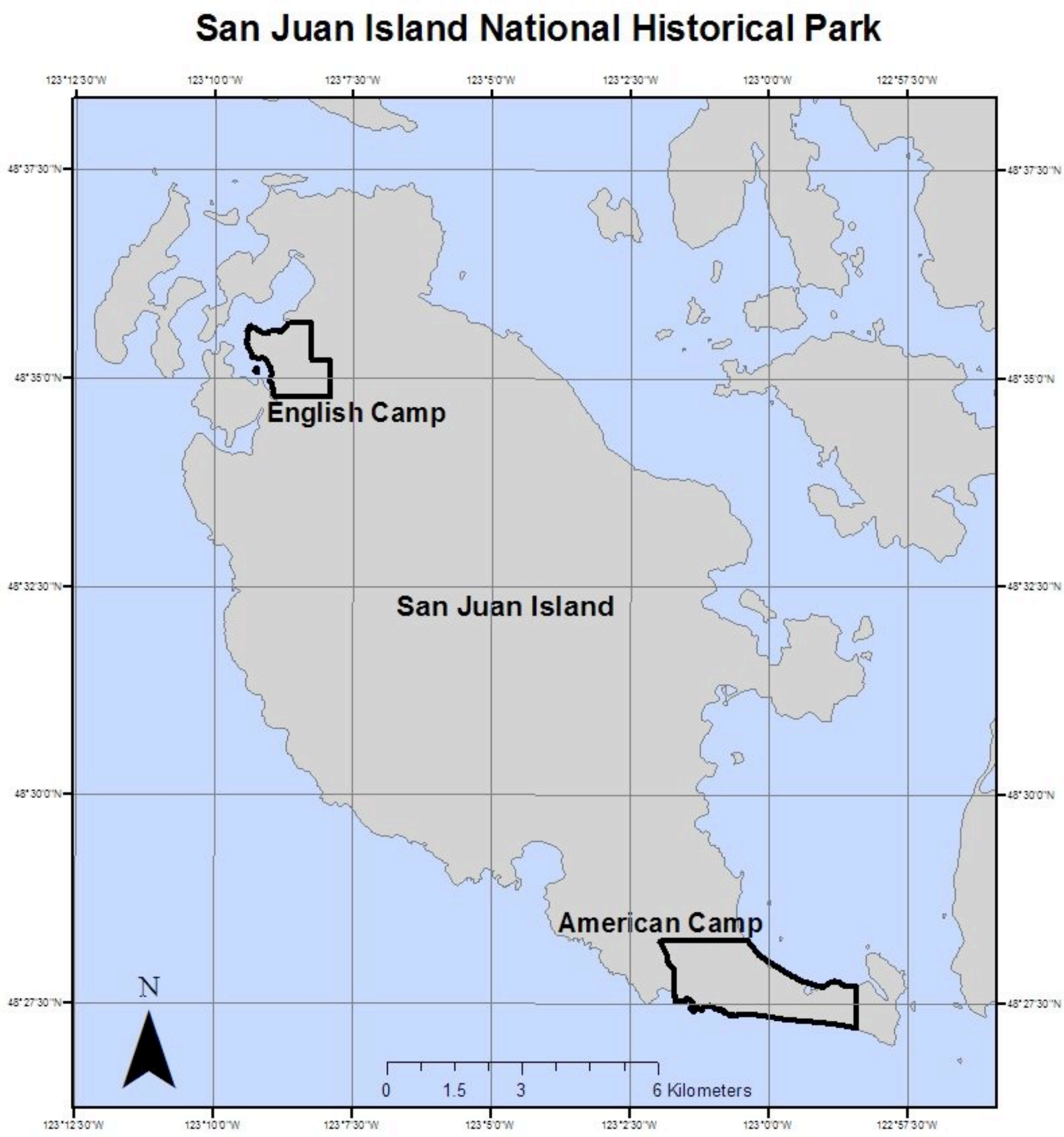
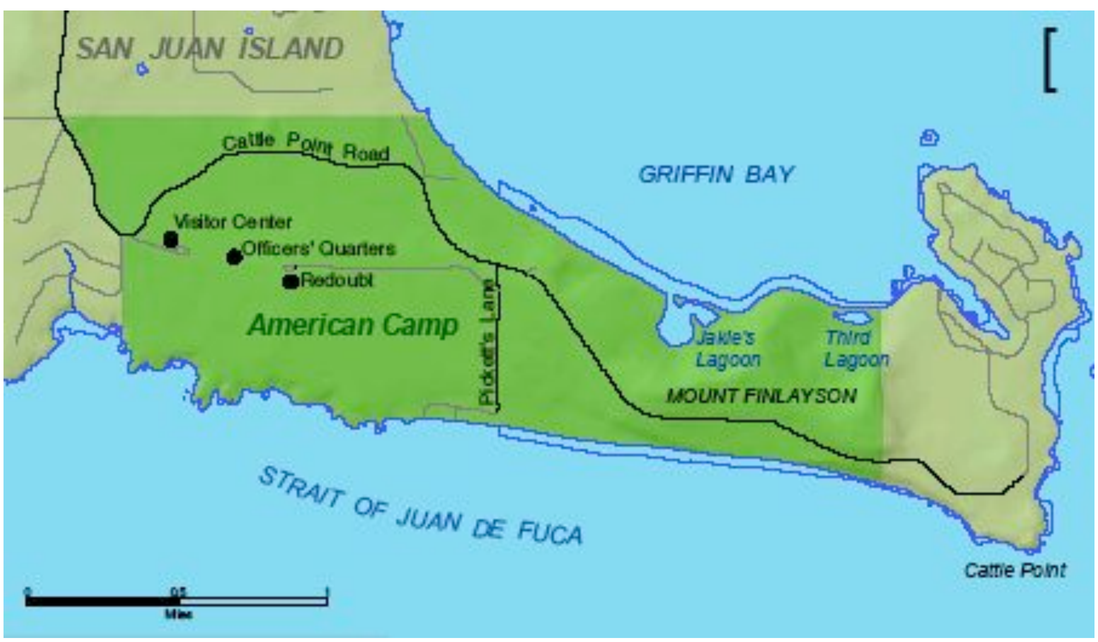


Figure 3. Location of English and American Camp units of SAJH on San Juan Island.



Figures 4a (above) and 4b (below). English Camp and American Camp units of SAJH, Source: Flora and Fradkin 2004

A.2. Hydrologic Information

A.2.a. Oceanographic Setting

SAJH exists within the larger oceanographic setting of the eastern Strait of Juan de Fuca and the southern Strait of Georgia (Figure 5). The region was carved by glaciers and sub-glacial erosion. Boulder moraines deposited by glaciers now form sills that divide the region into three submarine basins: the western Strait of Juan de Fuca, stretching from the Pacific Ocean in the west to the Victoria-Green Point Sill in the east; the eastern Strait of Juan de Fuca and Haro Strait, reaching from the Victoria-Green Point Sill to the Boundary Pass Sill; and the Strait of Georgia, extending northward from the Boundary Pass Sill. The Victoria-Green-Point Sill has a minimum depth of about 55 m; the Boundary Pass Sill is somewhat deeper, with a minimum depth of about 150 m. The sills influence circulation within and between the three basins. The interior waters are connected to the coastal ocean via the western Strait of Juan de Fuca (Matsuura and Cannon 1997). The coastal ocean here is influenced by large-scale oceanographic features associated with the North Pacific Gyre, including the California, Alaska, and Davidson currents, and is characterized upwelling, downwelling, and complex eddy fields.

The interior waters are characterized by estuarine circulation driven primarily by discharge from the Fraser River through the Strait of Georgia, Haro Strait, and the Strait of Juan de Fuca (Cannon 1978, Thomson 1981; Masson and Cummings 2000). Discharge from the Skagit River drainage and Puget Sound provide smaller influences to the system. The period of maximum discharge from the Fraser River occurs in May and June, with minimal discharge from December through March. The long-term average near-surface flow through the region is seaward (Cannon 1978, Holbrook et al. 1980, Thompson 1981), with an estimated speed of 6 km/day through Juan de Fuca Strait (Pashinski and Charnell 1979). The seaward flow of surface water is opposed by a landward flow of oceanic water at depth, some of which is mixed with surface water as it passes over the relatively shallow sills that separate the basins (Ebbesmeyer and Barnes 1980; Holbrook et al. 1980, Cannon and Bretschneider 1986; Crean et al. 1988, LeBlond et al. 1994).

Periodic reversals of the typical estuarine flow patterns are known to occur. During these episodes, oceanic surface waters are injected considerable distances into Juan de Fuca Strait. Flow reversals occur infrequently throughout the year; they are most often associated with winter storm events lasting approximately 1-10 days (Thomson 1981; Holbrook and Halpern 1982; Ebbesmeyer et al. 1995).

Mixed semi-dirunal tides create swift tidal currents that reach speeds of several knots. Intense tidal flows cause vigorous vertical mixing, especially at sills (Griffin and LeBlond 1990, LeBlond et al. 1994, Masson and Cummings 2000) and create tidal eddies that entrain and redistribute buoyant and suspended particles (Ebbesmeyer et al. 1991). Tidal forces tend to dominate circulation over periods of less than 10 hours; other forces dominate over longer periods.

The San Juan Archipelago

The San Juan Archipelago (SJA) is situated between the Victoria and Boundary Pass Sills, and is bounded on the west by Haro Strait and on the east by Rosario Strait. The SJA consists of hundreds of small islands and several larger islands, the largest of which (San Juan and Orcas) exceed 50 sq. mi. The islands are characterized by steep, rocky shores interspersed with cobble or sand beaches of shallower aspect. The subtidal topography typically is steep, reaching depths of more than 100 m within 1/2 mile of shore. Deep offshore areas are typically covered by depositional sediments.

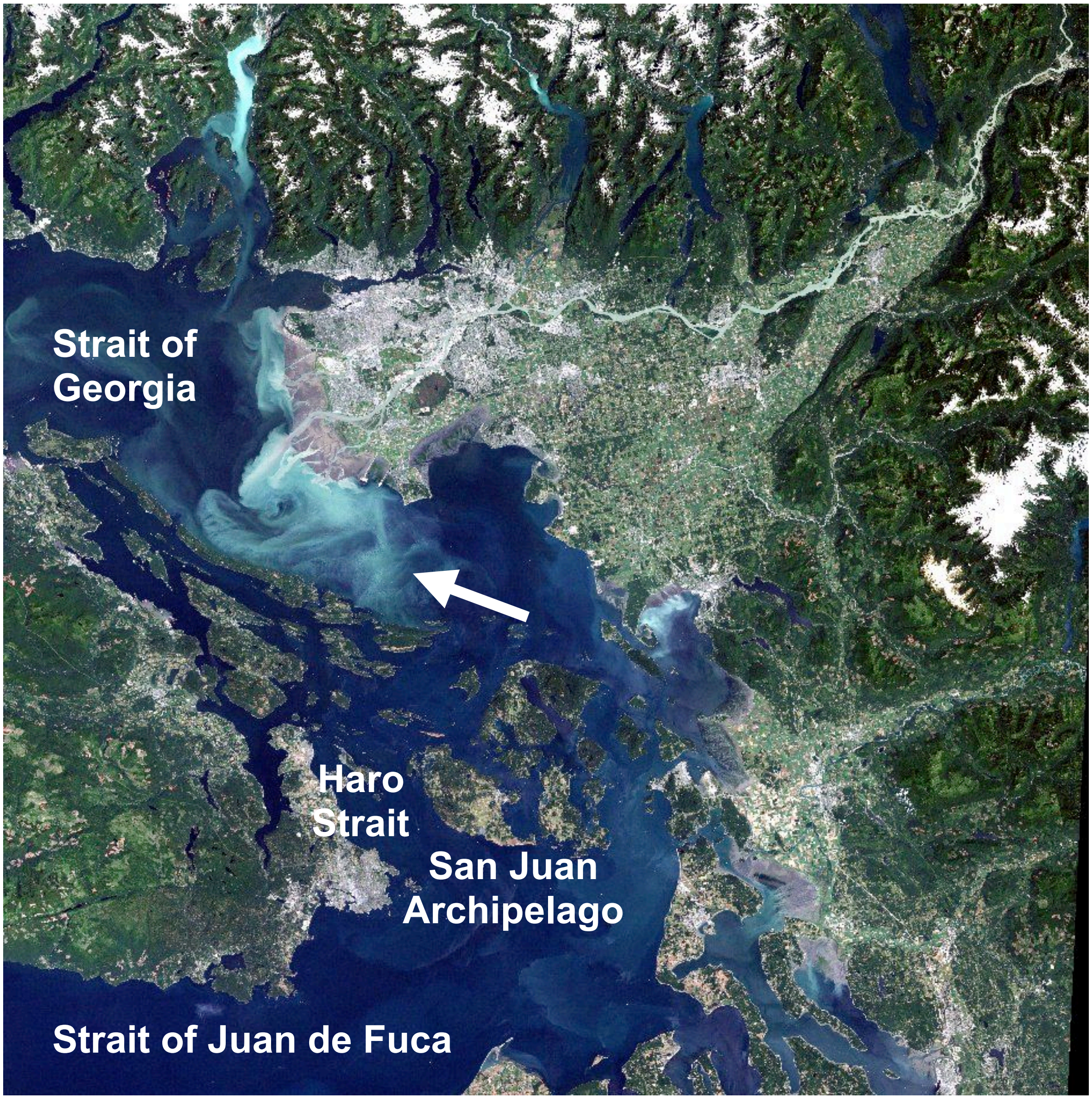


Figure 5. Regional oceanographic setting of the San Juan Archipelago. The Fraser River plume is conspicuous to the north of the archipelago (arrow).

Tidal channels running through and around the SJA serve to link the Straits of Georgia and Juan de Fuca. In addition to Haro and Rosario Straits, these include the San Juan and Middle Channels, situated between San Juan and Lopez Islands. Haro Strait is the deepest of the three channels and carries the greatest volumes of water. Flow volumes through Haro Strait are more than double those through Rosario Strait, and about 10 times greater than those through the San Juan and Middle Channels (Parker 1977; Crean et al. 1988).

These water bodies exert unequal influences on SAJH, according to site location and orientation. The southern and western shores of American Camp are most strongly influenced by oceanographic processes in the eastern Strait of Juan de Fuca and Haro Strait; the eastern shores of American Camp are dominated by processes occurring in the San Juan Channel; and the shores of English Camp are influenced by processes occurring in Haro Strait and the southern Strait of Georgia, although these are highly modified by local processes that occur within the embayment.

A.2.b. Hydrology and Nearshore Processes
The climate of the San Juan Archipelago is maritime and characterized by cool dry summers and moderately wet winters (Orr et al. 2002). Average air temperatures vary from about 40^{o} – 65^{o} F. Precipitation varies with location (Figure 6). Southern areas on San Juan Island are among the driest in the archipelago, averaging only about 17-19 inches per year in the vicinity of American Camp. Northern areas receive substantially more precipitation, averaging about 32-34 inches per year in the vicinity of English Camp. Most precipitation occurs during the winter months, with summer months being comparatively dry.

The geology of San Juan Island is characterized by sedimentary and volcanic bedrock overlain by unconsolidated glacial sediments of varying thickness (Figure 7). Glacial sediments are approximately 100 feet thick in the region of American Camp, but less than 20 feet thick in the vicinity of English Camp (San Juan County 2000). When saturated, glacial sediments can store large amounts of ground water. Ground water is substantially less abundant in bedrock, accumulating only in fractures and joints. An average rate of groundwater recharge of 1.99 inches/year was calculated for San Juan Island, based on simulations using the deep percolation method (Orr et al. 2002). According to the model, recharge rates are more closely related to the amount of area covered by glacial deposits than to actual precipitation rates. Consequently, areas with comparatively low annual precipitation can exhibit high recharge rates. This condition applies on Lopez Island, which is comparatively dry but has a high percent cover of glacial deposits (Orr et al. 2002); a similar case may exist on southern San Juan Island in the vicinity of American Camp, where thick glacial deposits exist. An aquifer recharge map published by San Juan County indicates American Camp as an area of significant recharge (Figure 8). The spatial distribution of simulated average annual recharge for San Juan Island, calculated using the deep percolation method, is shown in Figure 9, and the distribution of hydric soils is shown in Figure 10.

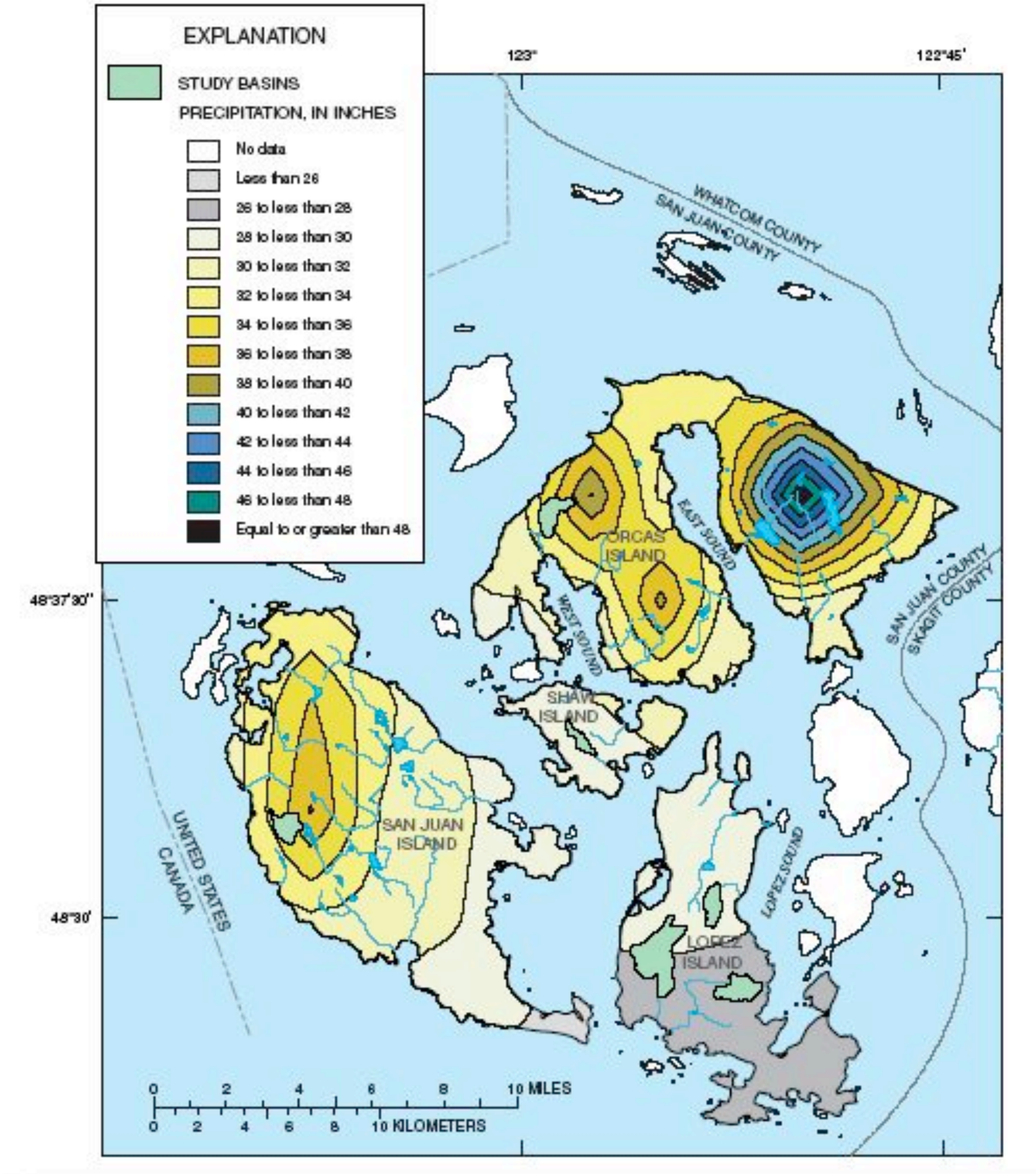


Figure 6. Average annual precipitation in the San Juan Archipelago, 1961-1990.
Source: Orr et al. 2002; http://pubs.usgs.gov/wri/wri024114/

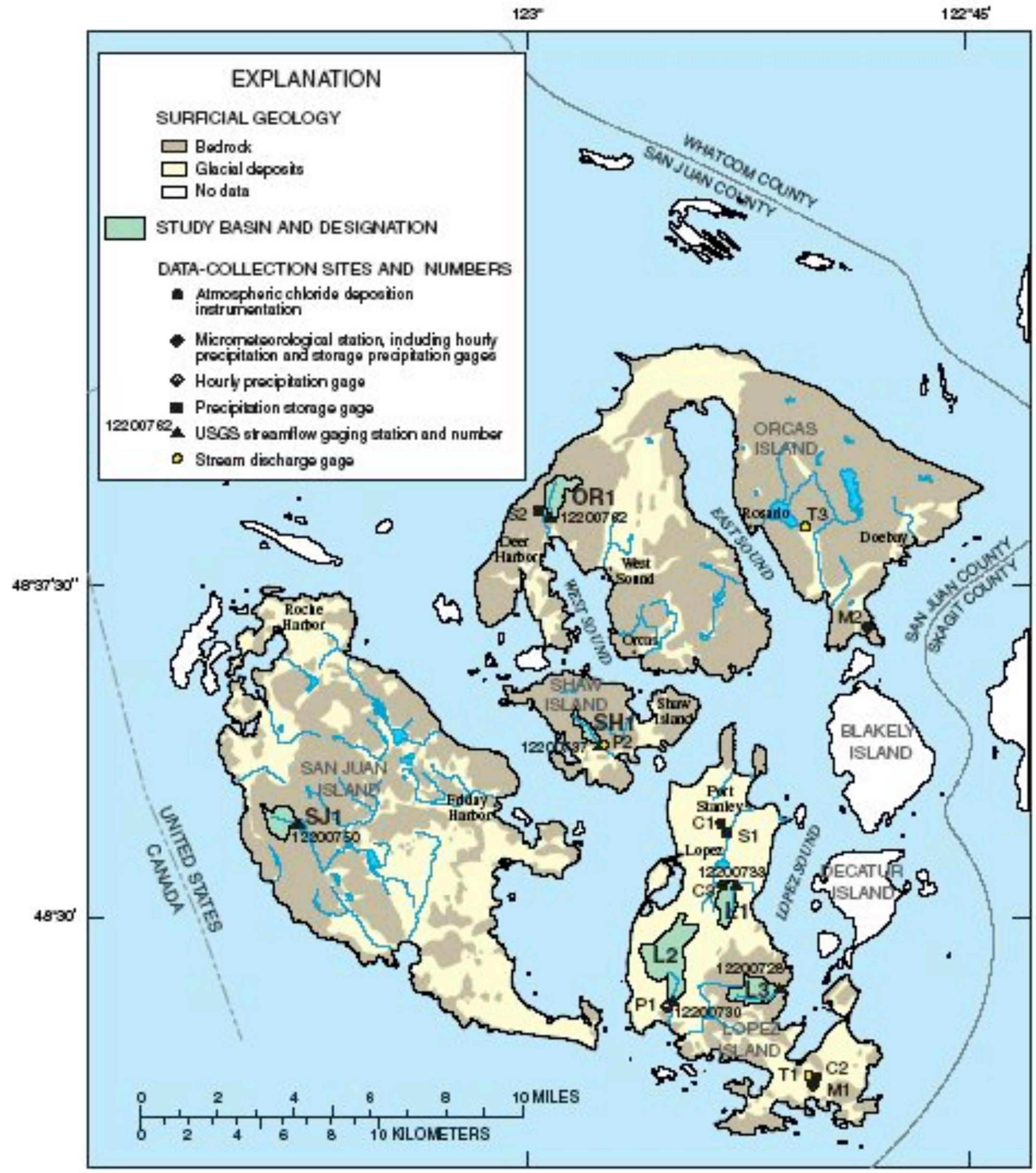


Figure 7. Generalized surficial geology of the San Juan Archipelago.
Source: Orr et al. 2002; http://pubs.usgs.gov/wri/wri024114/

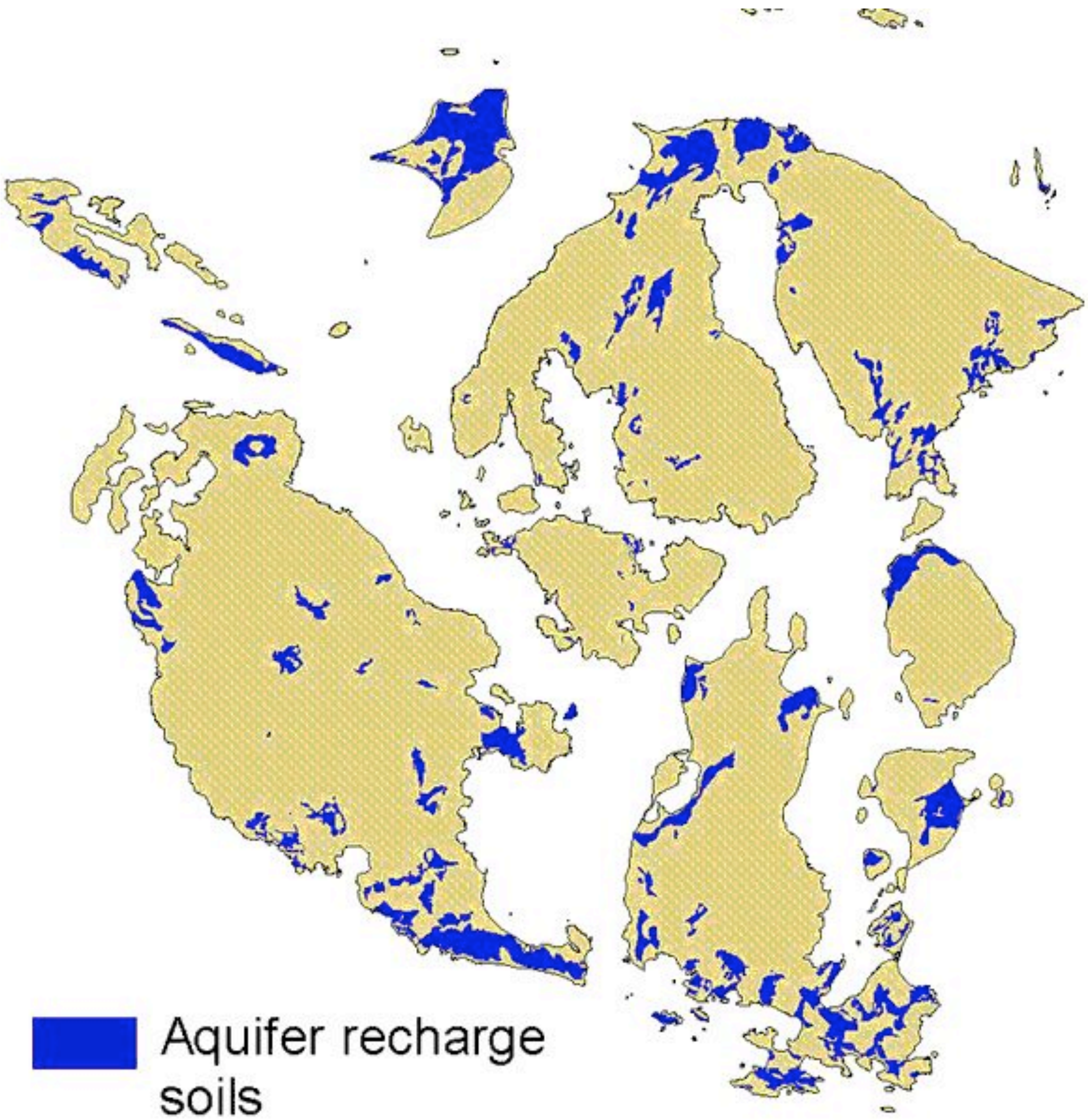


Figure 8. San Juan County Priority Aquifer Recharge Soils
Source: San Juan County Watershed Management Committee
http://www.co.san-juan.wa.us/Health/wtrshdpln/index.html

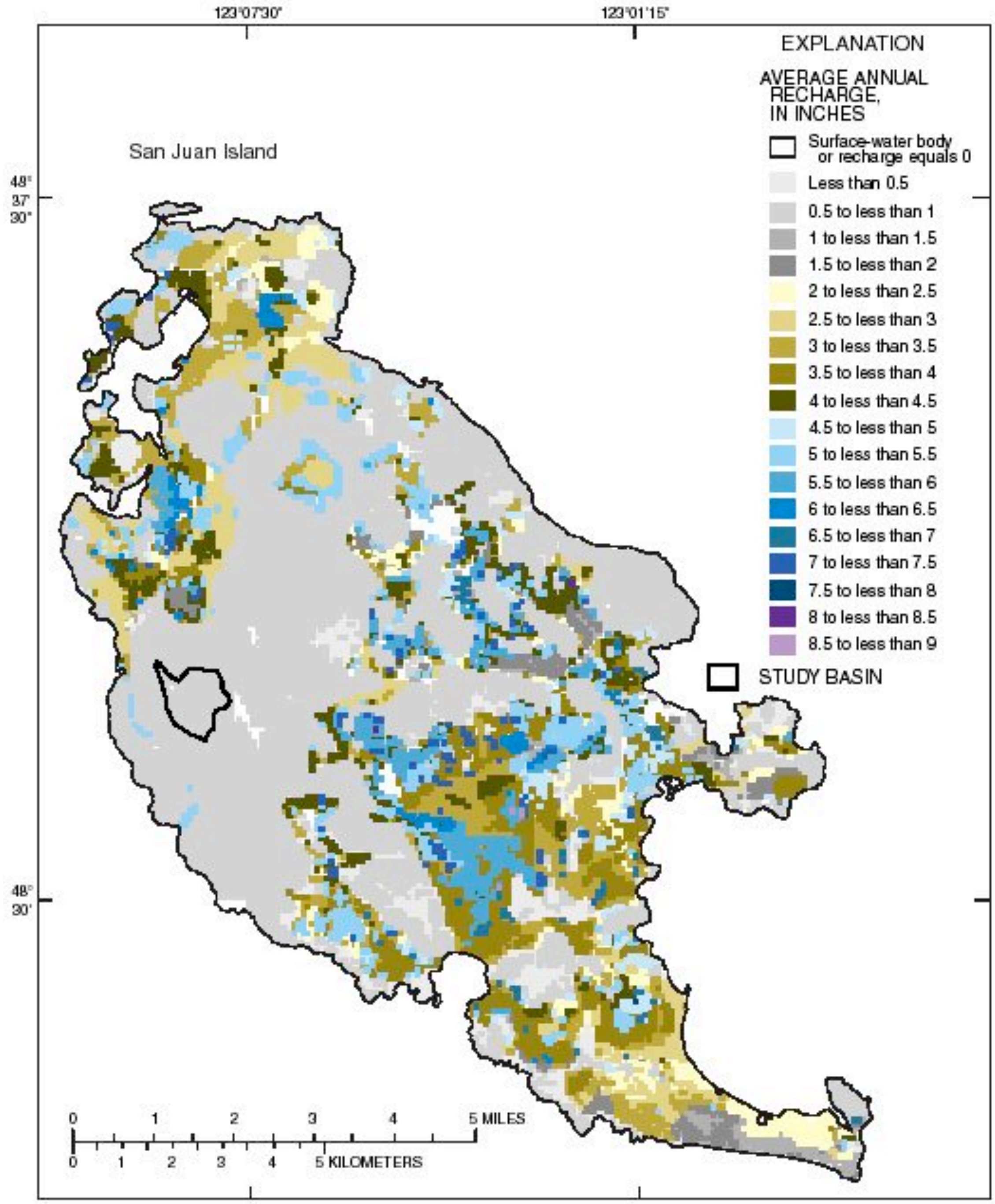


Figure 9. Spatial distribution of simulated average annual recharge for San Juan Island, for water years 1997-98.
Source: http://pubs.usgs.gov/wri/wri024114/

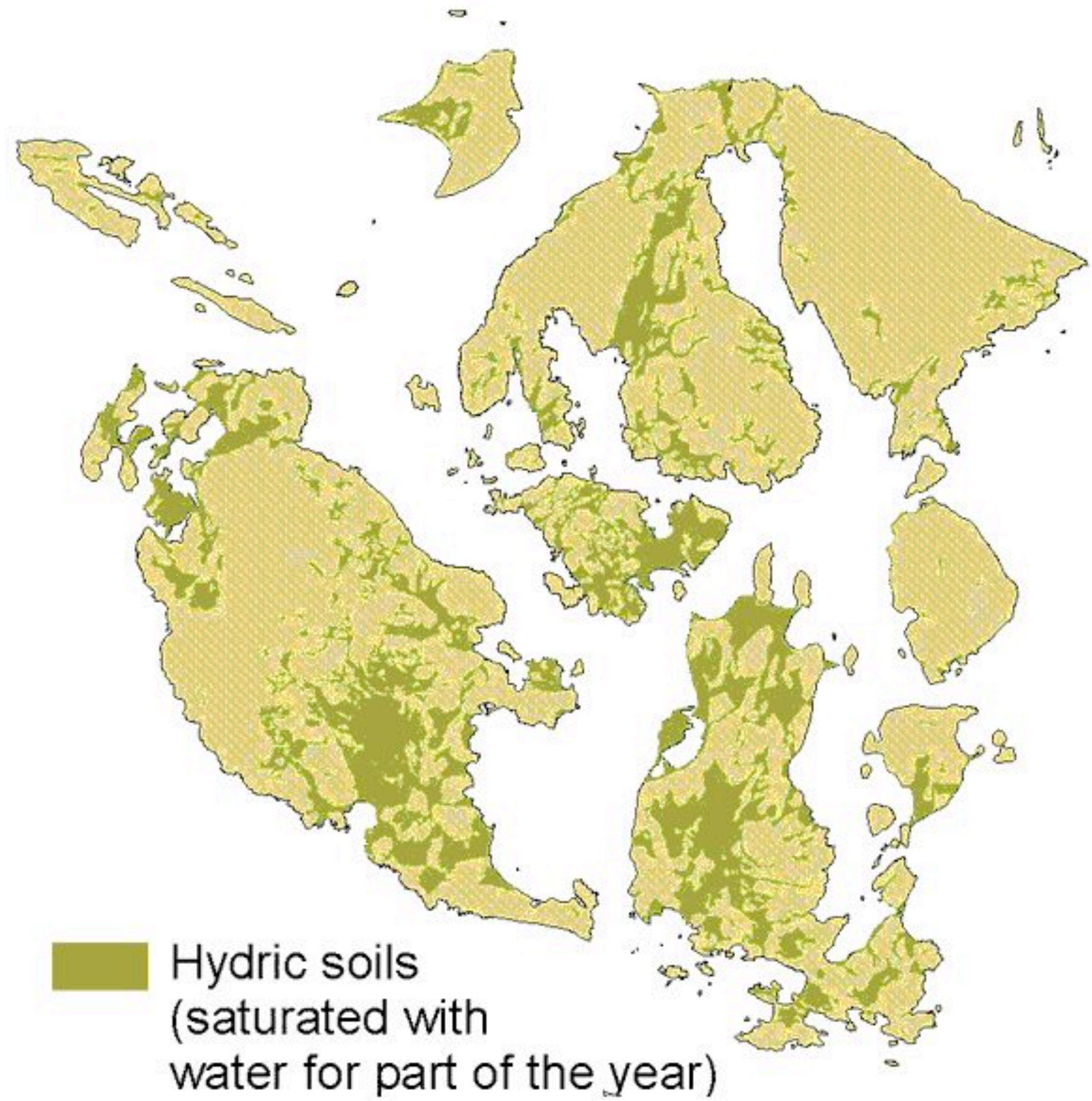


Figure 10. San Juan County Hydric Soils
Source: San Juan County Watershed Management Committee
http://www.co.san-juan.wa.us/Health/wtrshdpln/index.html

A.2.c. Water Resources

Watersheds are delineated by the US Geological Survey using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 sub-regions, 352 accounting units, and 2262 cataloguing units. A hierarchical hydrologic unit code (HUC) consisting of 2 digits for each level in the hydrologic unit system is used to identify any hydrologic area. The 6 digit accounting units and the 8-digit cataloguing units are generally referred to as basin and sub-basin, respectively. HUC is defined as the Federal Information Processing Standard (FIPS) and generally serves as the backbone for the country's hydrologic delineation. However, the HUC system is only rarely used in Washington State because the system is at variance with the State's Water Resource Inventory Area (WRIA) system, which pre-dates the HUC system and is mandated by statute. Washington's WRIA system, developed by the state in the 1960s, specifies 25 WRIAs in Washington's coastal zone; in comparison, the HUC system identifies 28 HUC-8 watersheds in the same region. San Juan County is one several cases in which the HUC-8 watershed and the WRIA are identical. The entire county comprises HUC 17110003 and WRIA 2.

Water resources within SAJH are predominantly marine, consisting of the marine shorelines along the Strait of Juan de Fuca and within Griffin Bay (in American Camp) and the shorelines of Westcott and Garrison Bays (in English Camp). Freshwater resources on San Juan Island are limited (Figure 11). According to Holmes (1998), no significant sources of freshwater exist within SAJH. However, small springs and seeps, intermittent streams, and other small wetland areas are present. Holmes (1998) reportedly mapped 79.2 acres of wetland in American Camp and 12.7 acres in English Camp. These values are significantly larger than those reported in the National Wetlands Inventory (Appendix A). The discrepancies may be attributable to different scales of investigation.

In American Camp, surface water is limited to a few small springs on the southern slopes evidenced by patches of willow (Figure 12). Other water resources within American Camp include a small freshwater pond on the north slope of Mt. Finlayson that in some years is filled with vegetation, and three coastal lagoons (Old Town Lagoon, Jakle's Lagoon, and Third Lagoon) along the shore of Griffin Bay. Such lagoons are rare features within Puget Sound; consequently, they are considered to be important resources. The lagoons are formed by accretion of beach materials that are deposited via longshore drift; the accreted materials eventually form a beach that separates the lagoons from the open marine environment. The three coastal lagoons in American Camp vary in size and other physical characteristics. Old Town Lagoon (Figure 13) is the smallest, and dries in most summers. Jakle's Lagoon (Figure 14) is the largest and deepest, and is persistent even in very dry summers. Third Lagoon (Figure 15) is smaller and shallower than Jakle's, but persists year-round. Jakle's and Third Lagoons are used throughout the year by resident and migratory birds (species summarized in Hanson 2001). Jakle's Lagoon has been the subject of multiple scientific studies performed by students and faculty from the University of Washington and elsewhere.

Surface water resources in the vicinity of English Camp include a stream entering Westcott Bay to the north of the park boundary, and another entering Garrison Bay to the south of the park boundary (Figure 4a). Within the park, the parade ground is wet for much of the year; it formerly may have functioned as a wetland. San Juan County has designated the Westcott-Garrison Bay Watershed as a priority watershed (Figure 16), and has developed an action plan for the area (San Juan County 2000, 2001). Elements of the action plan are discussed in more detail later in this report.

The shorelines of both American Camp and English Camp are dominated by unconsolidated sediments. Within American Camp, 70% of the southern shore consists of sand, gravel, and cobble (Fradkin 2004), much of which is covered with drift logs. Shallow rocky bedforms are interspersed with these unconsolidated areas. At its eastern end, the sandy shore of South Beach is backed by a steep eroding bluff face (Figure 17). On the northern shore of American Camp, along Griffin Bay, the shore is composed entirely of mud, gravel, and cobble (Fradkin, 2004). Shores within English Camp consist entirely of unconsolidated sediment, mostly mud, some of which has a shallow anoxic horizon.

A.3. Biological Resources

The benthic biological resources of SAJH have been summarized by Dethier (1993) and Dethier and Ferguson (1998). Fradkin (2004) has described the intertidal fish fauna of SAJH. Other sources treat selected groups of taxa on a regional basis, and investigators from the University of Washington have described the biota of sites within or adjacent to SAJH. A Beach Watchers group recently has been formed through which citizens will observe and report on various biological and physical attributes of the shore; this group is just now beginning to collect information. Geospatial data regarding specific biological targets have been collected and compiled by WDNR (Shorezone Atlas), WDFW, and FOSJ. These sources were used to create maps of the distribution of representative marine species within SAJH (Figures 18-24); the complete Shorezone and WDFW geospatial data sets are included in the GIS companion to this report, as are selected geospatial data provided by FOSJ.

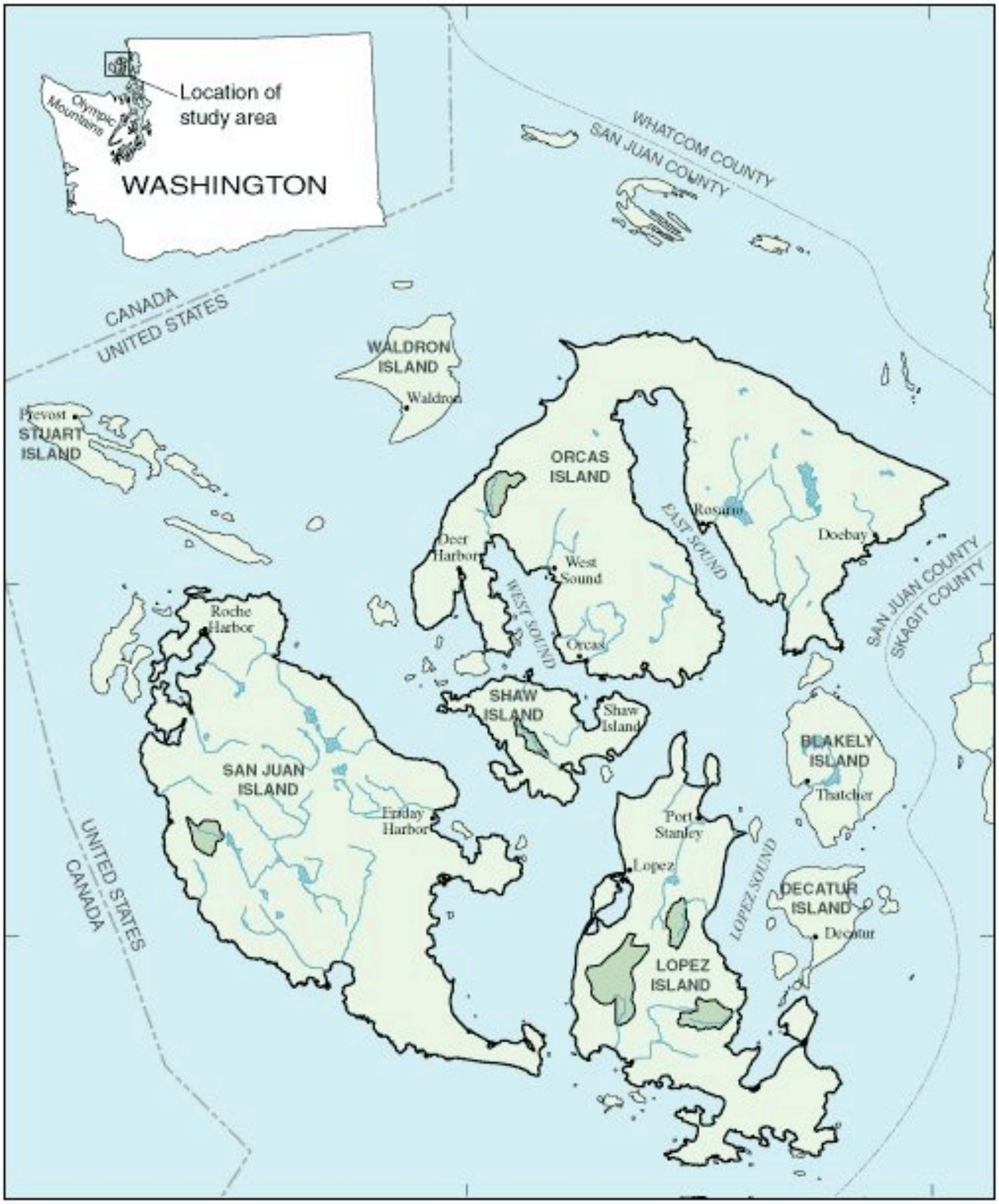


Figure 11. Hydrologic map of San Juan County.
Source: http://wa.water.usgs.gov/projects/sanjuan/

Figure 12. Aerial view of South Beach, American Camp, from the Strait of Juan de Fuca. Vegetation patches (foreground) indicate the likely location of springs.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Figure 13. Aerial View of Old Town Lagoon (in seasonally dry condition) from Griffin Bay.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Figure 14. Aerial view of Jakle's Lagoon from Griffin Bay.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Figure 15. Aerial view of Third Lagoon (far right), adjacent rocky bedforms (center), and nearby Cape San Juan marina (far left).
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

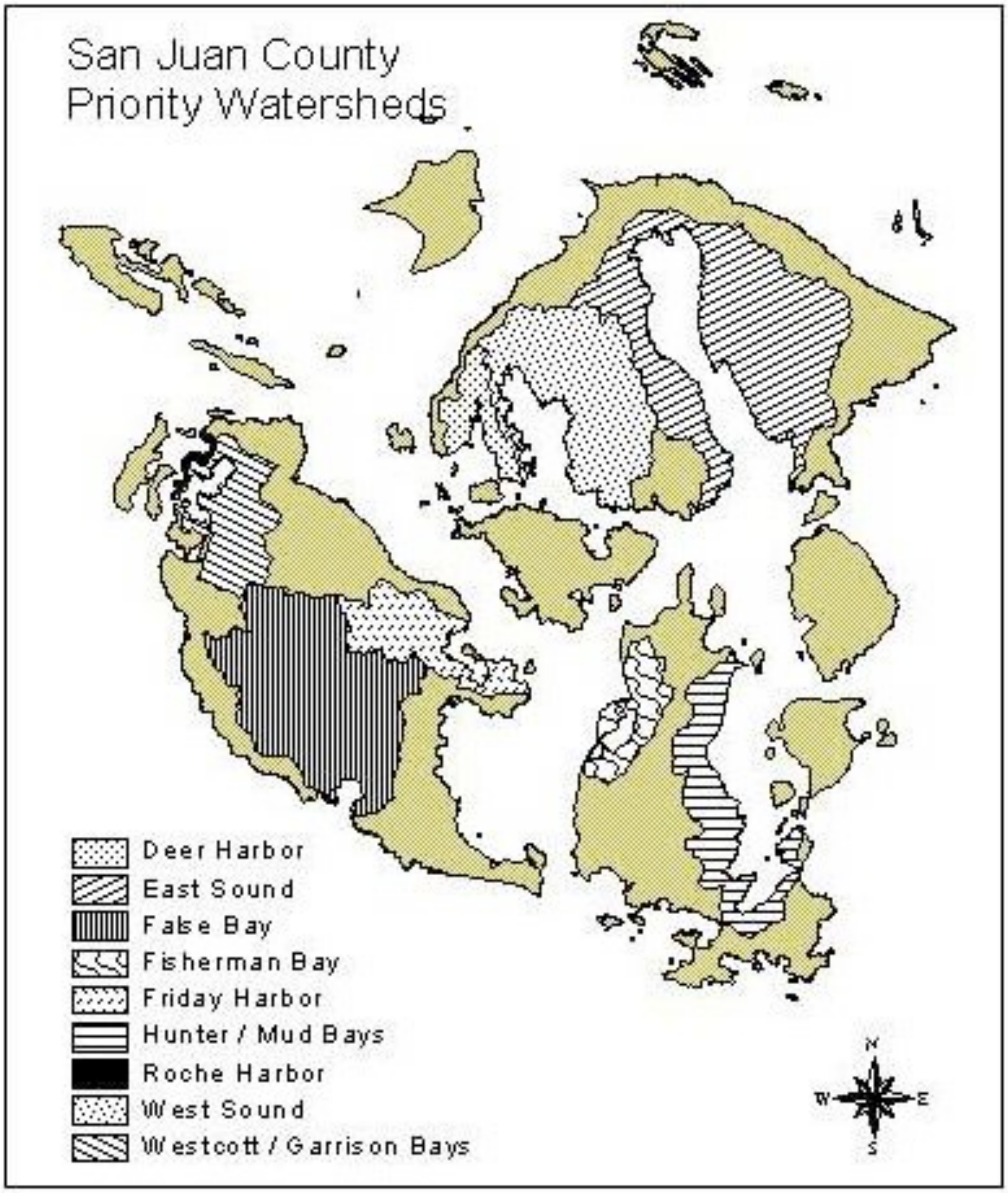


Figure 16. San Juan County Priority Watersheds, showing extent of the Westcott-Garrison Bay watershed.
Source: San Juan County Watershed Management Committee
http://www.co.san-juan.wa.us/Health/wtrshdpln/index.html

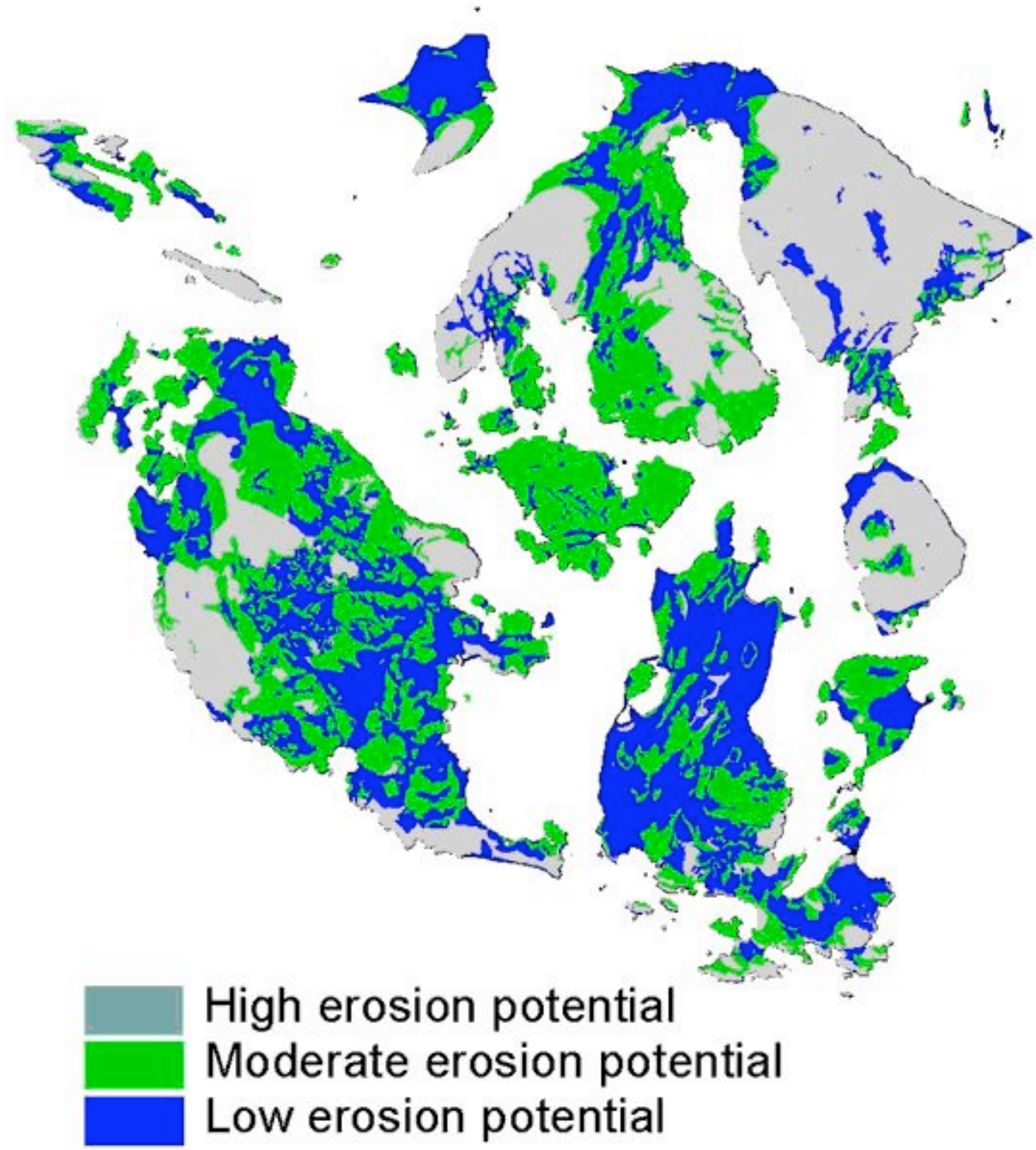


Figure 17. San Juan County Erosion Potential, indicating high erosion potential in parts of American Camp.
Source: San Juan County Watershed Management Committee
http://www.co.san-juan.wa.us/Health/wtrshdpln/index.html

Figure 18. Aerial view of Bell Point in English Camp, showing extensive unconsolidated sediments in intertidal areas.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

A.3.a. Marine Intertidal and Shallow Subtidal

Intertidal shorelines within SAJH consist of fine sediment, mixed sand and gravel, cobble, and bedrock. Fine sediments predominate in intertidal areas of English Camp. Sedimentary environments are characterized by infaunal communities typical of the region; constituent taxa are described in Dethier (1993) and Dethier and Ferguson (1998). Among the most conspicuous benthic species are native and non-native clams and epifaunal bivalves such as the mussel *Mytilus trossulus* and the non-native Pacific oyster *Crassostrea gigas.* Submerged and emergent vegetation tends to be patchy in distribution. The native eelgrass *Zostera marina* appears to be declining in Westcott and Garrison Bays; it formerly was abundant throughout the bay (Dethier and Ferguson 1998), but now is restricted to small patches (Figure 19). Eelgrass remains abundant in subtidal areas along of 4th of July Beach, and recently has been detected offshore of American Camp, on shallow areas of Salmon Banks (Figure 20). The pickleweed *Salicornia* occurs in patches along the upper intertidal margins of Westcott and Garrison Bays and along Griffin Bay.

Rocky shores comprise a smaller fraction of intertidal habitat within SAJH; they are best represented on the western shore of American Camp in the vicinity of Grandma's Cove. Where they occur, rocky shores are characterized by communities typical of the region. Conspicuous taxa include the rockweed *Fucus gardneri*, barnacles of several species *(Balanus glandula, Chthamalus dalli,* and *Semibalanus cariousus)*, limpets, and mussels. The kelp *Hedophyllum sessile* and the chiton *Katharina tunicata* are important components of low intertidal areas. Other kelps (*Laminaria spp., Agarum spp., Nereocystis lutkeana*) occur in rocky areas of the shallow subtidal. The distributions of representative taxa are shown in Figures 21-29.

Dethier (1993) conducted baseline surveys within SAJH spanning a diversity of intertidal habitats within the park. The surveys were performed to establish a baseline from which to infer changes in intertidal and shallow subtidal resources due to anthropogenic disturbance (e.g., oil spills). Permanent plots were established at six sites within American Camp and two within English Camp.

Habitats sampled at American Camp include:

- Exposed rocky shoreline (Monument Point)
- Protected rocky shoreline
- Gravel (South Beach)
- Gravel-mud mix (4th of July Beach)
- Lagoon (Jakle's Lagoon)

Habitats sampled at English Camp:

- Cobble-mud closed to clam harvest (Blockhouse area)
- Cobble-mud open to clam harvest

In rocky areas, four sets of permanent quadrats were established in the intertidal zone at vertical intervals of 0.8 m, designated high, high-mid, low-mid and low levels. Within each level, five 0.25m^2 quadrats were established and permanently marked using two large bolts anchored in the substrate. The number of motile invertebrates by species were tallied and the percent cover estimated for algae and sessile invertebrates within each quadrat. In soft sediment areas where permanent quadrats could not be established, alternate techniques were used. In sand and gravel areas, four 15cm deep cores were taken at each of four to six equally spaced tidal heights along the beach. The materials gathered were sieved and organisms tallied. The eelgrass zone at the 4th of July beach was sampled using a 60 m transect positioned parallel to shore. Organisms were sampled in each of 10 0.25m^2 quadrats placed randomly along the transect. In muddy habitats, four quadrats were sampled at four different tidal heights. In areas where clams were present, a 0.1 m^2 box core placed at random distances from a transect line was used to sample organisms and substrate characteristics; where necessary, excavations were made to quantify clam abundance and excavated material then sieved to enumerate small organisms. The lagoon site was sampled using a transect running from the seaward log boom to the edge of the water. Four 0.25 m^2 quadrats were sampled every 10 meters along the transect for plant cover and any other organisms present. Lagoonal mud was collected and sampled for invertebrates, although not in a quantitative manner.

Overall, 58 species of vascular plants, lichens and algae and 149 species of macroscopic invertebrates and fishes were found, though Dethier (1993) notes that a more exhaustive sampling effort that included more habitat types, more sites, and greater temporal and tidal variation might find 30% higher species richness. There was little overlap between the taxa found in rocky versus soft substrates. In her report, Dethier (1993) includes detailed descriptions of each site sampled and the species found there, data on size distribution of harvested clam species in areas closed to harvest versus areas open to harvest, abundance data, and rough maps of habitat distributions at American Camp and English Camp. A list of the species encountered is included in Appendix C of this report. Dethier's (1993) report concludes with a discussion of the likely impacts of oil spills on these habitats and makes recommendations for oil spill response priorities and for maintaining cost-effective monitoring of the transect sites by NPS.

Dethier and Ferguson (1998) performed a more intensive survey of Westcott and Garrison Bays for the San Juan County Planning Department. Their survey involved three primary components:

1. Geophysical characterization of the entire shoreline:
   A visual survey of the shoreline was conducted by walking along shoreline at low tide and annotating aerial photographs to divide the shore into 99 physically homogenous segments based on substrate type, wave energy, beach slope, bank characteristics, and aspect (compass direction). The extent and types of shoreline armoring and overwater structures (e.g., docks) present were also noted.

2. Biotic surveys of representative intertidal sites:
   The diversity and abundance of epibenthic and infaunal organisms were sampled at 5 soft-sediment sites, including one site at English Camp, and data were collected on clam densities and size distributions. All sites were marked with a rebar stake in the sediment just below the bank (although it is not known

whether these markers persist). A more qualitative sampling of the saltmarsh and lagoon in Westcott Bay was also performed.

3. Survey of the distribution and abundance of eelgrass in the shallow subtidal: At low tide (-1.0 to -2.1) on 3 sunny days, the presence or absence of eelgrass along the entire shoreline of Westcott-Garrison Bay was recorded. More detailed observations were made at 24 sites along 500-foot intervals of shoreline. The detailed observations included depth, visibility, distance from shore of the outer and inner edges of the beds, the density of eelgrass sin the bed and whether the bed was patchy or continuous. Sites 1, 2, 3, 11, 12 and 13 were located adjacent to English Camp.

The report provided by Dethier and Ferguson (1998) to San Juan County included an oversized GIS-generated map showing the delineation of the segments on an aerial photo with overlays indicating parcel boundaries (in light green) and segment delineation identification/number (in magenta) that was produced by San Juan County Planning Department. (The map was not included in the copy of the report that we obtained, and the original map copies poorly; however, it may be available in the future from the San Juan County Planning Department.) We examined the copy that Dethier maintains in her files. Segments 1-40, 97, and 98 are located along the shoreline within or adjacent to SAJH boundaries. The geophysical characteristics of these specific segments are not described in the report, nor are the results of the biotic surveys of specific intertidal sites. Consequently, we do not include species lists from Dethier & Ferguson's (1998) report because they are not indicative of specific locations within SAJH.

Even without location-specific data, generalities can be drawn from the report. The abundance of epibenthic organisms in soft-sediment areas was low, with fewer organisms found in areas with softer sediments. Mobile invertebrates such as periwinkles (*Littorina spp.)* and amphipods were found in the high intertidal along small amounts of algae (particularly *Fucus gardneri*) and barnacles affixed to pebbles and cobbles where present. Epibenthic organisms were least abundant in the mid-zone, although clam holes and polychaete worm tubes were visible. Large amounts of the green alga *Enteromorpha* were found in the low zone in some sites, providing habitat for polychaete worms and sea slugs (*Melanochlamys)*. Infaunal surveys showed differences in clam abundances and size distributions in areas open to harvest compared with those closed to harvest. In particular, fewer native littleneck clams *(Protothaca staminea*) and fewer bent-nose clams (*Macoma nasuta*) were found in areas open to harvest. Because bent-nose clams are not considered desirable for human consumption, the authors hypothesize that the reduced abundance of bent-nose clams in the area open to shellfish harvest in English Camp likely is due to frequent disruption of its habitat by harvesters targeting native littlenecks. They also noted the presence of a few invasive mahogany clams (*Nuttalia obscurata*, also known as the purple varnish clam) in the high zone at English Camp.

Dethier and Ferguson (1998) found that the upper- and mid-intertidal zones of rocky areas within the bays were similar to other rocky shores in the San Juans, but the low zones in most areas were covered with or affected by muddy sediment. Relatively few predators were observed in any of the zones; the authors hypothesize that the absence of predatory species may result from greater sensitivity to smothering by sediment or inability to move or across it.

The report includes a detailed table characterizing the length, width, depth, and density of eelgrass beds in each shoreline segment, including those located within SAJH. Significant among the findings was a nearly continuous band of eelgrass around the bays, similar to that represented in Figure 21. Surveys performed since 1998 (Wyllie-Echeverria et al. 2003, FOSJ 2004) have demonstrated sharp declines in eelgrass in Westcott and Garrison Bays; small, discontinuous patches now exist only in the vicinity of Bell Point and on the shoreline immediately opposite (Figure 19). The causes of this decline are not known.

Fradkin (2004) described the intertidal fish fauna of SAJH based on sampling performed in November, 2002. Sampling at 11 sites in English Camp and 15 in American Camp yielded 14 species, including surf smelt, sandlance, and herring (collectively known as forage fish), surfperch, flatfish, sculpins, and gunnels. According to Fradkin (2004), the prevalence of forage fish species among these samples suggests that intertidal areas within both English and American Camps function as forage fish nursery grounds. According to surveys performed by Friends of the San Juans, surf smelt spawn along the shores of English Camp, as indicated by eggs found on the beach (Figure 28).

A.3.b. Other Aquatic Habitats

The three coastal lagoons located along Griffin Bay in American Camp comprise features that are regionally rare. Dethier (1993) described the salt marsh habitat surrounding Jakle's Lagoon; she reports 17 species of vascular plants, several unidentified cyanobacteria and lichens, and small invertebrates from the lagoon. About half the vascular plant species reported are typical of salt marshes. Dethier suggests that the species reported from Jakle's Lagoon are probably typical of Old Town and Third Lagoons.

Hanson (2001) performed a brief ecological assessment of Third Lagoon Preserve, focusing on areas outside but immediately adjacent to park property. He reports that a preliminary botanical survey of the Third Lagoon Preserve found more than 150 plant species distributed among five major plant communities (Douglas fir/salal-oceanspray forest; pasture grass/Nootka rose meadow; Japanese beach pea/Virginia peppergrass/American sea rocket beach fringe; pickleweed/saltgrass tidal wetland; and red alder/skunk cabbage/slough forested wetland), plus other plants associated with disturbed areas. He lists nine priority habitats and species (estuary/estuary-like habitat; forested freshwater wetland; bufflehead; harlequin duck; bald eagle; peregrine falcon; pileated woodpecker; fishnet lichen; and Japanese oyster), plus one noxious invasive (bullthistle). The authors of this report note that the Japanese (Pacific) oyster also constitutes a non-native invasive species, and may not represent a priority species in this setting.

Holmes (1998) provides species lists of trees, shrubs, herbs, grasses, reptiles, birds, and mammals associated with wetland habitats within SAJH.

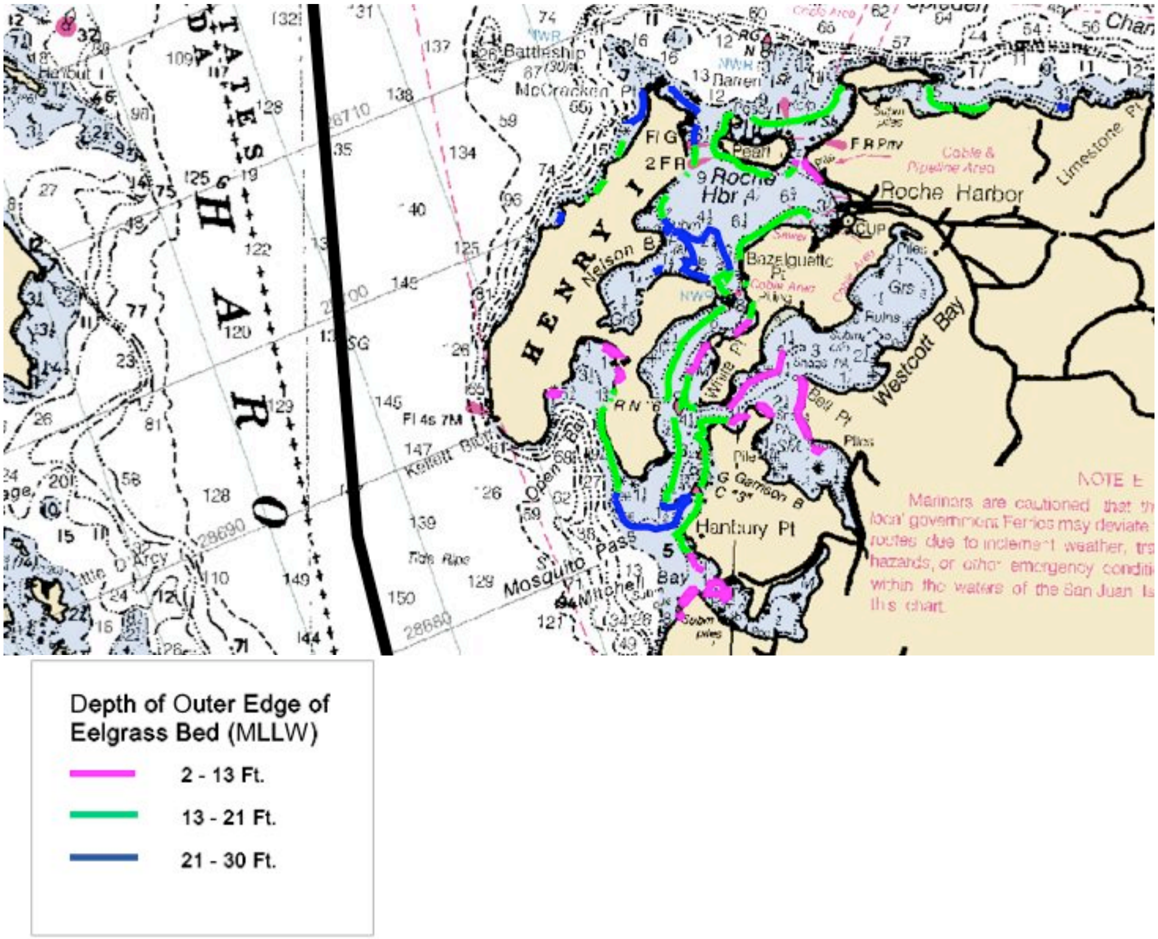


Figure 19. Eelgrass (*Zostera marina*) distribution in the vicinity of English Camp. Source: Friends of the San Juans, 2004.

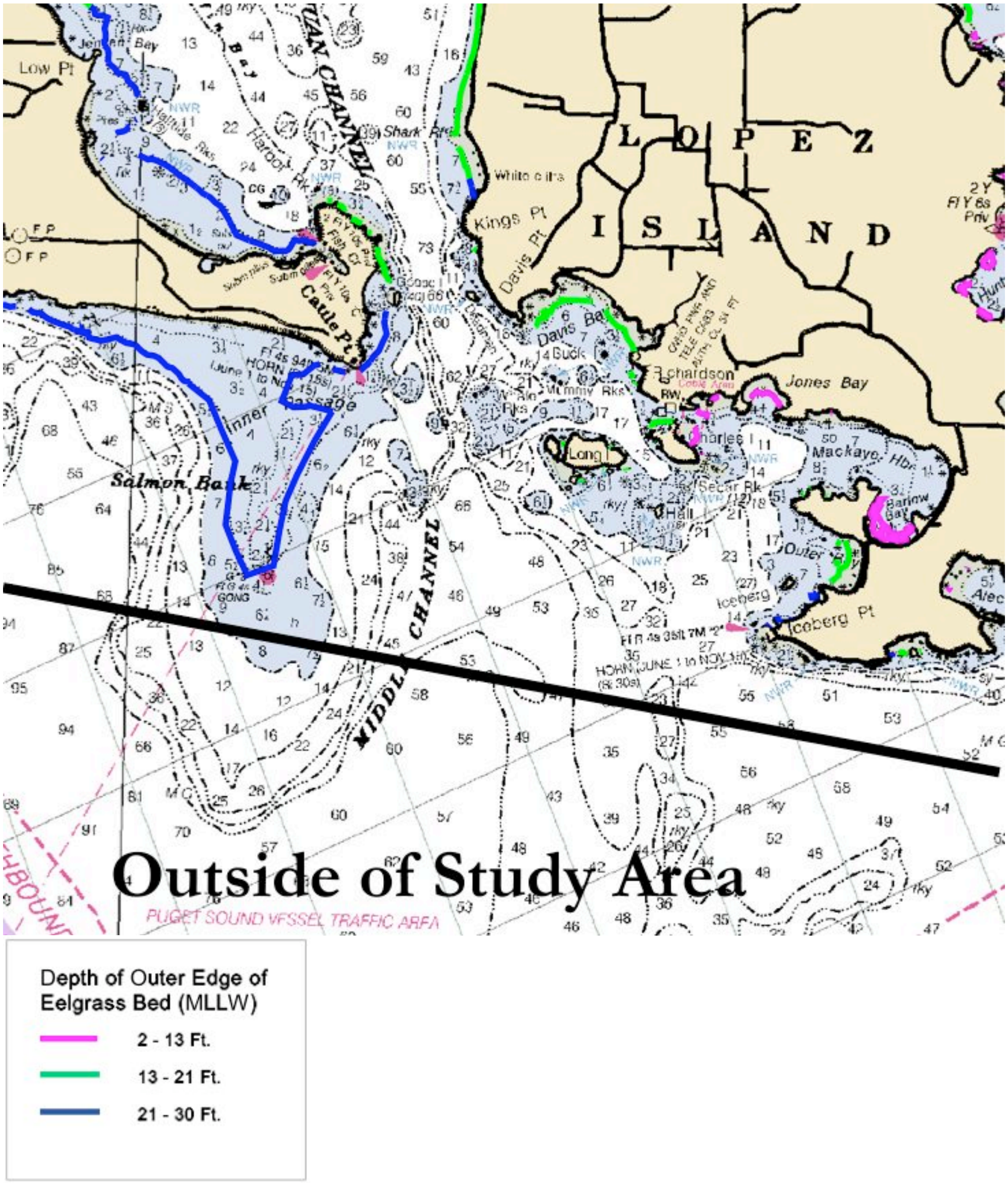


Figure 20. Eelgrass (*Zostera marina*) distribution in the vicinity of American Camp. Source: Friends of the San Juans, 2004.

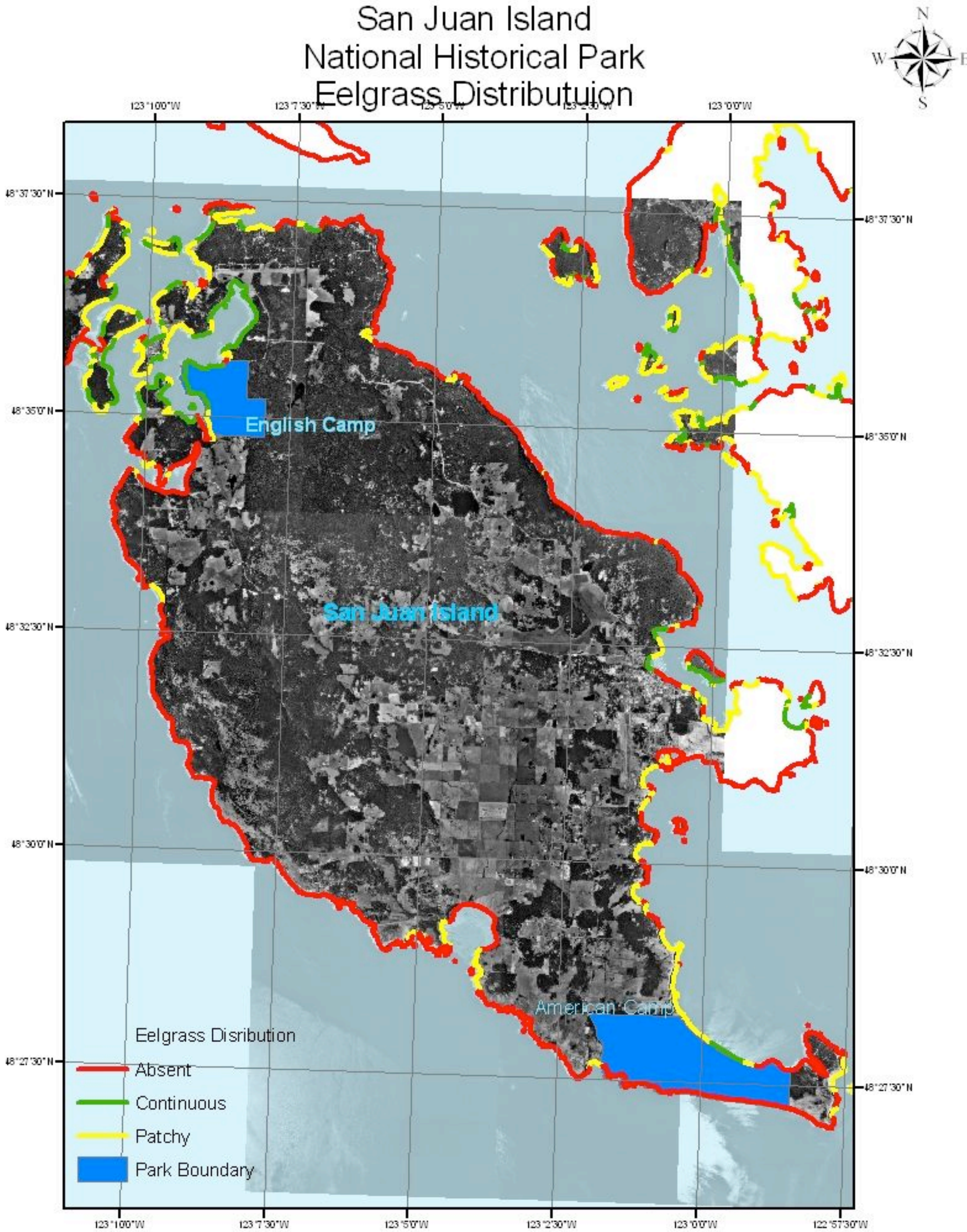


Figure 21. Eelgrass (*Zostera marina*) distribution on San Juan Island. Compare with Figures 19 and 20. Map created using Washington State Shorezone Altas.

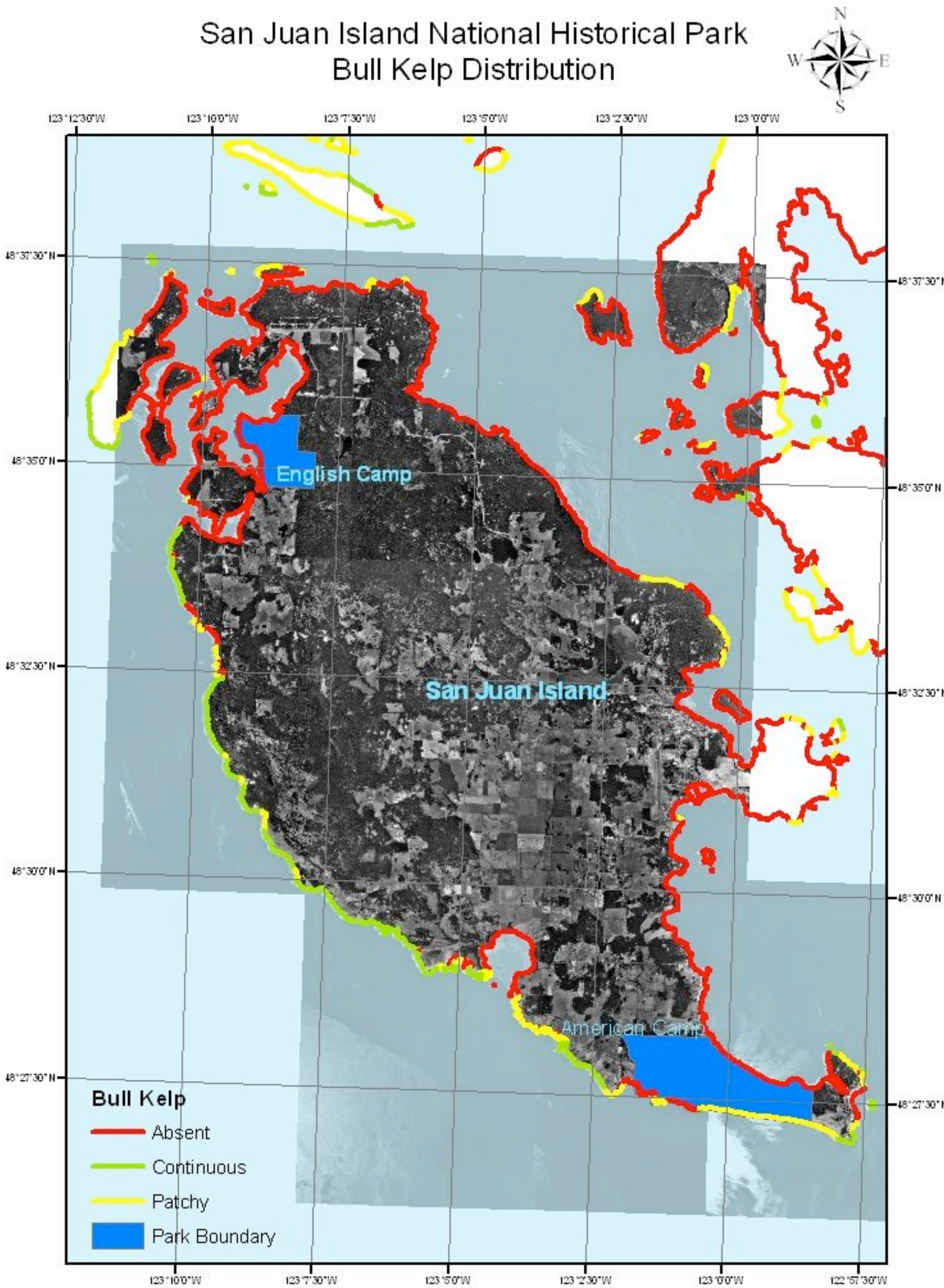


Figure 22. Bull kelp (*Nereocystis lutkeana*) distribution on San Juan Island. Map created using Washington State Shorezone Altas.

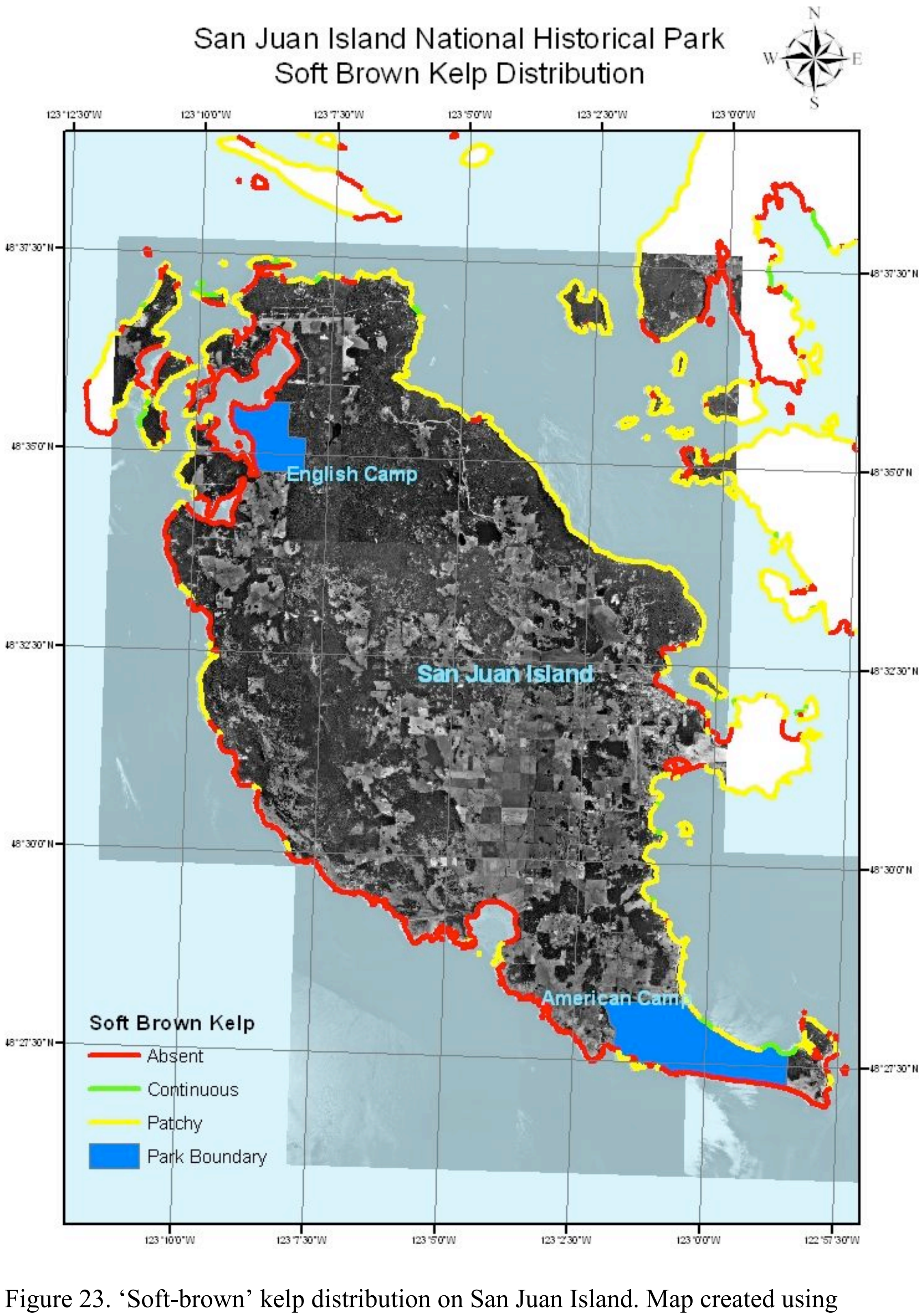


Figure 23. 'Soft-brown' kelp distribution on San Juan Island. Map created using Washington State Shorezone Altas.

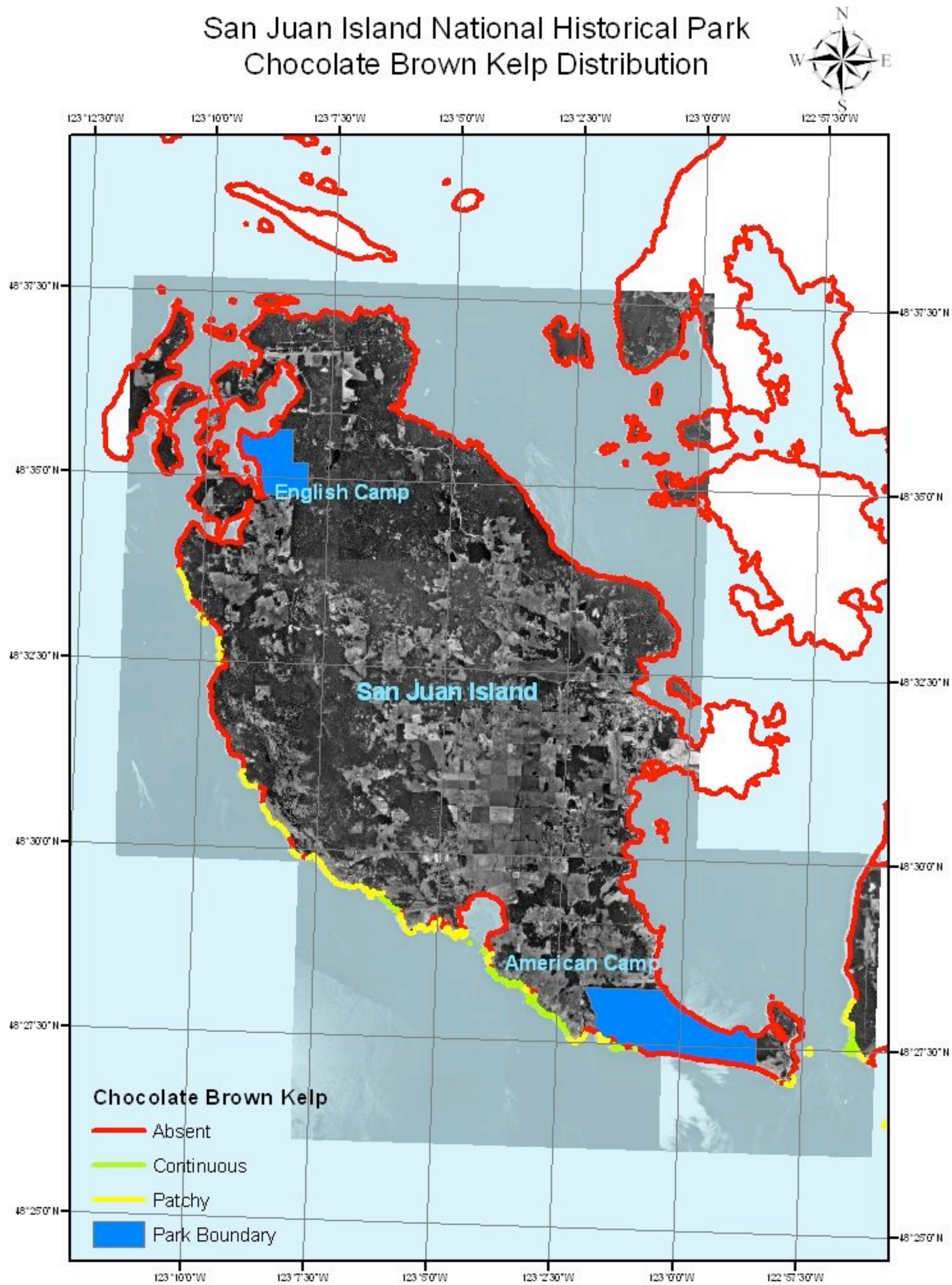


Figure 24. 'Chocolate-brown' kelp distribution on San Juan Island. Map created using Washington State Shorezone Altas

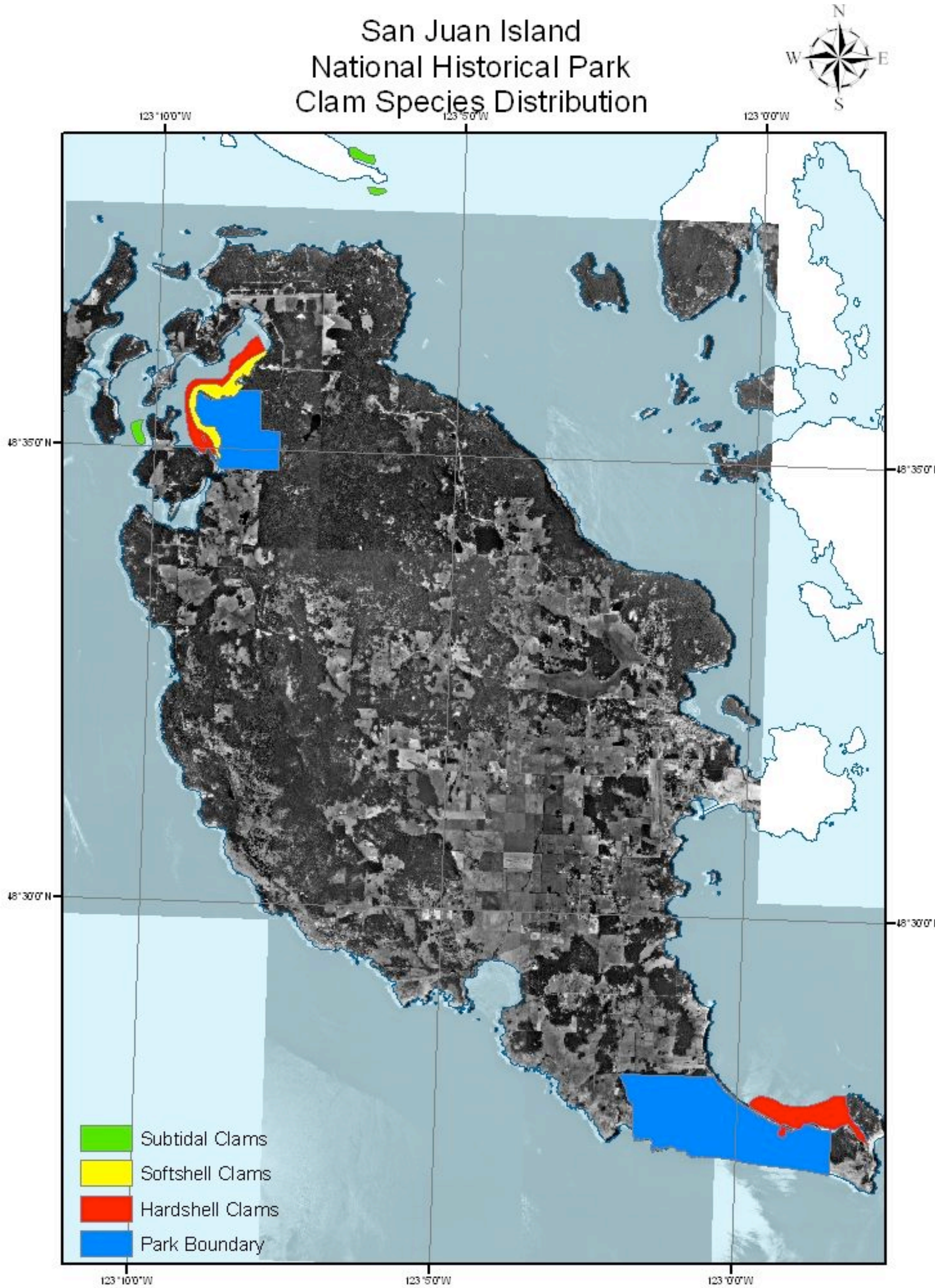


Figure 25. Clam distributions in the vicinity of SAJH. Map created from WDFW geospatial data.

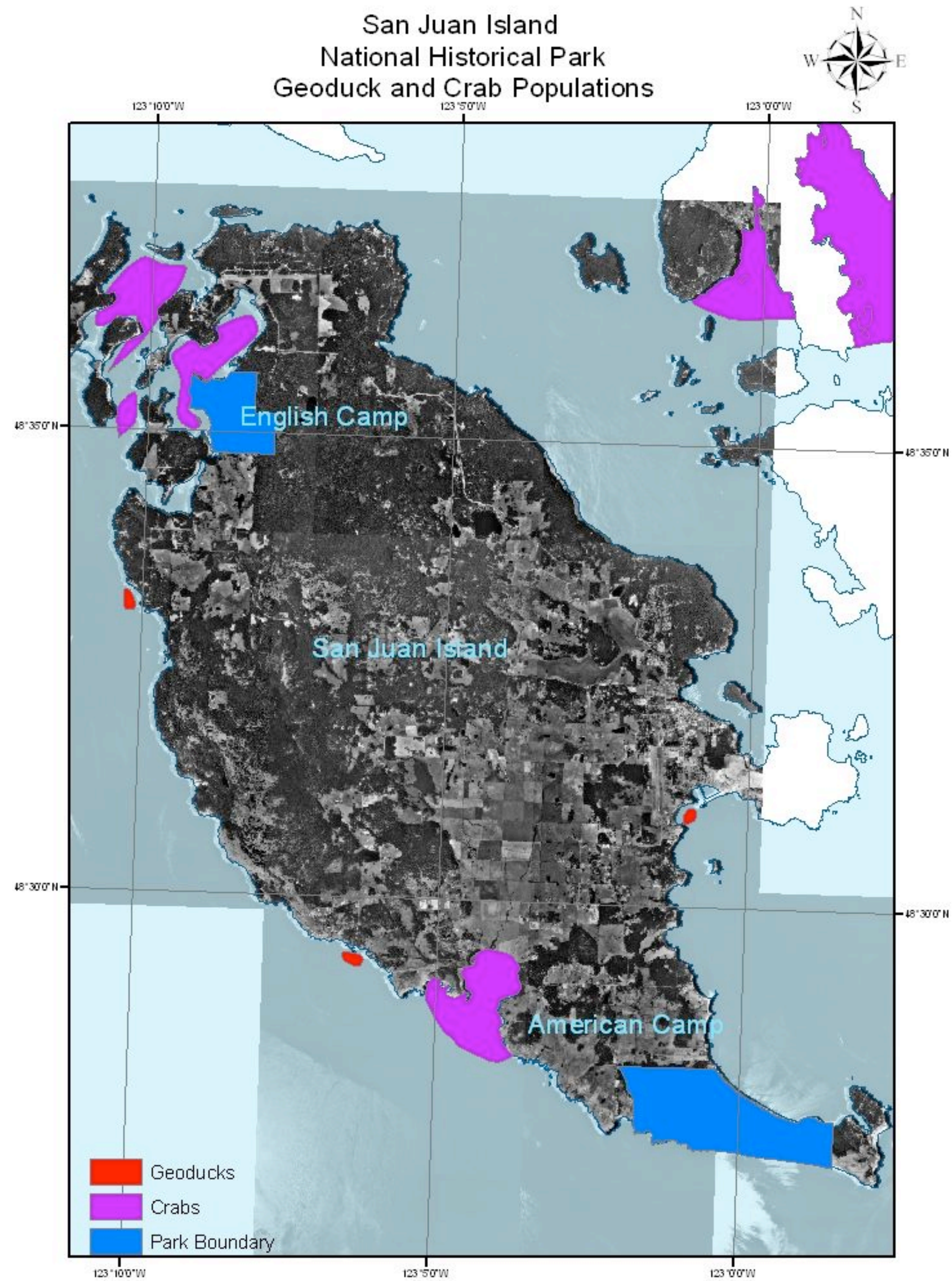


Figure 26. Geoduck and crab distributions in the vicinity of SAJH. Map created from WDFW geospatial data.

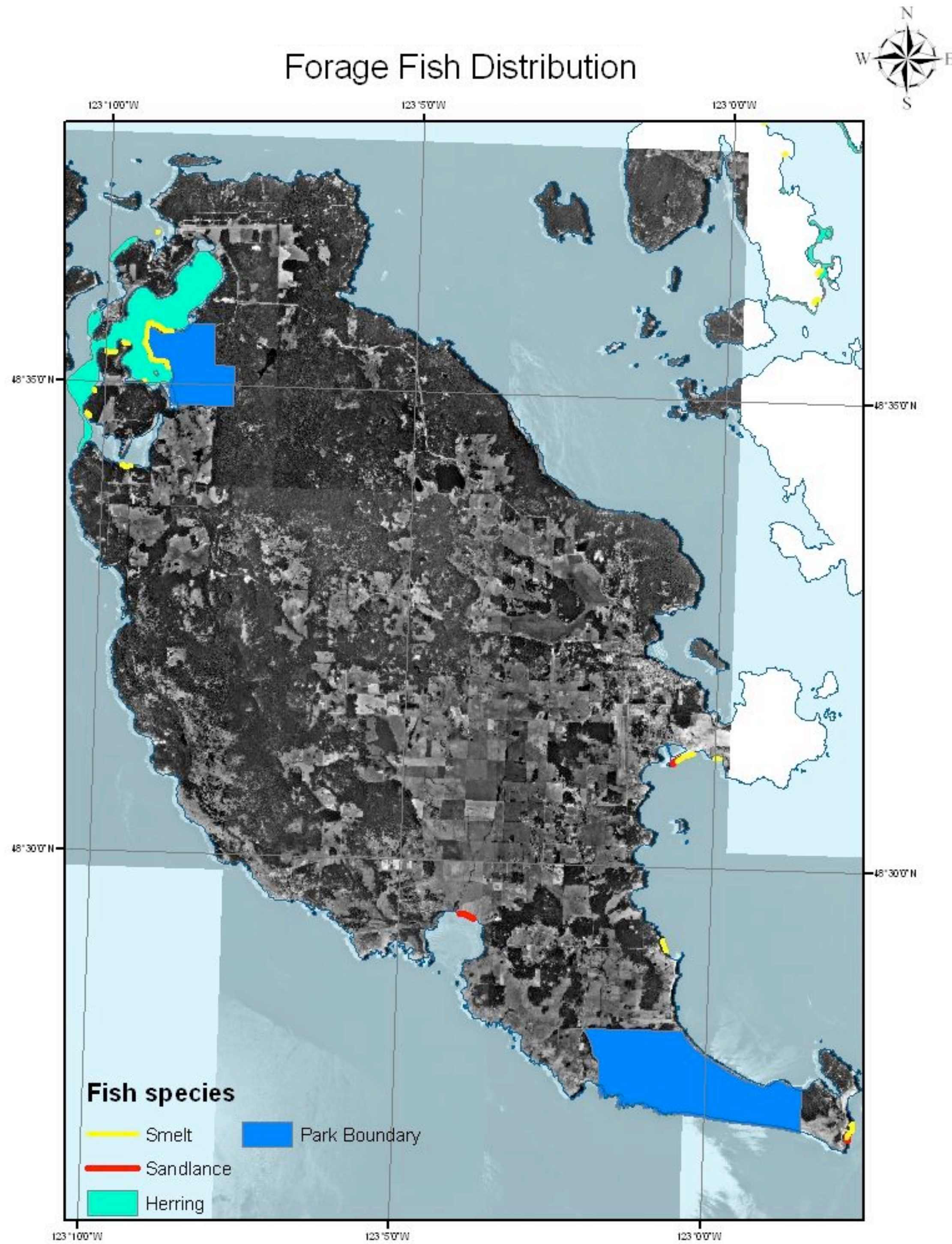


Figure 27. Smelt, sand lance, and herring distribution in the vicinity of SAJH. Map created from WDFW geospatial data.

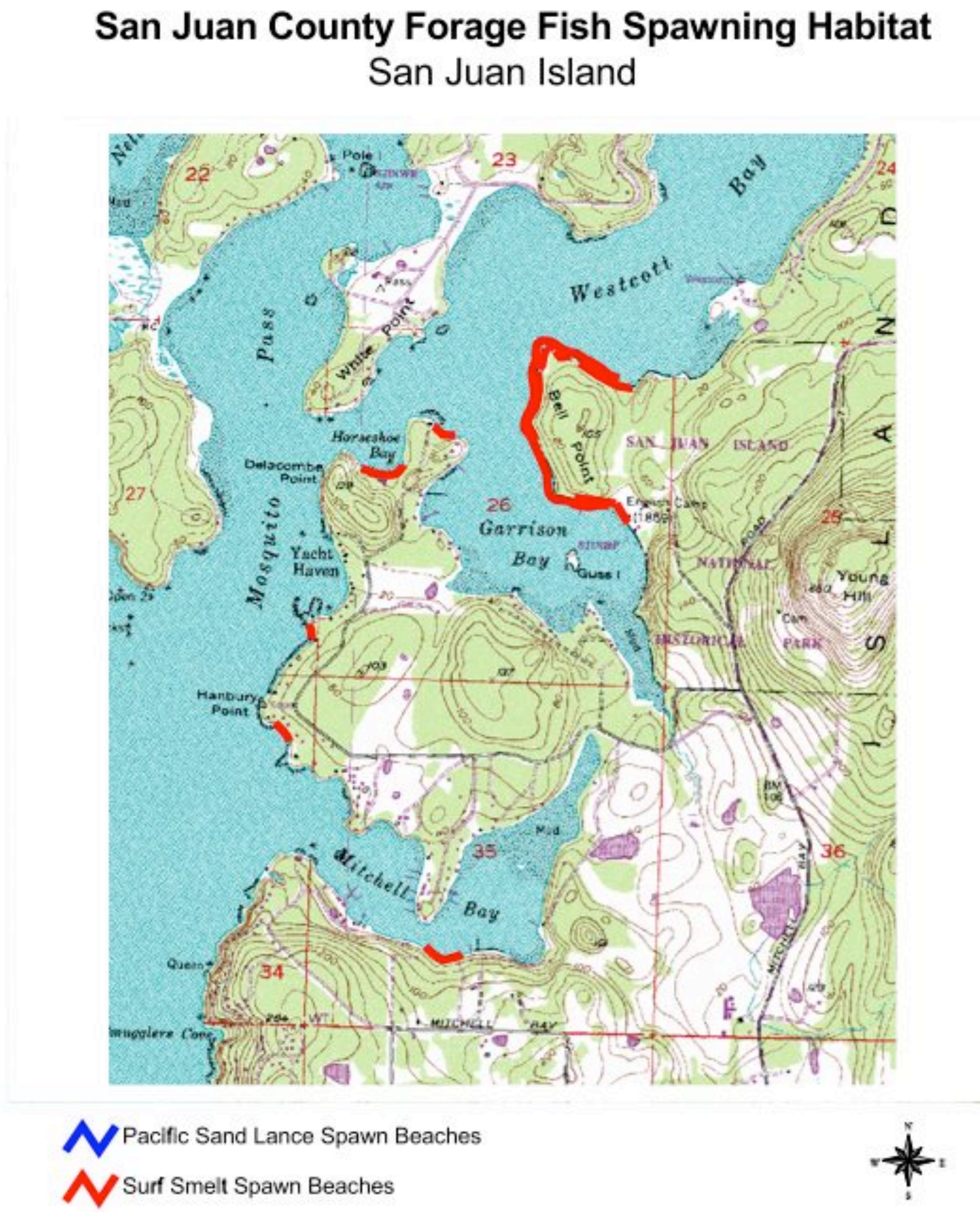


Figure 28. Forage fish spawning distribution in the vicinity of English Camp.
Source: Friends of the San Juans, 2004.

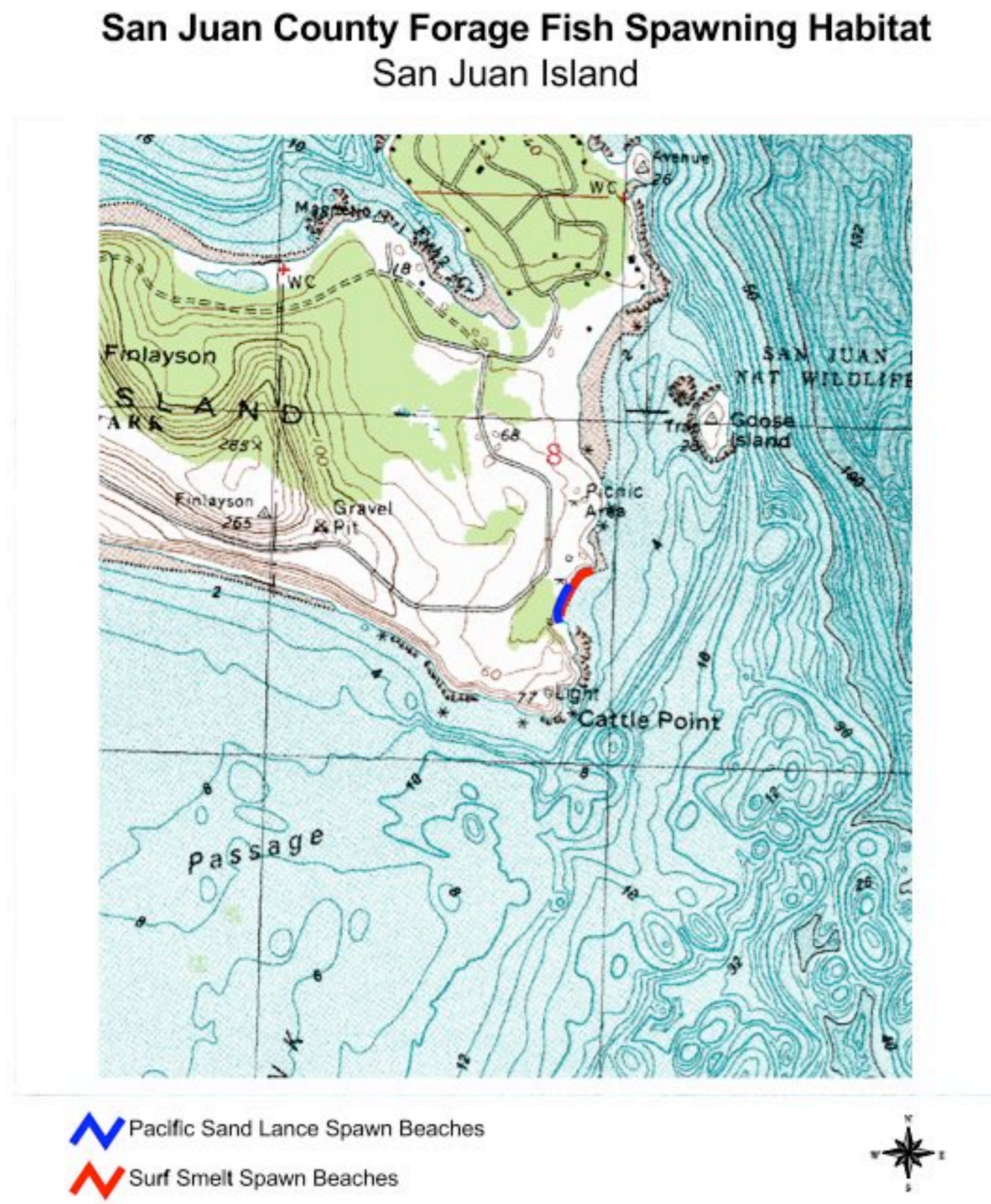


Figure 29. Forage fish spawning distribution in the vicinity of American Camp.
Source: Friends of the San Juans, 2004

B. Water Resources Assessment

B.1. Water Quality

Our review of existing sources of marine water quality data for SAJH yielded two types of information: marine water quality data collected by state and other agencies and assessments of marine water quality drafted by federal, state and local agencies. We also obtained three previous assessments of marine water quality:

- National Park Service's Water Resources Division's Baseline Water Quality Inventory Report for SAJH, completed in 1995 (NPS 1995).
- The results of a monitoring project conducted by Huxley College of Environmental Studies, contracted by San Juan County Health and Community Services Division, to 1) evaluate water quality at selected freshwater and marine sites on San Juan, Orcas and Lopez Islands, 2) provide an overview of water quality conditions for the period 1999- 2000, and 3) identify long-term water quality monitoring goals (Wiseman et al. 2000).
- The San Juan County Watershed Management Action Plan and Characterization Report, which includes the results of stream and marine water quality sampling conducted by San Juan County between May 1997 and February 1998 (San Juan County 2000).

Although the Washington State Department of Ecology (WDOE) produces periodic reports assessing marine water quality for Puget Sound (Newton et al. 2002), these assessments do not include stations sufficiently close to SAJH to provide management relevant information. Although we have chosen not to include discussion of the WDOE assessments in this report, we have included data from one station regularly monitored by WDOE, because that station (SJF000; Figure 19) is the most proximal to American Camp, and can be used as an indicator of probable marine water quality at that site.

B.1.a. Data Sources

Our efforts to retrieve marine water quality data from the Environmental Protection Agency's Environmental Protection Agency's online STOrage and RETrieval (STORET) database of biological, water quality and physical data yielded no marine water quality data for San Juan County. Consequently, we focused our assessment on data available from Washington State and local data sources. The majority of the marine water quality data discussed in this report were obtained from the Washington State Department of Ecology (WDOE) and Washington State Department of Health (WDOH). Additional data collected by local entities that provide snapshots of water quality conditions at a particular time are included where appropriate.

WDOE has monitored water quality in greater Puget Sound since 1967 through the Marine Waters Monitoring Program. WDOE maintains four sampling stations within the San Juan Islands region (Figure 30):

- SJF000 – The northernmost station in a 3-station transect south of South Beach
- SJF001 – The second station in a 3-station transect south of South Beach

- SJF002 – The southernmost station in a 3-station transect south of South Beach
- GRG002 – A station located in Georgia Strait, north of Patos Island

WDOE also collects water quality data at selected embayments within the San Juan Archipelago, including Friday Harbor (San Juan Island) and Fisherman's Bay (Lopez Island). Given the semi-enclosed nature of these embayments and their geographic location relative to SAJH, these data are not likely to be representative of conditions at SAJH and were not included in this report.

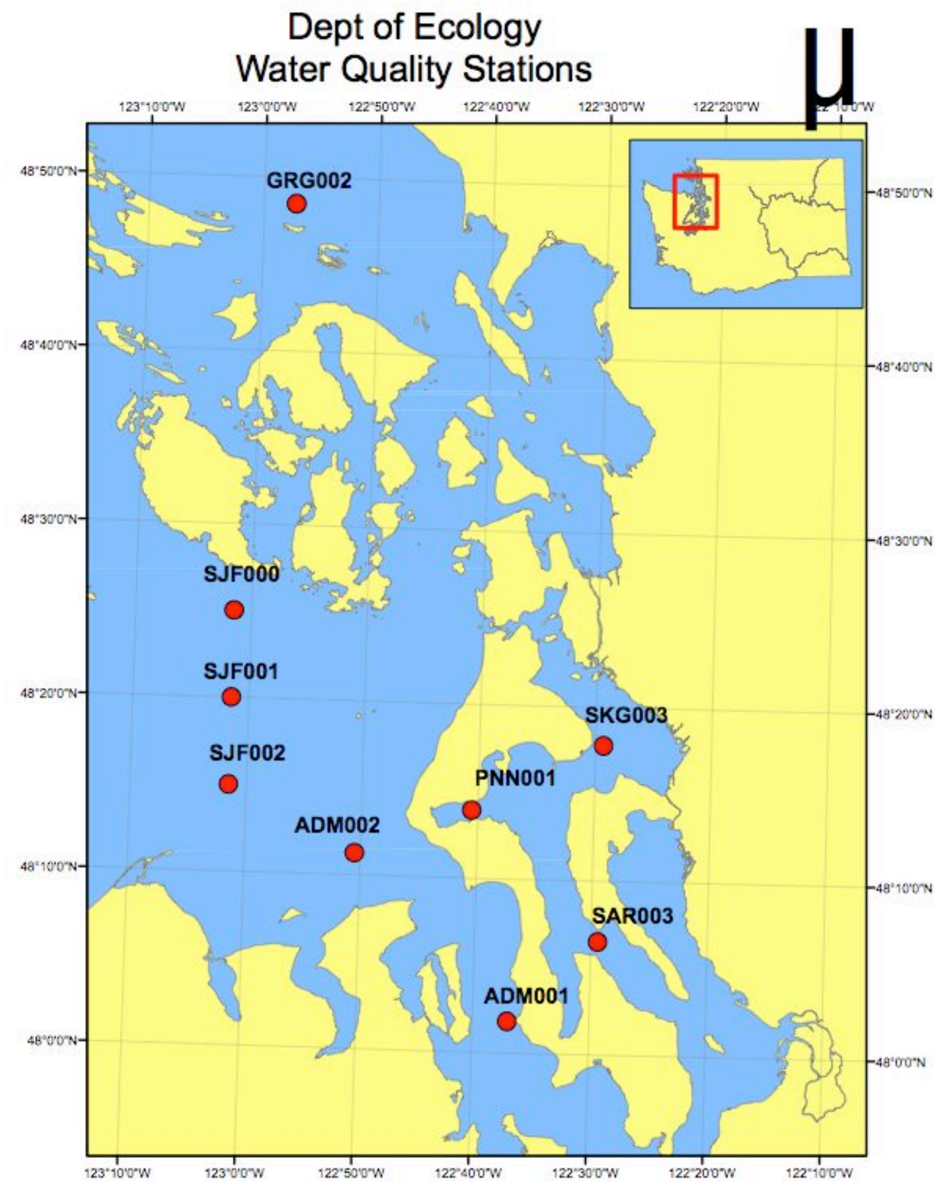


Figure 30. Washington State Department of Ecology Marine Water Quality Monitoring Program stations in the vicinity of SAJH. (Adapted from WDOE 2006a)

WDOE collects two kinds of water quality data at each station: a) water samples taken at discrete depths (0.5m, 10m and 30m) for fecal coliform bacteria, chlorophyll a, phaeopigment, nitrate, nitrite, ammonium, orthophosphate, silicate and Secchi disk depth, and b) depth profiles of temperature, salinity, density, light transmission and pH taken at 0.5 m intervals. Discrete sample data were collected on a near-monthly basis from 1999 to 2002 for stations SJF000, SJF001 and SJF002. Since 2002, these stations have been designated "rotating basis stations," and are scheduled to have discrete water samples taken monthly for 12 months every 3 years. Detailed profile data have been collected annually since 1999 (WDOE 2006a). Chemical contamination, plankton species (e.g., toxic blooms), and changes in flushing characteristics are not monitored. Data from 1990 and later for these and other stations monitored by WDOE's Marine Waters Monitoring Program, as well as quality assurance/quality control information for the data, are available online at: http://www.ecy.wa.gov/programs/eap/mar_wat/mwm_intr.html.

From the WDOE website we downloaded both discrete sample and profile data for SJF000, the station located closest to SAJH on 3/15/06 (WDOE 2006a). Stations SJF001 and SJF002 are considerably farther south, water conditions at these stations are less likely to be representative of conditions at SAJH and therefore were excluded from this analysis. Only data meeting WDOE's quality control rankings of "1 - State of art method, adequate QC" and "2 - Less precise method or QC" were analyzed.

The Washington State Department of Health (WDOH) monitors quality of waters within SAJH as part of its efforts to ensure the safety of shellfish harvested for human consumption. In commercially harvested shellfish growing areas such as Westcott-Garrison Bay, the WDOH Food Safety and Shellfish Program monitors fecal coliform bacteria, temperature and salinity on a near-monthly basis within commercial shellfish growing areas. WDOH monitors water quality at 11 stations within Westcott-Garrison Bay (Figure 31), three of which are close to SAJH shorelines: Station 11 is located just off the small dock north of the parade ground; Station 2 is located off Bell Point and Station 4 is located north of Bell Point. We reviewed the raw data collected by WDOH at these locations from 1988 through February 2005 (personal communication, Don Melvin, Office of Food Safety and Shellfish Programs, WDOH, 6/16/2005). These data indicate that WDOH monitored these stations annually from 1988-1991, four times in 1992 and then six times per year since 1993.

WDOH also monitors molluscan shellfish tissue samples taken from shellfish growing areas and recreational harvesting areas for marine biotoxins, specifically saxitoxins (algal compounds responsible for paralytic shellfish poisoning) and domoic acid. In the summer months, DOH also monitors levels of the bacterium *Vibrio parahaemolyticus* levels in shellfish and closes harvest areas when bacterial levels are high. Commercial growing areas are monitored more frequently, depending partly upon the level of harvesting activity. If conditions are such that biotoxin problems are more likely, WDOH increases the monitoring frequency of both commercial and recreational areas (WDOH 2006). WDOH does not currently monitor changes in phytoplankton assemblages in Puget Sound.

San Juan County funded a water quality monitoring study in 1999 to characterize water quality conditions at selected freshwater and marine sites on San Juan, Lopez and Orcas Islands and provide a general overview of water quality conditions, as part of the development of a county-wide watershed action plan (Wiseman et al. 2000). One of the marine sites (Site 33) was located in Garrison Bay at "the south end of the English Camp boardwalk."

San Juan County also sampled stream and marine water quality in eight watersheds in San Juan County, including the Westcott-Garrison Bay Watershed, between May 1997 and February 1998 (San Juan County 2000). Initial 'spot samples' in marine embayments at the mouths of streams where they enter the embayments were taken in May and June 1997 to survey conditions at all sites; follow-up samples were collected between November 1997 and February 1998 at locations where contaminant concentrations exceeded standards and additional locations further upstream in an attempt to isolate pollution sources. The initial samples were analyzed for temperature, pH, conductivity, nitrate, total suspended solids, dissolved oxygen, and fecal coliform. The follow-up samples were analyzed for the same parameters except nitrate.

Finally, marine water quality data for 12-13 stations in Roche Harbor, Mosquito Passage and the entrance to Westcott-Garrison Bay were required by San Juan County and WDOE as part of the pre- and post-project monitoring for an expansion to the Roche Harbor marina in the late 1990s (personal communication, Rowann Tallmon, Beach Watchers Program Coordinator, Washington State University Extension, 7/20/05). We were unable to obtain these data from either the consultant (who is deceased) or from San Juan County.

B.1.b. Marine Water Quality in English Camp (Westcott-Garrison Bay)
Nutrients and Dissolved Oxygen
As discussed above, WDOE's marine water quality program does not monitor water quality in Westcott-Garrison Bay. There have been various short-term efforts that measured water quality conditions at locations in and near Westcott-Garrison Bay but no sustained efforts.

In 1999 San Juan County funded a one year water quality monitoring study to characterize water quality conditions at selected freshwater and marine sites on San Juan, Lopez and Orcas Islands and provide a general overview of water quality conditions, as part of the development of a county-wide watershed action plan (Wiseman et al. 2000). One of the marine sites (Site 33) was located in Garrison Bay at "the south end of the English Camp boardwalk." This site was sampled on a monthly basis June through October only at a depth of 2 m. The parameters measured were temperature, dissolved oxygen, conductivity, pH, turbidity, soluble phosphate, nitrate/nitrite, fecal coliform bacteria and secchi disk depth (Table 1).

Table 1. Summer 1999 Water Quality Conditions in Garrison Bay, summary statistics (Wiseman et al. 2000).

Parameter	Min	Max	Mean	N
Conductivity (μS/cm)	43280	45000	44150	4
Dissolved oxygen (mg/L)	11.0	12.7	11.9	4
Fecal coliform (cfu/100 mL)	<1	1	1	4
Nitrate/Nitrite (μg-N/L)	12	29	19	4
pH	8.08	8.39	8.24	4
Secchi (m)	1.7	2.1	1.9	3
Soluble phosphate (μg-P/L)	9.7	14.4	12.8	3
Temperature (C)	10.3	15.7	13.7	4
Turbidity (NTU)	2.0	3.7	2.7	4

As part of the development of the San Juan County Watershed Management Action Plan and Characterization Report (a state requirement), San Juan County's Health and Community Services Department conducted water quality sampling in streams entering Westcott-Garrison Bay and at one station (SJ22) within Westcott-Garrison Bay at the Westcott Bay Sea Farms dock (a commercial aquaculture facility) in 1997-1998 (San Juan County 2000). While the parameters measured included temperature, nutrients, dissolved oxygen and turbidity, these data were apparently not collected at SJ22.

As a result of concerns over the apparent disappearance of eelgrass in Westcott-Garrison Bay in recent years, a joint project of WDOE and UW researcher Sandy Wyllie-Echeverria will include the installation of a permanent water quality monitoring station in Westcott Bay that will measure temperature, light transmission, dissolved oxygen, salinity and turbidity for a full year. (personal communication, Tina Whitman, Friends of the San Juans, 5/4/05).

Bacterial Contamination

The Washington State Department of Health (WDOH) monitors water quality within shellfish growing areas to ensure the safety of shellfish grown or harvested for human consumption. Within SAJH, WDOH monitors water quality within Westcott and Garrison Bays associated with the commercial shellfish aquaculture operation there. WDOH has monitored fecal coliform bacteria, temperature and salinity at 10 stations scattered throughout Westcott Bay and to the mouth at Mosquito Pass annually from 1988-1991, four times in 1992 and then six times per year since 1993 on a roughly bimonthly basis (Woolrich 2004, 2005; Lukes 2002). Stations 4 and 11 are directly adjacent to SAJH on the north and south sides of Bell Point; Station 2 is due west of Bell Point (Figure 31).

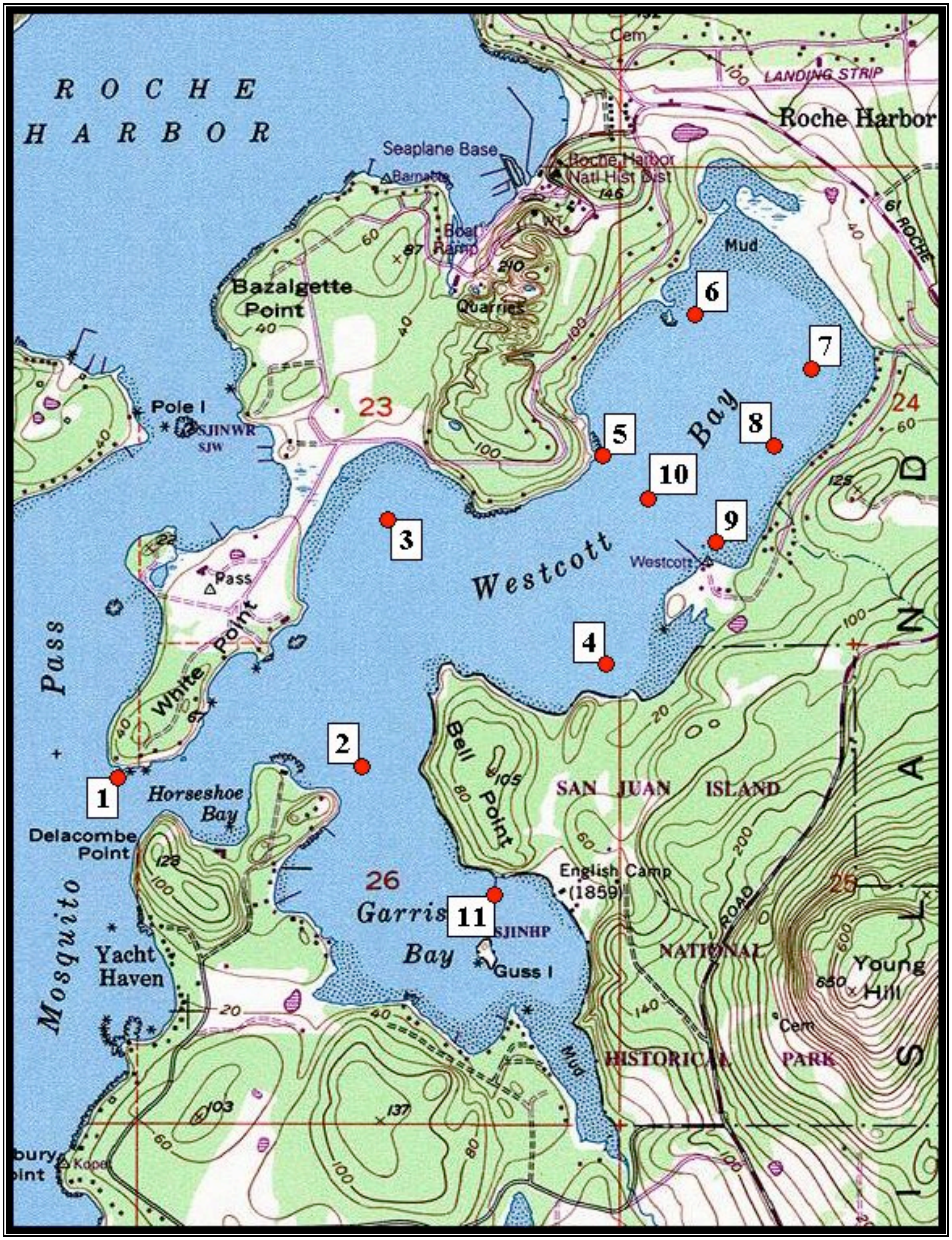


Figure 31. Locations of Washington Department of Health fecal coliform monitoring stations. (Map provided by Don Melvin, Office of Food Safety and Shellfish Programs, WDOH; created using TOPO! ® © 2002 National Geographic Society).

We obtained data from the more than 950 samples that have been collected from 1988 through 2005 from WDOH (personal communication, Deborah Sargeant, Office of Food Safety and Shellfish Programs, WDOH, 1/25/06). Fecal coliform, temperature and salinity for the three stations adjacent to SAJH (Stations 2, 4 and 11) are shown in Figures 32-34.

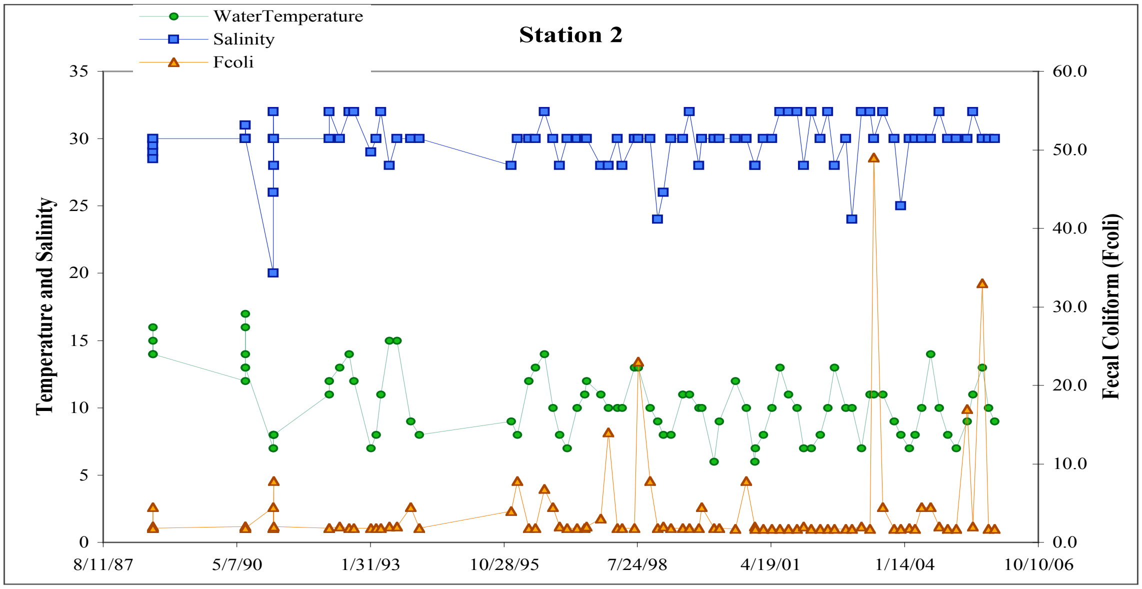


Figure 32. Temperature, salinity, and fecal coliform at Westcott Bay Station 2.

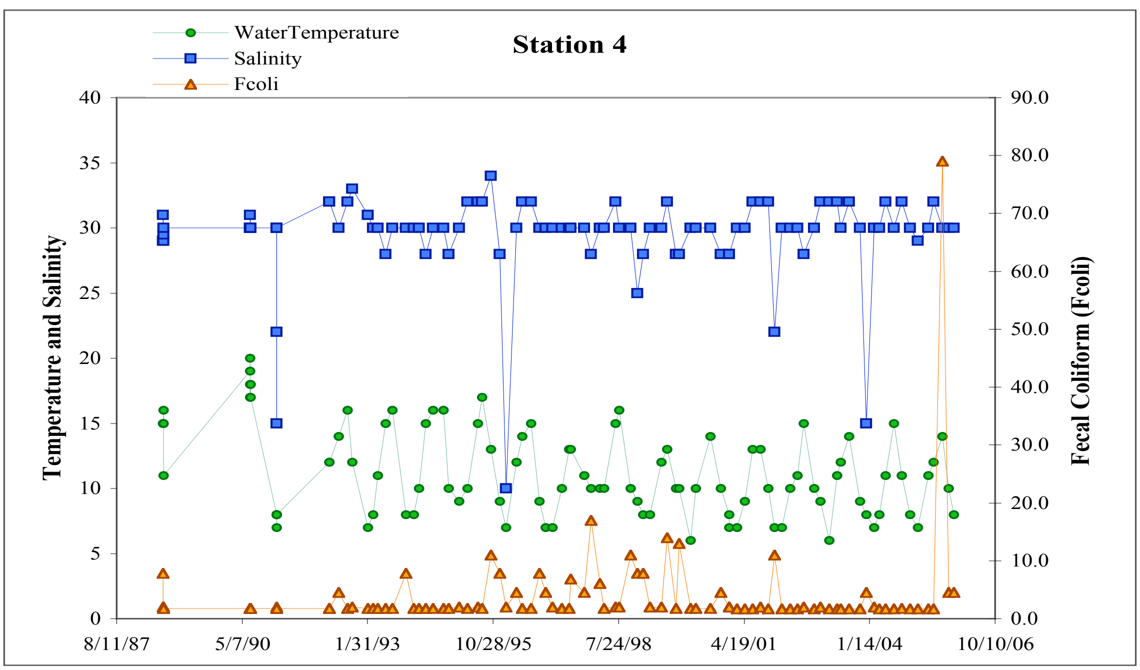


Figure 33. Temperature, salinity, and fecal coliform at Westcott Bay Station 4.

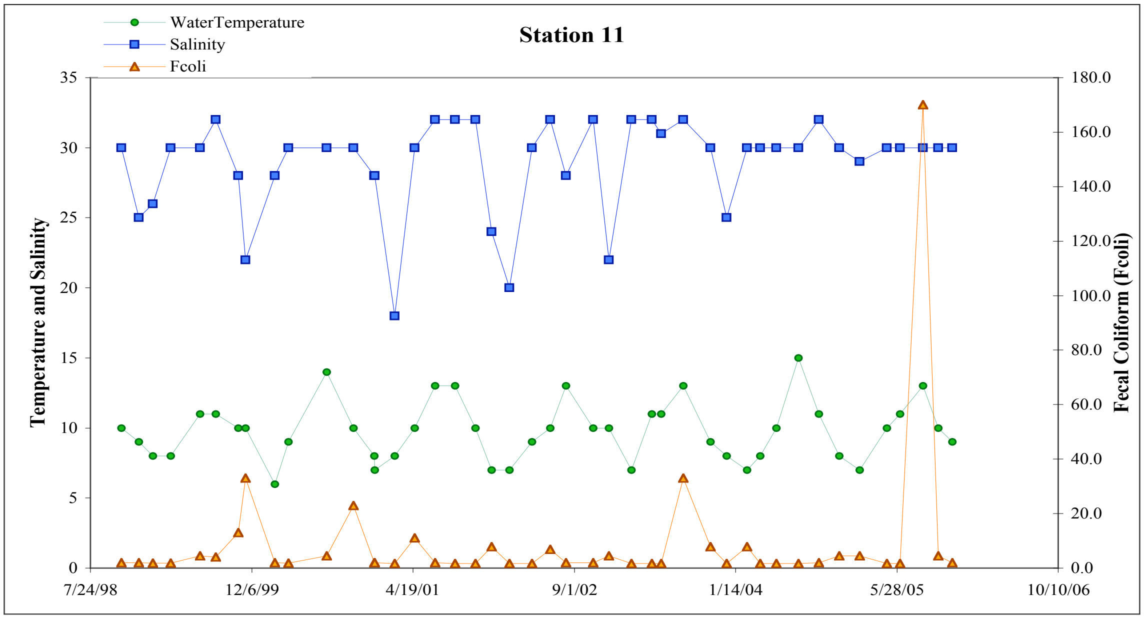


Figure 34. Temperature, salinity, and fecal coliform at Westcott Bay Station 11.

Salinity remains fairly constant across the time series, although several low-salinity events are discernable in the record, probably associated with extreme rainfall events. Seasonal variability in temperature is evident. Although levels of fecal coliform are typically low, several excursions are obvious. Fecal coliform reached exceptionally high levels in one sampling period.

From the individual sample results (given as most probable number or MPN), WDOH calculates two statistics for each station: a geometric mean and 90th percentile, both based on the 30 most recent samples for each station. These statistics are then compared with the National Shellfish Sanitation Program criteria for shellfish growing areas of a geometric mean equal to or less than 14 MPN/100 mL and a 90th percentile equal to or less than 43 MPN/100mL (if no point sources are present) or 10% of the results are not to exceed 43 MPN/100mL (where point sources are present). WDOH also provides these results to the Washington State Puget Sound Ambient Monitoring Program, which tracks changes in fecal coliform using the 90th percentile statistic.

Instead of using the geometric mean, we have taken a more conservative approach to assessing bacterial contamination (Newton et al. 2002): 14 MPN/100 mL, a “moderate” count, indicates contamination that may be of concern, while a “high” count of 43 MPN/100 mL indicates contamination that may be serious. Using this method, we find that between 1988 and 2005 there were 19 sampling days on which at least at least one station exceeded the 14 MPN/100 mL threshold; the 48 MPN/100 mL threshold was exceeded on 8 of those days. The results for August 17, 2005 warrant specific mention: on this date fecal coliform counts for samples taken at all stations except Station 1 (located at the mouth of the bay) exceeded 33 MPN/100 mL (Table 2).

Table 2. Fecal coliform levels at Westcott-Garrison Bay on August 17, 2005
Source: WDOH 2006

Station #	**Fecal Coliform (MPN/100 mL)**
1	11
2	33
3	33
4	79
5	350
6	2400
7	130
8	110
9	130
10	79
11	170

WDOH data indicates that these samples were collected on a flood tide. Since Station 1, which had the lowest fecal coliform levels, is located at the mouth of Westcott-Garrison Bay, the levels of bacterial contamination observed likely originate from within Westcott-Garrison Bay. A review of National Climate Data Center weather observations for Friday Harbor in 2005 indicates that 1.15" of rain were recorded overnight prior to sampling (NCDC 2006). Other than 0.07" of rain on August 1st, no rain had been recorded since early July. Thus, runoff associated with heavy rain may create water quality problems in Westcott-Garrison Bay.

As part of the development of the San Juan County Watershed Management Action Plan and Characterization Report, San Juan County's Health and Community Services Department conducted water quality sampling in streams entering Westcott-Garrison Bay and at one station (SJ22) within Westcott-Garrison Bay at the Westcott Bay Sea Farms dock in 1997-1998 (San Juan County 2000). While other water quality parameters were not recorded at Station SJ22, fecal coliform data were collected (Table 3).

Table 3. Marine Water Quality Conditions at the Westcott Bay Sea Farms dock, 1997-98.

Date	Fecal Coliform (cfu/100mL)
12/9/1997	3
12/16/1997	93
1/6/1998	3
1/27/1998	3
2/3/1998	3

Contaminants

The US Geological Survey (USGS) is currently conducting a study investigating possible relationships between eelgrass abundance, sediment composition, sedimentation rates and concentrations of metals in sediments in Padilla Bay, Skagit Bay and three sites in the San Juan Islands, including Westcott-Garrison Bay. Surface and core sediment samples were collected in early September 2004 and analyzed for grain size, lipids and sediment chemistry, specifically concentrations of sodium, magnesium, aluminum, phosphate, potassium, calcium, iron, manganese, strontium, barium, lithium, vanadium, chromium, cobalt, nickel, copper, zinc, arsenic, molybdenum, cadmium, lead, thorium, and uranium (Takesue et al. 2005b).

Preliminary results indicate that surface sediment concentrations of most metals were near natural background levels in Westcott Bay, with the exception of a sampling station located at the outlet of a seasonal stream that had cadmium concentrations of 2 ppm, five times higher than background levels and the highest concentration observed at all sites during this study. In general, Westcott-Garrison Bay had the highest average cadmium levels (1.5 ± 0.4 ppm) across the three San Juan sites (Takesue et al. 2005b). These authors also note that sites in Westcott Bay where eelgrass was present had significantly lower concentrations of molybdenum (1.5 ± 0.3 ppm) than did sites where eelgrass was missing (2.6 ± 0.2 ppm).

Marine Biotoxins/Harmful Algal Blooms

WDOH manages two biotoxin monitoring programs: 1) a general program in which biotoxins are monitored in numerous bivalve species collected by state, tribal, county, and local agencies as well as commercial shellfish ventures and volunteer organizations, and b) an early-warning "Sentinel Monitoring Program" using mussels (*Mytilus trossulus*, *Mytilus galloprivincialis* and *Mytilus californianus*) sampled at specific points throughout the marine waters of Washington State. When the level of PSP in a single sample of a particular shellfish species exceeds the US Food and Drug Administration (FDA) action level of 80 µg of PSP toxin in 100 g of shellfish tissue, WDOH closes commercial and recreational harvest areas for that species. The areas are reopened only when continued monitoring assures a return to safe conditions (Determan 2003).

We reviewed biotoxin data collected through the general biotoxin monitoring program in Westcott –Garrison Bay from 1990 through 2005 (personal communication, Jerry Borchert, Office of Food Safety and Shellfish Programs, WDOH, 11/10/05). During this period, a total of 625 samples were tested for biotoxins. The comparatively large number of samples reflects the frequent monitoring required of commercial shellfish operations; these data also include samples taken by the San Juan County Health Department and a few samples taken by Adopt-A-Beach in 1991 only. These data show no exceedances of the FDA criterion and only five instances in which detectable levels of PSP were found, four of which occurred in the summer of 1993 and the fifth in 1997 (Figure 35). Domoic acid has not been detected in any samples collected to date. We found one anecdotal account of observations of *Alexandrium* in water samples taken by a visiting biologist at Westcott Bay Sea Farms, but no blooms seem to have occurred (personal communication, Mark Billington, Westcott Bay Sea Farms, 5/5/05).

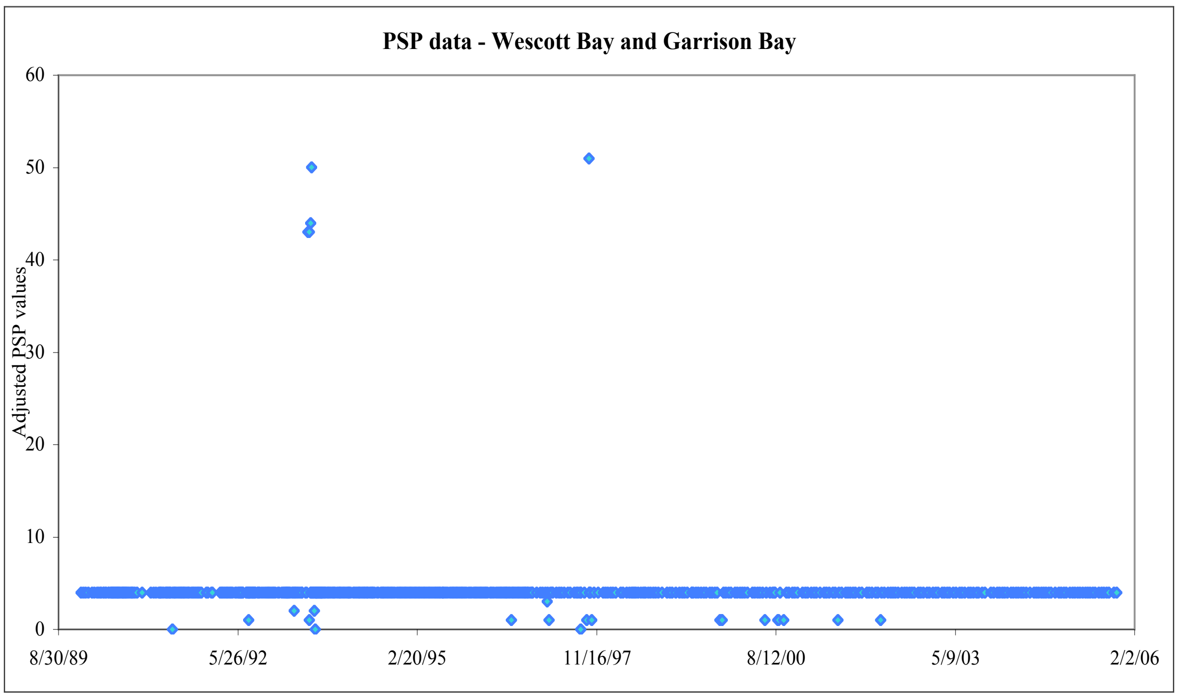


Figure 35. Paralytic Shellfish Poisoning (PSP) levels in Westcott and Garrison Bays. PSP concentrations exceeding FDA-specified levels occurred infrequently (1993, 1997). All other samples tested well within the acceptable range. (The blue 'line' at the bottom of the figure represents a high density of individual samples within acceptable range).

B.1.c. Marine Water Quality in American Camp (Griffin Bay and South Beach)
Nutrients and Dissolved Oxygen
WDOE has monitored water quality at station SJF000, a deepwater station located to the south of American Camp. It is the northernmost station in a three-station transect off South Beach. We downloaded WDOE data for this station (WDOE 2006a); water quality parameters measured at the surface are shown in Figures 36-38. These data are not interpreted in the periodic assessment reports produced by WDOE (e.g., Newton et al. 2002); however, they show interannual variability in all metrics, some of which likely is attributable to variable flow from the Fraser River and physical forcing associated with atmospheric and other climate events (Newton et al. 2003).

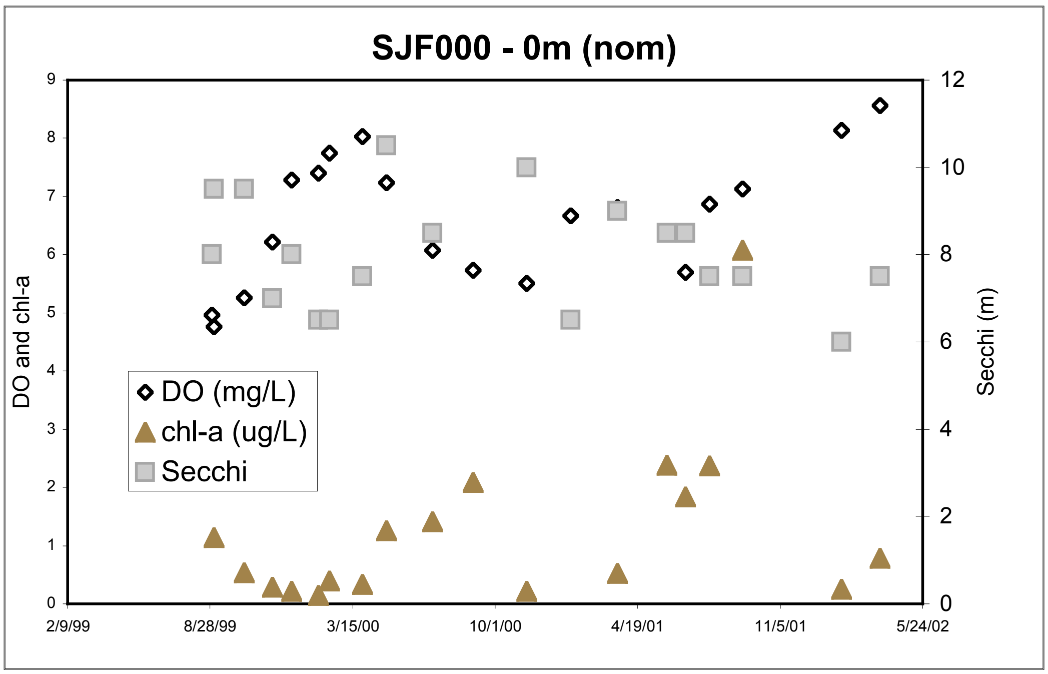


Figure 36. DO, chl a, and secchi depth measured at the surface, Station SJF000

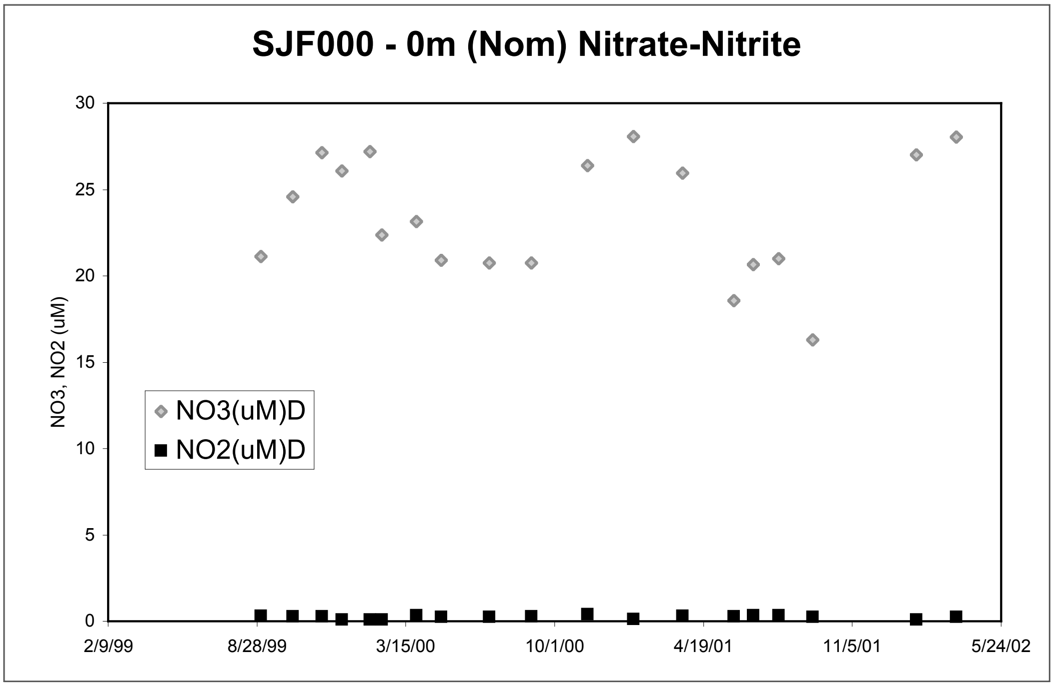


Figure 37. Nitrate and nitrite measured at the surface, Station SJF000

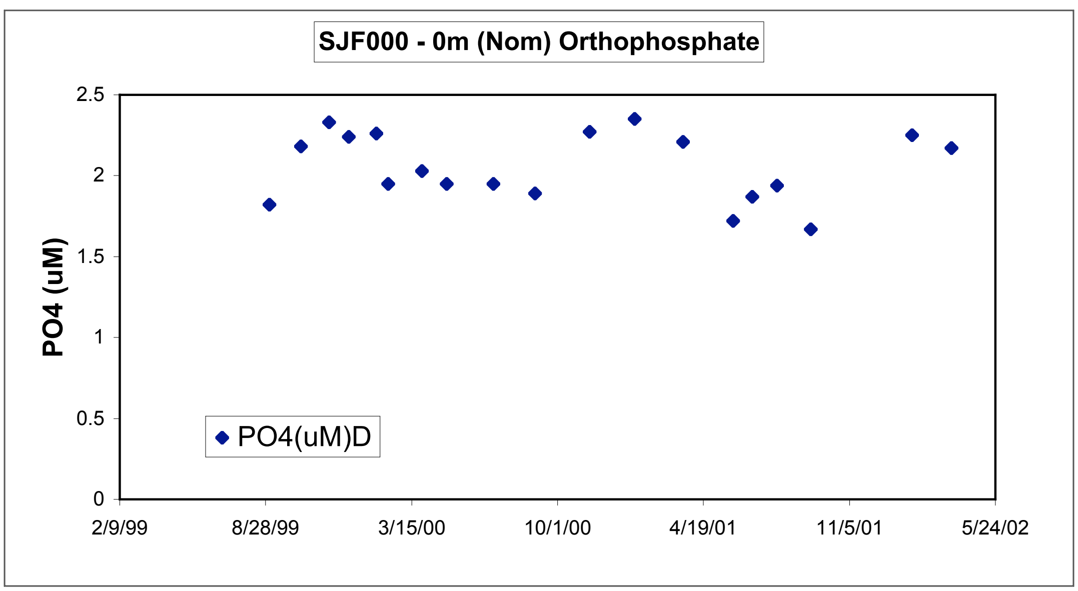


Figure 38. Orthophosphate measured at the surface, Station SJF000

We found no water quality data for Griffin Bay. UW Friday Harbor Laboratories researchers have observed that eddy formation within Griffin Bay reduces flushing (Staude 1997). A few observations of water temperature and salinity were collected in the vicinity of the discharge pipe for the Cattle Point Estates desalinization plant located to the south of the SAJH property line in Griffin Bay, as part of the permitting process (Drahn 1999), and later by student investigators from UW Friday Harbor Laboratories (Karlson 2000).

Bacterial Contamination

Fecal coliform levels at South Beach were measured in discrete water samples taken by WDOE; we found no fecal coliform data for Griffin Bay.

Contaminants

We found no data on sediment quality in Griffin Bay or along South Beach. On a regional scale, WDOE has conducted a sediment monitoring program as part of the Puget Sound Ambient Monitoring Program (PSAMP) since 1989. Baseline data assessing the toxicity and chemical contamination of the sediments and characterizing infaunal invertebrate assemblages were collected at 76 stations from 1989 through 1995. Thirty-four stations were sampled annually while the remaining forty-two stations were sampled on a three-year rotational schedule (WDOE 2005a). In June 2002 and 2003, WDOE took 81 samples in the San Juan Archipelago, eastern Strait of Juan de Fuca, and Admiralty Inlet. None of the San Juan locations sampled were near SAJH. Along with testing for 118 different potentially toxic chemicals, the benthic infauna of the samples were analyzed and laboratory toxicity tests were performed. Results indicated that in general, the marine sediments of the San Juans tend to be among the least degraded regions of Puget Sound (Aasen et al. 2005).

Marine Biotoxins/Harmful Algal Blooms

We found no data concerning biotoxins or harmful algal blooms for Griffin Bay or South Beach. We reviewed biotoxin data for the south Lopez Island-Cattle Pass region collected through general biotoxin monitoring program since 1990 (personal communication, Jerry Borchert, Office of Food Safety and Shellfish Programs, WDOH, 11/10/05). This included two samples taken on Long Island, located near the entrance to Cattle Pass, within a few miles of South Beach. Samples taken by the San Juan County Health Department on July 4-5, 1993 on Long Island and forwarded to WDOH for testing showed PSP toxin levels greater than 1100 µg. The WDOH data for shellfish samples taken at Cattle Pass by Adopt-a-Beach and the Puget Sound Restoration Fund show that the FDA limit of 80 µg was exceeded every summer from 1991-2002 and again in 2005, although the levels of PSP appear to be declining over time. These results suggest that harmful algal blooms likely occur in the American Camp region.

B.1.d. Water Quality in Wetlands and Coastal Lagoons

As part of a wetland inventory, Holmes (1998) reported temperature, salinity, and conductivity measurements made at selected sites within SAJH but draws no conclusions regards water quality at the sites sampled. An earlier report (NPS 1992) reports water temperature and salinities observed in various research studies conducted in the 1960s and 1970s (NPS 1992).

B.2. Water Quality Impairments

Under Washington State water quality standards, surface waters are classified into five classes based on present and future uses of the waters:

- Class AA, Extraordinary
- Class A, Excellent
- Class B, Good
- Class C, Fair
- Lake Class

All marine waters in San Juan County are classified as Class AA (Extraordinary). The criteria for these and other applicable state and federal standards are listed in Appendix B.

Westcott-Garrison Bay has not received any designations or listings related to water quality impairments. However, the water quality of Westcott-Garrison Bay is of local concern. The bays experience a flushing rate of roughly 57% in a 24-hour period (San Juan County, 2000), which is low compared with flushing rates of areas outside embayments. The bays are subject to a number of water quality threats stemming from residential shoreline development and associated septic systems, heavy seasonal recreational boating use and poor boating practices, and non-point source pollution impacts stemming from watershed development and land use patterns. The unnamed creek designated as "Westcott Bay South Stream Outlet" was added to the state 303(d) list for fecal coliform in 2004 as a Category 5 polluted waterbody requiring the development of TMDLs (WDOE 2006b). Water quality monitoring of streams, culverts and ditches discharging to Westcott-Garrison Bay conducted by San Juan County in 1997-1998 also found exceedances of state water quality standards for fecal coliform and total suspended solids (San Juan County 2000). These exceedances are discussed in greater detail in the section B.3.b below.

San Juan Channel was cited on the 1996 and 1998 State 303(d) list for fecal coliform with fecal coliform from boat waste identified as the probable pollution source (WDOE 1998). San Juan Channel is currently listed as category 2, "waters of concern," for fecal coliform and dissolved oxygen.

In 1995, the NPS Water Resources Division (NPS WRD) completed a baseline water quality data inventory and analysis report for SAJH (NPS 1995). This was an effort to retrieve and describe existing data on surface water quality, both marine and freshwater, collected by various agencies and housed in the EPA national databases, including STORET. None of the stations for which monitoring data were found were located within SAJH, and all of the data had been collected prior to 1975. The data were assessed against published EPA water-quality criteria and instantaneous concentration values selected by NPS WRD to identify potential water quality problems within the study area. According to that report, "Twenty-three observations ranging from 3.6 milligrams per liter (mg/L) to 4.0 mg/L were less than or equal to the 4 mg/L EPA criterion for the protection of aquatic life. The criterion was exceeded at ocean stations including Cattle Point (SAJH 0002), Eagle Point (SAJH 0003), Kellett Bluff (SAJH 0008), and Henry Island (SAJH 0009)". No data were found for turbidity, chlorophyll *a* or toxins. The authors concluded that "minimal conclusions concerning surface-water quality can be made given the limited number of monitoring stations, and the quantity and the age of the data" (NPS 1995).

WDOH's Shellfish Growing Area Classification Program evaluates and monitors all commercially harvested shellfish growing areas in Washington State. A growing area's classification is determined by conducting a "sanitary survey," which evaluates the results of a shoreline survey conducted to identify and assess possible pollution sources, the results of fecal coliform monitoring performed by WDOH in that area and an assessment of how weather conditions, tides, currents, and other factors may affect the distribution of pollutants in the area. WDOH conducts a sanitary survey and reassesses the classification of a growing area periodically. Westcott-Garrison Bay has been continually classified as "Approved."

WDOH prepares annual reports assessing the health of the Westcott-Garrison Bay shellfish growing area, which are forwarded to the county government, growers, area tribes, and other state agencies. The 2004 annual growing area review, which includes samples taken from 1999-2004, indicates that all eleven stations in Westcott and Garrison Bays meet the NSSP standards (Woolrich 2005; Table 4).

Table 4. Results of WDOH Annual Growing Area Review for Westcott Bay (Woolrich 2004). * Denotes stations closest to English Camp/SAJH property.

Station	Range *fc/100mL*	Geometric mean *fc/100mL* (Std. is 14)	90th percentile *fc/100mL* (Std is 43)
3	1.7 – 11	2.2	4.0
4*	**1.7 – 11**	**2.0**	**3.0**
5	1.7 – 22	2.8	8.0
6	1.7 – 22	2.6	7.0
7	1.7 – 31	3.1	9.0
8	1.7 – 49	2.7	9.0
9	1.7 – 33	2.3	5.0
10	1.7 – 33	2.8	8.0
1	1.7 – 4.5	1.9	2.0
2*	**1.7 – 49**	**2.2**	**5.0**
11*	**1.7 – 33**	**3.0**	**8.0**

B.3. Sources of Pollutants

We reviewed two previous water quality assessments relevant to SAJH. In 2001, the National Park Service held a "Vital Signs" Scoping Workshop to develop a conceptual model of the linkages between 'agents of change,' 'stressors' and 'ecosystem responses' in order to begin identifying the key vital signs that could serve as early warning indicators of ecosystem changes and recommend monitoring strategies (Flora and Fradkin 2004). The final report highlights several water quality-related stressors and the agents of change contributing to them, excerpted in Table 5 (see also Table 9).

Table 5. Water quality stressors and agents of change identified at the 2001 Vital Signs Workshop (Flora and Fradkin 2004).

Agent of change	Stressor (mechanims of change)
Aquaculture (incl. oyster, clam and salmon)	**Increase nutrients/pathogens** **Increase turbidity**
Boat maintenance and operation (incl. sewage discharge, boat hull maintenance, marine debris and bilge water discharge)	**Increase nutrients, pathogens and chemical compounds associated with boat maintenance and operation** **Introduce toxic compounds to system**
Terrestrial runoff	**Increase nutrients** **Introduce toxic compounds to system** **Locally decrease salinity**
Oil and toxic substance spills and discharges	**Lethal and sub-lethal intoxication of native organisms**

The San Juan County "Watershed Management Action Plan and Characterization Report," adopted by the Board of County Commissioners on June 21, 2000, provides an overview of sources of water quality impairment throughout the county (San Juan County 2000). It focuses on several priority watersheds in greater detail, including Westcott-Garrison Bay. The action plan was prepared by the San Juan County Watershed Management Committee, a group of citizens, in cooperation with the San Juan County Health and Community Services department and the San Juan County Conservation District with funding from a WDOE Centennial Clean Water Fund grant.

To develop the plan, the Watershed Management Committee first examined all the uses of water, both freshwater and marine, in the county and ranked them in order of priority. Domestic water supply and habitat were considered the top priority uses (equal priority); the third priority use was recreation. The committee then ranked the priority uses by the level of threat posed to each by pollution. Finally, they ranked the various pollution sources to develop a priority issue list. Once the beneficial uses and priority problems were identified, the committee developed a series of recommended strategies and action items to be implemented. The committee also rated the various sources of pollutions affecting each of the nine priority watershed based on existing and potential impacts. It is not clear what information the committee used as a basis for their prioritization. The report acknowledges that little information is available for many of the priority watersheds and in some cases anecdotal information was used as a basis for the ranking (San Juan County 2000).

On a county-wide basis, the top water quality issues identified by the committee, in order of priority, were:

- On-site sewage disposal (most residential dwellings in the county have on-site sewage disposal (septic) systems);
- Conversion of forestlands, grasslands and wetlands through residential and commercial development;
- Stormwater runoff (bedrock and clay soils are prevalent throughout the county, and the two urban centers (Friday Harbor and Eastsound) have had significant stormwater quality violations);
- Agricultural practices, particularly in a few watersheds, and a shift towards more small-parcel livestock operations;
- Forestry practices, particularly smaller-scale logging and clearing that is not addressed by state forest practice regulations;
- Marinas and associated boating activities (recreational boating is a major activity in the county);
- Solid waste and hazardous waste as potential sources of pollution.

The report indicates Westcott-Garrison and Griffin Bays as popular boat anchoring areas, and shows the location of an NPDES discharge site at the head of Westcott Bay (Figure 39).

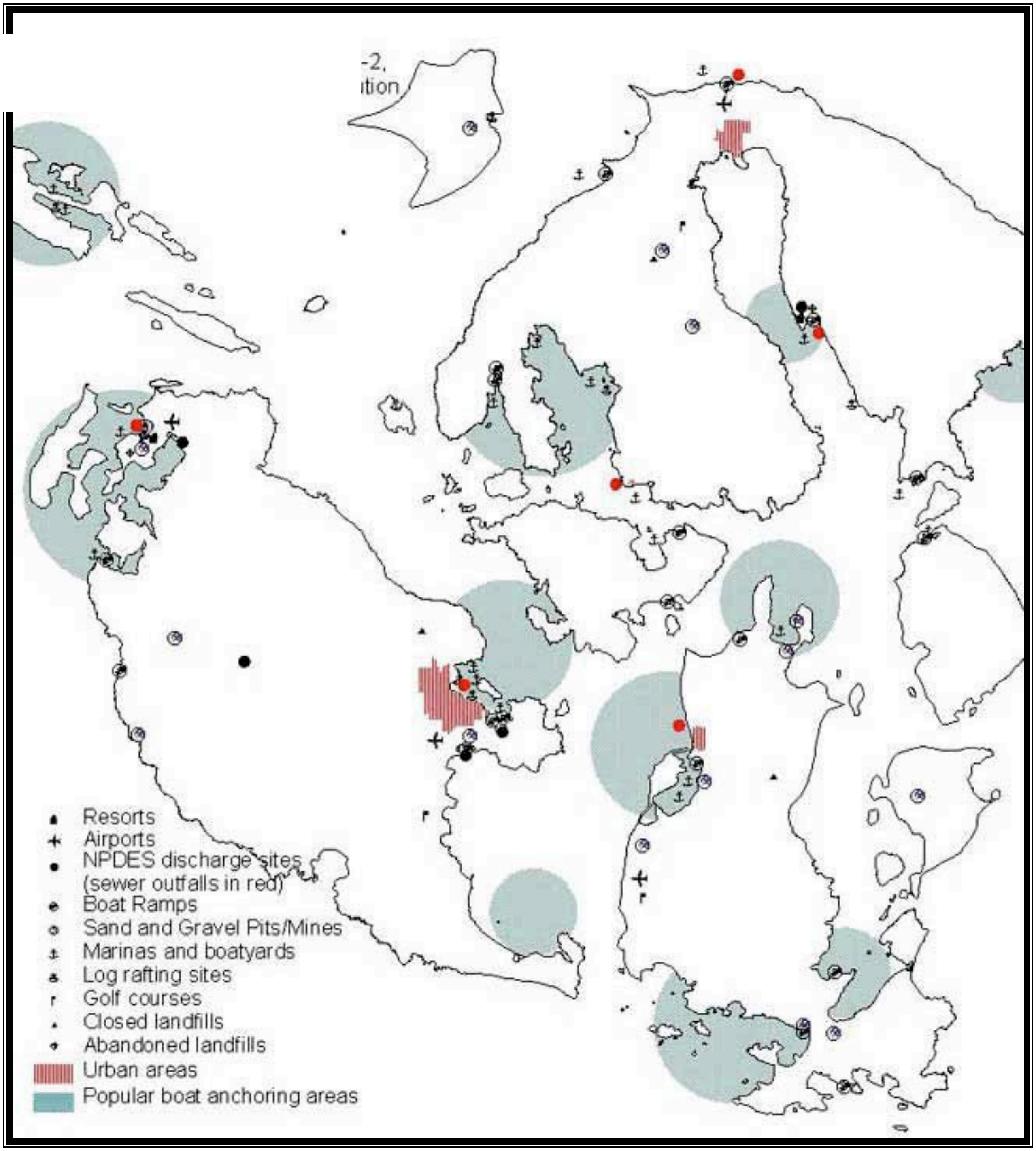


Figure 39. Potential Sources of Pollution Identified in the San Juan County Watershed Management Action Plan and Characterization Report.
Source: San Juan County 2000

B.3.a. Point Sources
English Camp (Westcott-Garrison Bay)
We found no data concerning point source outfalls entering Westcott or Garrison Bays. The grey- water discharge from the Roche Harbor drinking water treatment facility reaches Westcott Bay indirectly: the grey water is discharged into a roadside swale and then into a pond above the salt water lagoon at the north end of Westcott Bay. Water from the pond reaches Westcott Bay via overflow and groundwater seepage (Larkin 1999). Wiseman et al. (2000) sampled the water quality of the outlet stream in 1999-2000 and found high levels of nitrate/nitrate (mean value of 519 mg N/L) and fecal coliform (mean value of 38 cfu/100 mL), although these values may reflect inputs from other sources such as stormwater runoff.

American Camp (Griffin Bay and South Beach)
We found no data concerning point source outfalls into the marine waters within American Camp. A desalinization plant serving the Cattle Point community is located just south of the NPS boundary and discharges into the marine waters of Griffin Bay near Third Lagoon. The desalinization plant was built in 1998 to serve as an auxiliary water supply for the Cattle Point Estates development. The plant withdraws marine water from Griffin Bay, treats it using reverse osmosis, then discharges the hypersaline brine back into Griffin Bay. The plant has a maximum production capacity of 21,400 gallons of freshwater per day; at this rate it would discharge 40,000 gallons of concentrated brine (~46 ppt) per day. The plant, however, is intended to serve only as a supplement to existing water supplies and as of 2000 has been used only intermittently (Karlson 2000).

During the permitting process, concerns were raised by UW Friday Harbor Laboratory researchers regarding impacts to marine life in the vicinity of the discharge pipe, which is located 400 feet offshore at a depth of -12 feet. FHL researchers have observed that eddy formation within the bay can reduce the flushing rate; this could allow the possible accumulation of the dense, briny discharge in localized depressions or in the large basin of Griffin Bay, leading to impacts to the benthic community (Staude 1997). Unfortunately, no baseline studies of benthic community composition were made prior to the installation of the outfall. As a permit condition, two monitoring dives were conducted by the proponents, one in February 1999 and the other in February 2000, to verify whether mixing, dilution and dispersion of the discharge were occurring as anticipated with the plant operating at full capacity. On both occasions, it appeared that the discharge was dispersed and reached background salinity concentrations within 9 feet of the discharge pipe (Drahn 1999, 2000).

In 2000, students at FHL performed a study characterizing the biological and physical conditions around the plant’s outfall and comparing them with two nearby control sites of similar sediment type and depth (Karlson 2000). The parameters measured included species richness and abundance of benthic invertebrates, sampled using benthic cores, and water quality parameters – salinity, temperature, conductivity, dissolved oxygen – sample at slack tide. Because the plant was operating intermittently at that time, they were not able to measure salinity and oxygenation of the water column while the plant was operating. Given the short duration of the study (2 weeks), they focused the majority of their effort on the discharge site and one of the two control sites. Their results suggested that no differences in species richness or abundance were found among the sites. The appendix of the report includes their raw data; voucher samples were preserved and added to the FHL permanent collection.

B.3.b. Non-point Source Pollution in English Camp

Water quality in Westcott-Garrison Bay has been of increasing concern to the local community and to the Westcott Bay Sea Farms, the commercial shellfish aquaculture enterprise operating to the north of SAJH in Westcott Bay. This concern has intensified recently given the unexplained loss of nearly all eelgrass in the bay since 2000.

In 1999, San Juan County prepared a Westcott-Garrison Bay Watershed Assessment as a precursor to the development of a watershed management plan that discusses the types of non-point source pollution that may be affecting the bay. The Watershed Assessment identified water quality degradation stemming from agricultural practices, land conversion and post-development uses among the top management issues of concern for Westcott-Garrison Bay (Larkin 1999). Citing estimates of a bay-wide flushing rate of roughly 57% in a 24-hour period, the report identified the Westcott Bay as highly susceptible to concentrated levels of pollution (ibid).

Water quality impacts from non-point source pollution in Westcott-Garrison Bay were also addressed in the San Juan County Watershed Management Action Plan and Characterization Report (San Juan County 2000). The top management issues identified by the citizen committee that drafted the report were:

- The presence of enclosed shallow bays with valuable habitat, shellfish, educational and recreational resources;
- High potential for conversion of steep forested upland areas for development;
- The fact that the watershed includes the source of domestic water for the suburban and master-planned resort area at nearby Roche Harbor;
- The presence of agricultural activities with high livestock densities in the watershed.

In 2002, a draft watershed management plan was prepared by the San Juan County Planning Department (San Juan County 2001), but the plan has not been formally adopted. Management actions identified in the plan are discussed in the following section.

B.3.b.1. Shoreline and On-Water Activities

Recreational Boating

Westcott-Garrison Bay is a popular recreational boating location. Garrison Bay in particular is a popular overnight mooring location. The Westcott-Garrison Bay Watershed Assessment notes that during a 10-day period in August 1997, an observer counted an average of 40 boats per day moored in Garrison Bay, and personal (anecdotal) accounts of up to 120 boats per day exist (Larkin 1999). We (Evans) counted 25-30 boats moored in Garrison Bay during the middle of the week on two occasions in July 2005. Better quantification of the use of Garrison Bay for mooring is identified as a management strategy to be addressed in the Westcott-Garrison watershed management plan (yet to be adopted by San Juan County).

The Westcott-Garrison Watershed Assessment Report (Larkin 1999) highlighted the following issues of concern related to recreational boating uses in Westcott-Garrison Bay:

- increased fecal coliform levels, pathogens and chemical additives from the discharge of treated and untreated sewage
- contamination with petroleum hydrocarbons and metals (particularly arsenic, copper, lead and zinc) stemming from incomplete fuel combustion and bilge discharges
- seabed scouring through boat anchoring and by buoy line-dragging
- increased turbidity due to resuspension of soft bottom sediments through propeller wash.

From 1986 through at least 1997, the US Coast Guard, which is responsible for enforcing vessel compliance with marine sanitation device requirements, followed a policy of not-enforcement of MSD requirements in Puget Sound (PSWQA 1986, cited in Larkin 1999). Thus, it is likely that some fraction of pleasure vessels operating in the marine waters adjacent to SAJH are equipped with marine sanitation devices that are insufficient to prevent impacts to water quality.

Management and Use of SAJH Property

The Parade Ground at English Camp is a National Historic Register site and is managed by consultation between the NPS and the State Historic Preservation Office to maintain historic character. Vegetation along the shore is sparse, as it has been historically, and provides little buffer between upland and intertidal areas. A Type 5 intermittent stream crosses the Parade Ground, draining into the bay. Grassy areas of the Parade Ground have been observed to carry a relatively high fecal load deposited by Canada geese, deer and pets. Consequently, it is likely that fecal bacteria are introduced into the bay from the Parade Ground.

Aquaculture operations

Westcott Bay Sea Farms produces oysters, clams and mussels at its 23-acre site in Westcott Bay using a variety of in-water culturing systems. The particular species produced are:

- European Flat or "Belon" oysters (*Ostrea edulis*), native to France, Holland, and the British Isles and "Westcott Bay Petite" oysters (*Crassostrea gigas*), a Pacific hybrid from Japan, both of which are spawned in their hatchery and cultivated on rafts in deep water;
- Manila clams (*Tapes japonica*) native to Japan, produced in their hatchery and planted on the beach; and
- Mediterranean mussels (*Mytilus galloprovincialis*).

Oyster cultivation methods used at this facility require that once the oyster seeds reach 2-4 mm in size, they are suspended in a floating raft system called an upweller, which uses a submersible motor to filter seawater through barrels containing small shellfish. Then, when the oysters reach 12 mm in size, they are moved to a suspension culture system with stacks of plastic trays holding oysters that are suspended from lines that stretch across the cultivation area (Figure 40). After 6-9 months, the oysters are loaded into lantern nets that are suspended from the longlines for approximately six months and then harvested to order and shipped (Westcott Bay Sea Farms 2005). Some oysters are also sold on site; in addition, visitors may harvest oysters directly from the beach. All of the cultivated species now can be found outside of cultivation in Westcott-Garrison Bay.

Figure 40. Aerial view of Westcott Bay Sea Farms.
Source: WDOE Shoreline Aerial Photos (http://apps.ecy.wa.gov/shorephotos/)

Commercial shellfish farming likely provides some water quality benefits. For example, adult mussels are able to filter nearly 15 gallons of water per day, removing up to 60% of the plankton from the water they take in (Penn Cove Shellfish website, 2005). However, shellfish farming can also produce negative impacts on water quality, through the production of fecal pellets and pseudofeces by oysters and mussels. Accumulation of fecal pellets and pseudofeces beneath the cultures could produce a net negative impact to the benthos by increasing the BOD load in those areas.

Shoreline Development and Use

The development and use of shoreline properties exert a relatively greater influence on water quality than properties located further from shore due to sheet flow runoff. Impacts from residential properties include direct inputs of nitrogen, phosphate and pesticides via runoff from lawns, along with other household chemicals, as well as pet waste. Landscaping practices may magnify the impacts by removing native shoreline vegetation that serves to filter excess nutrients and contaminants.

The shoreline adjacent to English Camp, particularly on the Westcott Bay side, is dominated by suburban-density development with lots of 0.5 to 2 acres in size. As of 1999, there were a total of 85 residential lots along the shoreline of Westcott Bay lots and 47 residential lots along the shoreline of Garrison Bay (Larkin, 1999). This contrasts sharply with the current zoning and allowable density for Westcott and Garrison Bays (Figure 41). Under the 2003 Comprehensive Plan, the allowable density for most of the shoreline of Westcott Bay and adjacent uplands is 1 unit per 5 acres; the allowable density for most of the shoreline for Garrison Bay is 1 unit per 10 acres (San Juan County 2002).

Several shoreline parcels in Westcott Bay are dedicated to agricultural uses, including the parcels extending north of Bellevue Farm Road to the lagoon system at the north end of Westcott Bay and those along White Point Road directly across the bay from SAJH. These farms feature pasture down to the shoreline with little to no vegetative buffer. Depending on agricultural uses, these parcels could provide direct inputs of nutrients, eroded soil and agrochemicals into the marine waters via sheet flow runoff.

Septic Systems

Residences in the Westcott-Garrison watershed are served by septic systems. Septic systems were identified as the top priority source of water quality impairment on a county-wide basis in the San Juan County Watershed Management Action Plan and Characterization Report (San Juan County 2000). Malfunctioning septic systems can contribute pathogens, nutrients and chemicals to nearshore waters. Even when septic systems are functioning correctly, they do not significantly reduce nitrogen inputs and may contribute significant amounts of nitrogen nutrients to surface and ground waters (Larkin 1999). Most of the older septic systems within this watershed are gravity systems, which require at least three feet of separation between the drainfield and any underlying impermeable layers. Whether or not existing systems meet this requirement is not clear; however, there are areas of shallow rock, clay and other impermeable layers in this area, so gravity-based septic systems may not be appropriate for future development (Larkin, 1999). Furthermore, the predominant soil types within this area – Bay series and Roche series – are "generally not suitable for on-site sewage treatment" (Larkin, 1999). Also, since occupancy patterns may have shifted from seasonal, vacation use to year-round occupation, some septic systems may be experiencing greater use than the levels for which they were designed.

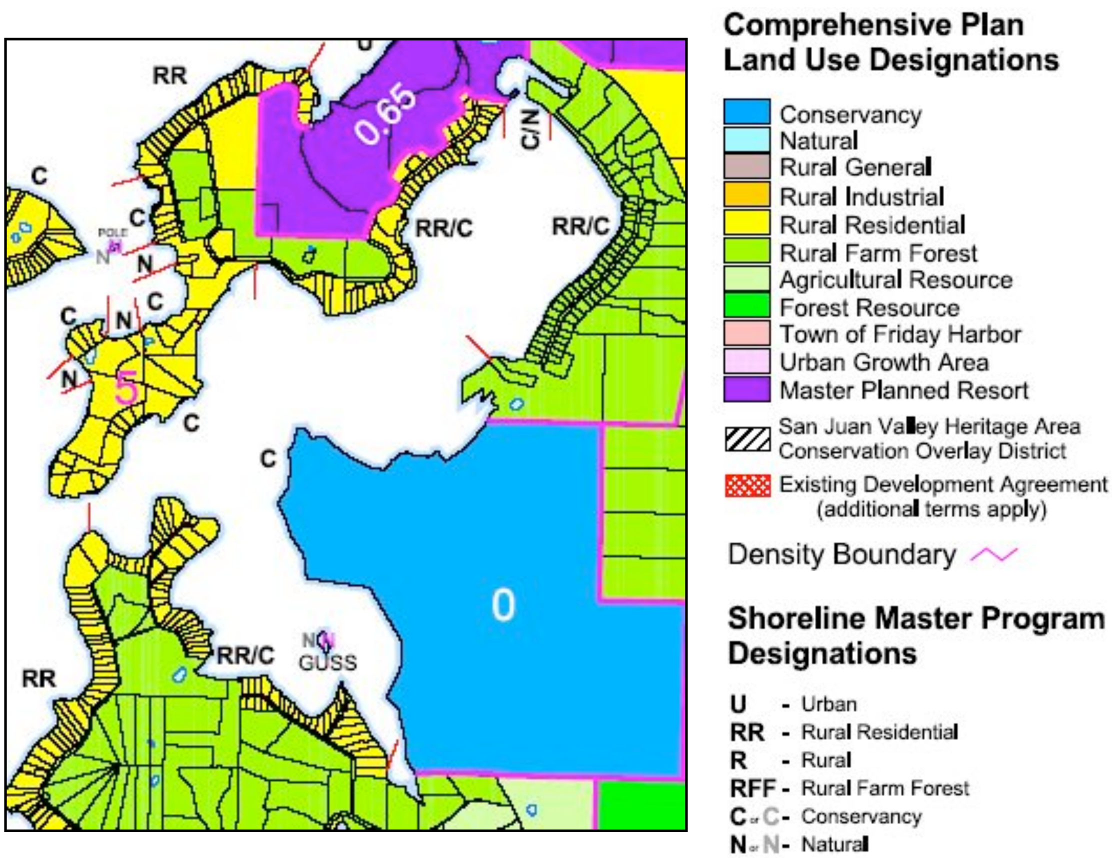


Figure 41. Shoreline zoning and land use designations for Westcott and Garrison Bays. (Excerpted from San Juan County, 2003)

According to the Westcott-Garrison Bay Watershed Assessment, the majority of septic drainfield absorption failures are due to more effluent being produced than the drainfield was designed for. Clogging and failure of the septic system can also result from loading of solids due to garbage disposal use. Anticipated garbage disposal use is not factored into the septic design assessment conducted by the county (Larkin 1999).

No inventory currently exists of the number, type, age and condition of the septic systems in the Westcott-Garrison Bay watershed, though there have been several efforts to sample a subset of the septic systems along the shoreline. The new Beach Watchers program in development by the local Washington State University Extension Program will likely become involved in this area (personal communication, Rowann Tallmon, Beach Watchers Program Coordinator, Washington State University Extension, 7/20/05). (WSU Beachwatchers programs in other counties, particularly Island County, have implemented septic system inventory and property owner outreach programs.)

As part of its 1989 sanitary survey for the Westcott-Garrison Bay shellfish growing area classification review, WDOH evaluated the status of septic systems of residences that were immediately adjacent to the shoreline (Larkin 1999). Interestingly, only 50% of the residences selected for inspection were occupied at the time despite the fact that the survey was conducted during the summer peak season. Of the 19 sites that were inspected, 35% were failing – five were found to be discharging effluent to the surface of the ground on the east shore of Westcott Bay and two failures were recorded on the west shore (Larkin 1999). WDOH did a cursory review of the unoccupied properties and found that three relied on outhouses while two others appeared to have system failures.

In winter 1997, the San Juan County Health and Community Services Department performed dye testing of on-site sewage systems in Westcott Bay. Seventy parcels were surveyed and four failures (5.6% failure rate) were identified (Larkin 1999). These four properties were also among those identified as having failing systems in the 1989 WDOH survey. Three of the failures were on properties bordering Doe Creek which drains to Westcott Bay. In October 1989, the county Health and Community Services Department surveyed the condition of septic systems of 75 shoreline parcels (42 owners) in Garrison Bay. Five failures were identified, four of which are rental properties located on the same property, and one incident of a laundry discharge apparently draining directly to the bay (Larkin 1999).

In 1998, San Juan County conducted another survey of septic systems in Westcott-Garrison Bay. Out of the 90 septic systems surveyed, they identified 9 failures; 9 property owners did not grant permission to survey their systems (San Juan County 2000).

As of 1999, the County did not require any testing or maintenance of septic systems on a regular basis. San Juan County is in the process of establishing an inspection system for owners of onsite disposal system that would require inspection of sand filter and mound systems once a year and conventional gravity and pressure systems every three years; however, broad-scale implementation of the program has been constrained by a lack of funding.

B.3.b.2 Watershed Impacts

The Westcott-Garrison Bay watershed covers approximately 3,600 acres, the majority of which is a mix of forested lands, open lands and scattered small farms. Drainage occurs though sheet flow, creek flow, and stream flow (Table 6). Although the surface area of Garrison Bay is much smaller than Westcott Bay, the two bays drain roughly equivalent watershed areas.

Table 6. Area (in acres) of watershed drainages (San Juan County 2001).

	Area (acres)		
Bay and Watershed Drainage Area	Westcott Bay	Garrison Bay	Combined
Bays	493.8	158.2	652.0
Watershed			
Sheet or minor creek flow directly into bays	549.0	354.7	903.7
Sheet or minor creek flow into Westcott Bay marsh	189.2		189.2
Stream flow			
Briggs Lake/Doe Creek	654.6		654.6
Portion intercepted by Briggs Lake	442.5		442.5
North Westcott Bay Creek	389.0		389.0
Garrison Bay Creek		1434.4	1434.4
Portion intercepted by farm pond		432.4	432.4
Total stream flow	1043.6	1434.4	2478.0
Total Watershed	1781.8	1789.1	3570.9

Human activities occurring upstream within the Westcott-Garrison Bay watershed may exert significant impacts to the water quality of Westcott-Garrison Bay by affecting stormwater quality and quantity. Potential impacts include:

1. Changes in the rate and amount of freshwater runoff in the rainy and dry seasons due to changes in vegetation cover and increases in impervious surfaces;
2. Changes in water temperature;
3. Increased soil erosion leading to greater turbidity and sedimentation rates in the receiving waters;
4. Inputs of pollutants from diverse sources including residential and agricultural pesticides, household hazardous wastes, and automotive products among others; and
5. Increased nutrient inputs due to excessive fertilizer use, animal waste and onsite sewage disposal (septic systems and outhouses).

The 1999 Westcott-Garrison Bay Watershed Assessment Report produced by San Juan County (Larkin 1999) provides a detailed review of the status of the watershed and associated threats to marine water quality.

Stormwater Quality
Although there is no ongoing monitoring of stormwater quality in Westcott-Garrison Bay, several lines of evidence suggest that poor stormwater quality likely impacts conditions in Westcott-Garrison Bay. In fact, the unnamed creek designated as "Westcott Bay South Stream Outlet" was added to the state 303(d) list for fecal coliform in 2004 as a category 5 polluted waterbody requiring the development of TMDLs (WDOE 2006b).

A study sponsored by San Juan County and conducted by researchers and students at Western Washington University's Huxley College of Environmental Studies sampled water quality at selected freshwater and marine sites in 1999-2000 to provide an overview of current water quality conditions and help identify long-term water quality monitoring goals (Wiseman et al. 2000). In addition to the marine water quality samples taken at Westcott-Garrison Bay (described in Section B.2 above), Wiseman et al. (2000) sampled freshwater quality at two streams draining into Westcott-Garrison Bays: Station 21 was located on the Roche Harbor outlet stream, and Station 22 was located on the stream draining into Garrison Bay near Yacht Haven Rd. Although the data are limited, their results provide a useful snapshot of the types and kinds of runoff entering Westcott-Garrison Bay (Figure 7).

Wiseman et al. (2000) sampled the Roche Harbor outlet stream site (Station 21) monthly from March-June and November-February (1999-2000); most streams were dry July to October 1999). The stream draining into Garrison Bay (Station 22) was only sampled until August 2000 due to access difficulties. Parameters measured included temperature, dissolved, conductivity, turbidity and pH *in situ;* water samples were collected for phosphate, ammonia, nitrate/nitrite and fecal coliform bacteria laboratory analyses (Figure 7).

Table 7. Water quality in freshwater streams entering Westcott-Garrison Bay (Wiseman et al. 2000).

Parameter	**Site 21 – Roche Harbor Reservoir outlet stream** Latitude: 48 35'53" Longitude: 123 08' 25" Westcott Dr. and Roche Harbor Rd.			**Site 22 – Garrison Bay stream** Latitude: 48 34'37" Longitude: 123 08' 50" Yacht Haven Rd. and Mitchell Bay Rd.		
	Mean	Min	Max	Mean	Min	Max
Conductivity	251.8	180.3	321.6	298.3	274.1	322
Dissolved oxygen (mg/L)	11	9	12.5	9.8	7.4	13.1
Fecal coliform (cfu/100mL)	38	1	88	104	2	230
Ammonia (mg-N/L)	<20	<20	33	<20	<20	20.2
Nitrate/nitrite (mg-N/L)	519	122	1648	31	<10	96
pH	7.8	7.5	8.1	7.9	7.8	8.0
Temperature (C)	7.9	4.3	12.2	14.1	8.1	18.4
Phosphorus (mg-P/L)	34.9	16.3	71.3	38.4	23.1	54.4
Turbidity (NTU)	9	3	17	11.7	5.9	18.2

The results show that the stream entering Garrison Bay exhibits relatively high fecal coliform counts and temperatures and low dissolved oxygen. The water quality of Roche Harbor Reservoir outlet stream was better, meeting Class AA standards for fecal coliform, pH and temperature, and Class A standards for dissolved oxygen. It had elevated nitrate/nitrite values, particularly in December 1999.

As part of the development of the San Juan County Watershed Management Action Plan and Characterization Report, San Juan County's Health and Community Services Department conducted water quality sampling in nine streams, culverts and ditches emptying into Westcott-Garrison Bay and at one station (SJ22) within Westcott-Garrison Bay at the Westcott Bay Sea Farms dock in 1997-1998 (San Juan County 2000). Station locations are shown in Figure 42. Initial 'spot samples' at the mouths of streams where they enter marine embayments were taken in May and June 1997 to survey conditions at all sites; follow-up samples were collected between November 1997 and February 1998 at locations where contaminant concentrations exceeded standards and additional locations further upstream in an attempt to isolate pollution sources. The parameters measured included temperature, pH, total suspended solids, fecal coliform and nitrate. Nitrate was only measured in the initial spot samples and not the follow-up samples. The results for all stations are shown in Table 8.

Under Washington State regulations, all unclassified fresh surface waters flowing into Class AA waters are also classified as Class AA. Therefore, all freshwater creeks flowing into Westcott-Garrison Bay are classified as Class AA. As the above results illustrate, Station SJ6 exceeded the state water quality standards for Class AA waters of a geometric mean of 14 cfu/100 mL, with less than 10% of samples exceeding 43 cfu/100 mL. Stations SJ5 and SJ6 exceeded the EPA recommended threshold value of 50 mg/L of total suspended solids (TSS). Based on these results, San Juan County concluded that stations in Westcott/Garrison Bay could be affected by both on-site sewage disposal systems and agricultural operations in the watershed (San Juan County 2000).

Uplands Development and Land Use

According to the Westcott-Garrison Bay Watershed Assessment Report, the soils in this area tend to be of two types: Bow series, which are hydric soils, and Roche series, which support the growth of forested lands and woodlands (Larkin, 1999; Figure 43). More than 70% of the drainage basin was forested in 1999; however much of the land is slated for future residential and recreational development, partly through the implementation of the Roche Harbor community development plan and partly through conversion of other forested lands for residential development (Larkin 1999).

The San Juan County Westcott-Garrison Bay Watershed Assessment raises concerns about cumulative impacts to streams and drainage channels as a result of land development and land use practices associated with residential, agricultural, recreational and resort development in the watershed may be causing reductions in instream flows and thus freshwater inputs to Westcott-Garrison Bays, particularly in small channels like Doe Creek (Larkin 1999). Reduced instream flows can also lead to a buildup in sediments that can be catastrophically released in heavy rainflow events, leading to increased sediment loading and turbidity in the receiving marine waters. The Assessment highlights several gaps in the then-existing management regime (Larkin 1999):

- Many types of land use activities that may impact streams and riparian areas do not require any type of permit.
- There are no incentives for landowners to protect streams and riparian areas.
- There is no regular monitoring of these areas that could identify changes and impacts requiring attention.
- There are no existing outreach or regulatory programs that aid landowners in implementing Best Management Practices for streams and riparian areas on their property.
- Agricultural activities that are not part of the San Juan County Open Space Agricultural Program are not accountable for water quality management.

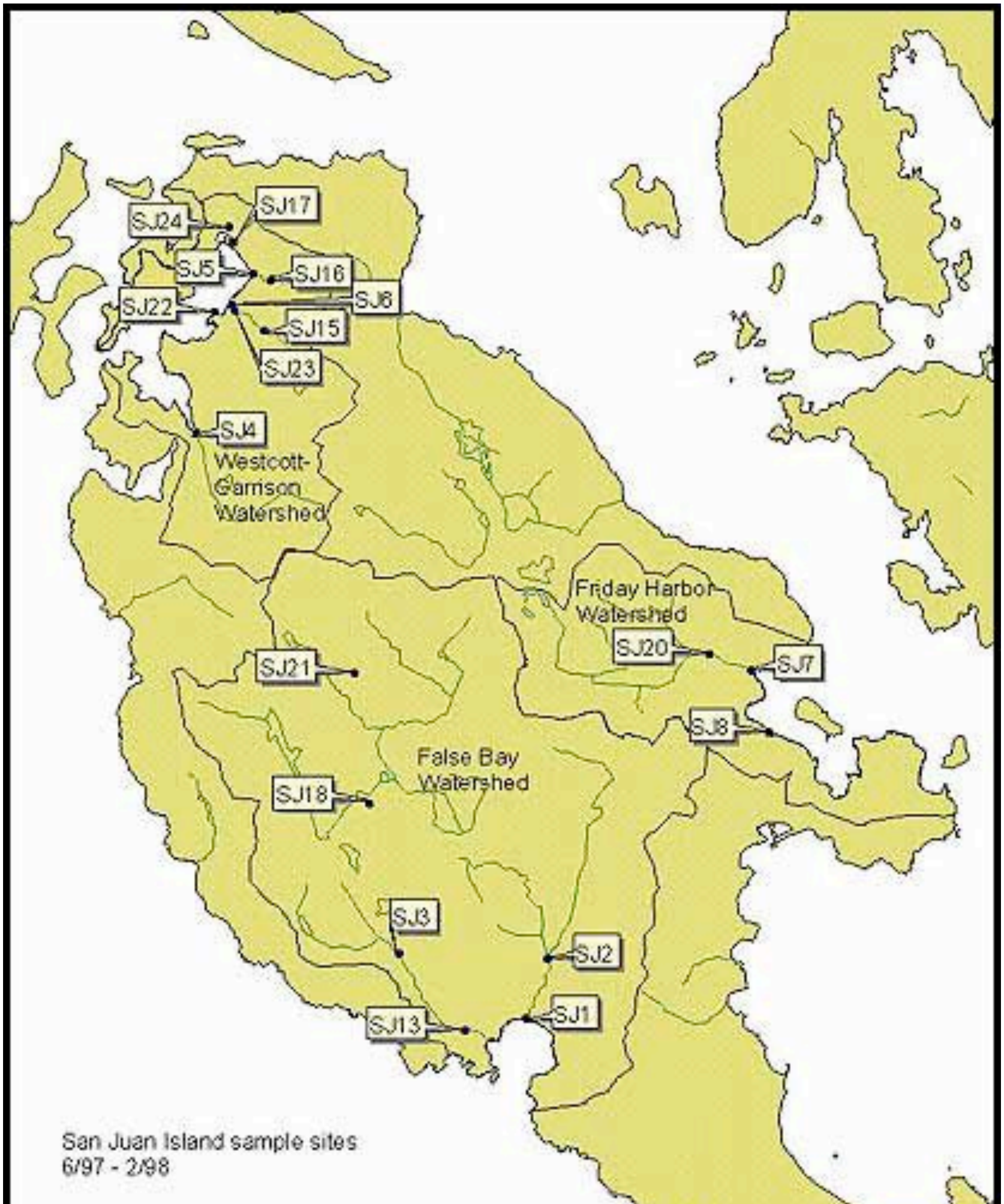


Figure 42. Water Quality Stations in Westcott-Garrison Bay Monitored in 1997-1998. Source: San Juan County 2000; available online at http://www.co.san-juan.wa.us/health/wtrshdpln/appendixAsanjuanmap.html

Table 8. Water quality conditions in streams and culverts entering Westcott-Garrison Bay in 1997-1998. Table adapted from San Juan County 2000. (Continued on next page)

Station	Date	Fecal Coliform (cfu/100mL)	Nitrate (mg/L)	pH	Total Suspended Solids (mg/L)	Water Temp. (C)
SJ5: North Stream Outlet	5/19/1997	3	0.23	7.8	175	11.02
	6/17/1997	240				
	8/5/1997	93				
	11/18/1997	240				
	12/9/1997	9				
	12/16/1997	39				
	1/6/1998	43		7.67	48	4.8
	1/27/1998	23		8.05	23.1	6.3
	2/3/1998	23		8.19	45.6	5.3
	Geometric mean	37				
SJ16: E. side of N. Roche Harbor Rd Culvert	6/2/1997	43				
	6/17/1997	93				
	8/5/1997	240				
	11/18/1997	75		7.3	23	6.6
	12/9/1997	23		7.4	28	5.1
	12/16/1997	93		7.5	32	6
	1/6/1998	9		3.19	48	5.2
	1/27/1998	4		7.62	20.9	5.9
	2/3/1998	43		7.62	28.2	5.6
	Geometric mean	40				
SJ17: Bellevue Farm Pond Westcott Bay	6/2/1997	23				
SJ24: Ditch at Alpaca Ranch	1/27/1998	23				

Table 8, continued

Station	Date	Fecal Coliform (cfu/100mL)	Nitrate (mg/L)	pH	Total Suspended Solids (mg/L)	Water Temp. (C)
SJ4: Garrison Bay Creek	5/19/1997	9	ND	8.06	9	14.7
SJ15: South Mitchell Bay Road Culvert	6/2/1997	9				
	6/17/1997	2400				
	11/18/1997	4		8.1	23	6.7
	12/9/1997	4		7.3	33	6.2
	12/16/1997	93		8.7	54	6.6
	1/6/1998	75		7.97	70	5.1
	1/27/1998	3		8.11	4.8	6
	2/3/1998	9		8.29	22.8	6
	Geometric mean	22				
SJ6: South Stream Outlet	5/19/1997	1100	0.56	8.3	90	11
	6/17/1997	1100				
	8/5/1997					
	11/18/1997	43		7.7	104	6.3
	12/9/1997	1100		7.5	278	6
	12/16/1997	1100		7.7	323	5.1
	1/6/1998	93		7.68	142	5.2
	1/27/1998	15		8.42	22.7	5.8
	2/3/1998	4		8.42	22.3	6.1
	Geometric mean	156				
SJ16A: Ditch at SJ 16	2/3/1998	3				
SJ22: Westcott Bay Sea Farm Dock	12/9/1997	3				
	12/16/1997	93				
	1/6/1998	3				
	1/27/1998	3				
	2/3/1998	3				
	Geometric mean	6				
SJ23: Ditch at Westcott Bay Estates	1/27/1998	9				

Residential Development and Use

A build out analysis for the Westcott-Garrison watershed prepared by the San Juan County Planning Department in 2001 (San Juan County 2001) for the draft watershed management plan indicates that the watershed incorporates all or part of 452 parcels, 161 (36%) of which had residences and other dwelling units in place as of 2001. While development is precluded on approximately 25 parcels (corresponding to 850 acres) due to public ownership, conservation easements and other restrictions, another 12 parcels can be further subdivided for residential development. As a result, the total build out potential for the Westcott-Garrison Bay watershed under the San Juan County 2000 Comprehensive Plan is 620 residential units, more than triple the current number. San Juan County is considering proposals to allow the construction of additional dwelling units, or guest houses, on lots with single family homes, which would result in denser development than that contemplated in the build out analysis. Finally, in addition to changes in the level of development, the type of residential use is changing as well from seasonal, vacation usage to more year-round occupancy.

The San Juan County Westcott-Garrison Bay Watershed Assessment identifies the cumulative effects of 'small-scale residential use spread indiscriminately throughout the watershed' as an issue of concern and highlights the need for attention to the following possible impacts (Larkin 1999):

- Nonpoint water pollution impacts from post-development household use of paint, solvents, lawn and garden products, detergents and cleansers, antifreeze and automotive oil, etc.
- Changes in the timing and volume of stormwater runoff resulting from increasing areas of impervious surfaces and decreases in vegetative cover.

Residential uses within the watershed can contribute to water quality problems through a number of sources of non-point source pollution. Sources identified by Larkin (1999) include:

- Residential use of pesticides/herbicides and fertilizers.
- Inadequate erosion control and other BMPs for residential construction.
- Onsite disposal and/or burning of construction site wastes.
- Inappropriate disposal and/or illegal dumping of household, small business, commercial and agricultural hazardous wastes
- Untreated stormwater runoff from impervious surfaces
- Poorly functioning, broken or inadequate existing oil/water separators
- Sediment loading due to inadequate forestry management practices on small private parcels and inappropriate and destructive logging practices
- Conversion of forested lands to developed residential or commercial lands, thereby increasing stormwater quantity
- Increased untreated surface runoff resulting from loss of critical ecological features on individual parcels (habitat, native vegetation, mature trees, riparian corridors, and others). As more parcels are developed, increased sediment loads enter down slope wetlands and streams, adversely effecting water quality, wildlife habitat, and the overall function and values of the ecosystem.

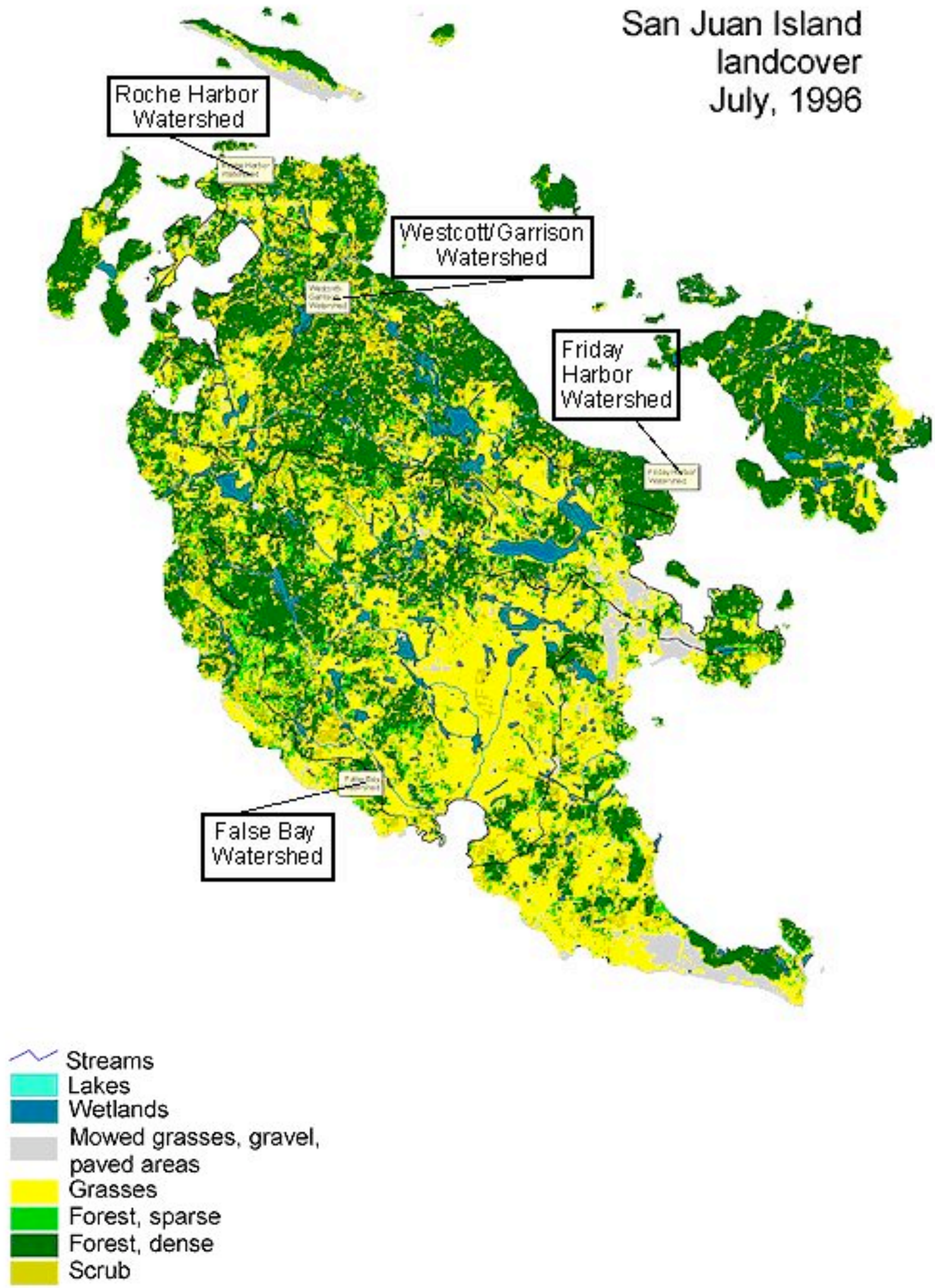


Figure 43. San Juan Island Landcover
Source: San Juan County Watershed Management Committee
http://www.co.san-juan.wa.us/Health/wtrshdpln/index.html

Commercial Development and Use
While none of the Westcott-Garrison Bay drainage basin is zoned for rural industrial or commercial use, there are two preexisting commercial developments: Roche Harbor Master Planned Resort (1,300 acres of which extend into this watershed) and the Westcott Bay Sea Farms, an aquaculture facility adjacent to English Camp. The Roche Harbor Master Planned Resort includes a resort core area and a resort recreational/residential area, in which the resort's current and future commercial and light industrial activities occur. Roughly 120 acres of this core and recreational/residential area lie within the Westcott Bay watershed (Larkin 1999) and is presently a mixture of undeveloped forest and pasture lands. Under current county regulations, commercial uses allowed within the Roche Harbor Resort core area include: restaurants, retail, grocery stores, gas stations, and maintenance facilities for automobiles, marine and airplane maintenance. Uses allowed within the resort recreational/residential district include: golf courses, clubhouses, sports fields, tennis courts, swimming pools and community facilities (Larkin 1999).

In the Garrison Bay watershed, the only quasi-commercial development is a 20-room hotel and seminar facility called the States Inn. Located off West Valley Road, the States Inn can accommodate 40 overnight guests and 84 day-use seminar guests and has a 64-seat dining room. The States Inn also provides horse boarding facilities and riding facilities. There is an auto repair shop located within the watershed on West Valley Road on land zoned as Agricultural Resource Land. In addition to these commercial uses, San Juan County regulations also allow for cottage industries in areas zoned for residential use.

Logging
The San Juan County Watershed Management Action Plan (San Juan County 2000) identifies the following potential pollution sources from logging activities in the County:

- Soil erosion and sedimentation from skid trails and roads;
- Increased surface water temperatures due to loss of shading;
- Run-off contaminated with chemicals and nutrients.

Selective logging occurs in the watershed; the extent to which loggers employ Best Management Practices during selective thinning or during conversion for construction affects the degree of sediment loading that can result. San Juan County Westcott-Garrison Bay Watershed Assessment highlighted the following management gaps:

1. There exist no requirements for reseeding and/or control of noxious weeds on private forested lands cleared and left bare;
2. There exist no regulatory mechanisms to address cumulative impacts of forest clearing on private lands throughout the watershed and particularly within areas near the shoreline;

3. There exist no limitations on the amount of forest clearing for forest land conversions beyond those occurring in the shoreline area, which are subject to a 30% limit under county shoreline regulations.
4. There exist no BMPs for the conversion of forested lands for development;
5. Inadequate training of County staff to identify potential adverse effects in permit applications and provide follow-up review of permit implementation.

Agricultural Uses

The Westcott-Garrison Bay watershed includes approximately 600 acres zoned as Agricultural Resource Lands, 400 of which are currently used for agricultural activities (San Juan County 2001) and most of which drain to Garrison Bay. In the immediate vicinity of Garrison Bay, some small farms include the Blazing Saddle Ranch and an alpaca farm, and contiguous agricultural land use at the base of Garrison Bay (latter from Larkin 1999). Further upstream, the Westcott-Garrison Bay watershed includes portions of the Beaverton Valley agricultural area. Garrison Bay Creek, a year-round creek emptying into Garrison Bay just south of the NPS boundary, is fed by several small tributaries and wetlands that pass through some of these agricultural areas.

The county-wide Watershed Management Action Plan (San Juan County 2000) describes a shift in the kinds of agriculture practiced in San Juan County, from large commercial operations to smaller, more intensive uses. This shift has been particularly evident in the Westcott-Garrison Bay watershed, where agricultural activities feature relatively high livestock densities (San Juan County 2000).

Agriculture activities can contribute to water quality problems in several ways:

1. increased nutrient loads from animal wastes and fertilizers;
2. toxic substances from use of pesticides and herbicides, fuel, solvents and cleaners; and
3. increased erosion and sedimentation from tilling, poor pasture management practices and travel on unpaved roads.

The chief non-point source pollution threats stemming from agricultural uses within the drainage basin include poor pasture management, livestock wastes, and agrichemicals used for orchards (Larkin, 1999). Several interviewees also raised concerns about sediment loading due to historical and current land management practices at a specific ranch located in the Garrison Bay watershed.

The Washington State University Extension Program and San Juan County Conservation District (part of the Natural Resources Conservation Service) both provide technical assistance and financial to farmers in the area to develop of ‘farm plans’ to guide their farming activities and implement best management practices. There are currently three farms in the Westcott-Garrison Bay watershed with active farm plans and a commercial garden also implementing best management practices (personal communication, Heather Hankins, San Juan Conservation District, 9/13/05). Best management practices being implemented include:

- livestock exclusion: keeping livestock off pastures in the winter and confining them to an area where manure is picked up and stored under cover
- composting manure, or spreading it on pastures as fertilizer in appropriate seasons (when grass is growing)
- prescribed grazing (cross-fencing) reduce overgrazing and thus the potential for soil erosion
- maintaining a well-vegetated filter strip between agricultural activities and any surface waters
- conducting soil testing prior to fertilizing so as to better manage nutrient levels of the soil.

B.3.c. Non-Point Source Pollution in American Camp
B.3.c.1. Shoreline and On-Water Activities
Recreational Boating Impacts
As discussed above, recreational vessels can have a number of water quality impacts, including increased fecal coliform levels, pathogens and chemical additives from the discharge of treated and untreated sewage, contamination from petroleum hydrocarbons and metals stemming from incomplete fuel combustion and bilge discharges, and increased turbidity due to resuspension of soft bottom sediments through propeller wash (Larkin 1999). Griffin Bay was identified as a popular boat anchoring area in the San Juan County Watershed Management Action Plan and Characterization Report (San Juan County 2000).

A small private marina is located at the mouth of Fish Creek, just beyond the southern boundary of American Camp on Griffin Bay. Marinas can serve as a source of a number of kinds of water pollution, including illegal sewage discharges, oil and fuel spills, and solvents and other toxic compounds used for vessel maintenance. A number of private docks also exist in Fish Creek. and the area has been identified as one of several locations with high concentrations of mooring buoys (surveyed by WDNR in 2004).

Management and Use of SAJH Property
The saltwater lagoons of American Camp are natural depositional areas for driftwood. We noted that some of the logs present appear to have been treated with creosote, particularly at Jakle's Lagoon. Creosote contains numerous polycyclic aromatic hydrocarbons (PAHs) which are toxic to marine life, and the Washington State "State of the Sound 2004" report identified creosote as a pollutant of concern for water and submerged lands. Researchers with the Skagit County Marine Resources Committee found that even 60 year old pilings are leaching creosote daily into the marine environment and a scratch with a finger nail can bring fresh chemicals to the surface (Northwest Straits Commission 2005). Communications with Park staff in 2006 indicate that a joint project sponsored by the Northwest Straits Commission and WDNR will remove creosote logs from lagoons and American Camp sites.

Shoreline Development and Use
The shorelines adjacent to American Camp are dominated by residential development and uses. The heavily-developed Cattle Point and Cape San Juan communities are found to the south of the American Camp property along Griffin Bay and Cattle Pass. Although this area is zoned "Rural Residential" with a minimum parcel size of 5 acres, the existing development in this area is much denser than that.

The levels and kinds of residential development occurring along the shoreline and in the uplands adjacent to American Camp have the potential to impact water quality in Griffin Bay. Potential impacts include:

1. Changes in the rate and amount of freshwater runoff in the rainy and dry seasons due to changes in vegetation cover and increases in impervious surfaces;
2. Changes in water temperature;
3. Increased soil erosion leading to greater turbidity and sedimentation rates in the receiving waters;
4. Inputs of pollutants from diverse sources including residential and agricultural pesticides, household hazardous wastes, and automotive products among others; and
5. Increased nutrients due to excessive fertilizer use, animal waste and onsite sewage disposal (septic systems and outhouses).

Residences in the vicinity of American Camp are served by septic systems. Shoreline properties with malfunctioning septic systems can contribute pathogens, nutrients and chemicals to nearshore waters. Even if septic systems are functioning correctly, they do not significantly reduce nitrogen nutrients and may contribute significant amounts of nitrogen nutrients to surface and ground waters.

B.3.c.2. Watershed Impacts and Uplands Development
Although we found no records of studies or assessments of the water quality of freshwater inputs into the marine waters of American Camp in either Griffin Bay or along South Beach, development and land use practices occurring within the Griffin Bay and American Camp watersheds beyond the SAJH boundaries may contribute to non-point source pollution. The uplands adjacent to Griffin Bay include some lands zoned for agricultural uses while the remainder is zoned for relatively low density residential development.

C. Vital Signs Workshop and Other Areas of Concern

In 2001, the National Park Service convened a "Vital Signs" Scoping Workshop to develop a conceptual model of the linkages between 'agents of change,' 'stressors' and 'ecosystem responses' in order to begin identifying the key 'vital signs' that could serve as early warning indicators of ecosystem changes and recommend monitoring strategies. Participants identified the potential 'agents of change' likely to have an effect on marine habitats adjacent to SAJH, and the stressors associated with each agent of change (Table 9).

Participants at the Vital Signs Scoping workshop identified the following research questions (Flora and Fradkin 2004):

- Effects of 'normal' human use of the intertidal communities, such as trampling, terrestrial runoff, dock building, aquaculture etc.
- Whether current levels of harvest of targeted species is jeopardizing populations and/or substantially altering community composition
- Possible declines in percent cover of eelgrass
- Effects of catastrophic anthropogenically-caused events such as oil/toxin spills on intertidal communities and existing background levels of oils/toxins
- "how remediation/restoration goals are determined"
- How the physical shoreline is changing over time
- The extent to which anthropogenic effects are increasing the rate of change in a manner that jeopardizes biological communities, particular species of interest, and/or valued physical features (beaches, lagoons, etc.).

Table 9. Agents of change and stressors identified at the 2001 SAJH Vital Signs Workshop (Flora and Fradkin 2004)

Agent of change	Stressor (mechanism of change)
Aquaculture (incl. oyster, clam and salmon)	• **Increase nutrients/pathogens** • **Introduce exotic organisms** • **Increase turbidity**
Boat maintenance and operation (incl. sewage discharge, boat hull maintenance, marine debris and bilge water discharge)	• **Increase nutrients, pathogens and chemical compounds associated with boat maintenance and operation** • **Introduce exotic organisms** • **Introduce toxic compounds to system**
Shoreline modification	• **Potentially intensify wave action and beach erosion due to bulkheads, docks and jetties** • **Alter long-shore currents and sediment movement patterns**
Terrestrial runoff	• **Increase nutrients** • **Introduce toxic compounds to system** • **Locally decrease salinity**
Species harvest	• **Alter species diversity** • **Alter age/stage population structure**
Oil and toxic substance spills and discharges	• **Lethal and sub-lethal intoxication of native organisms**

C.1. Harmful Algal Blooms

Harmful algal blooms (HABs) are discussed as a source of water resource impairments, above. HABs represent a growing threat to regional water quality; consequently, we treat the topic in more detail in this section.

Toxins produced by phytoplankton appear to have been present throughout the region for centuries (reviewed in Horner et al., 1997). Within Puget Sound, HABs that cause paralytic shellfish poisoning (PSP) and domoic acid poisoning are of most concern. In collaboration with local agencies and commercial shellfish operations WDOH monitors beaches around Puget Sound for biotoxins and pollution and issues public notices regarding shellfish harvest closures based on this monitoring. Information is made available to the public via their website: http://ww4.doh.wa.gov/scripts/esrimap.dll?name=bioview&Cmd=Map&Step=1 and the Marine Biotoxin Hotline (1-800-562-5632). However, WDOH does not release to the public information regarding causes of specific closures, so it is impossible to discern the number of closures that are due to HABs.

As discussed in Section B, there have been no documented occurrences of PSP or domoic acid in Westcott-Garrison Bay since 1993. In contrast, given the near-annual summertime occurrences of high PSP levels in shellfish samples taken from Cattle Point, it seems likely that harmful algal blooms are occurring in the waters off South Beach.

C.2. Non-native and Invasive Species

Seventy-six non-native species reportedly are established in marine and estuarine environments in the Puget Sound Region (Wonham and Carleton 2005). More than 90% of these are invertebrates; fish, vascular plants, and algae combined account for fewer than 10% of established invasives. A large fraction of the invasive taxa were introduced with the growth of the oyster industry in the middle of the past century; additional introductions have come from ballast water and other intentional and unintentional sources.

C.2.a. English Camp

A few studies have documented the presence of invasive or introduced species at English Camp. Dethier (1993) reported the presence of the introduced Japanese littleneck clam, *Tapes*. Dethier and Ferguson (1998) reported measurable densities of the invasive mahogany clam, *Nuttallia* in the high intertidal at their transect site at English Camp. Do et al. (2003) evaluated the percent cover of the introduced oyster *Crassostrea* along intertidal transects in English Camp. Westcott Bay Sea Farms staff monitor for the presence of European green crab in Westcott Bay; none have been recorded to date. They have reported abundant populations of *Nuttallia* on both sides of Bell Point, and have also noted the presence of the invasive alga *Sargassum* on the Sea Farm property (personal communication, Mark Billington, Westcott Bay Sea Farms, 5/5/05).

The Westcott Bay Sea Farms raises the European oyster *Ostrea edulis*, Pacific oyster *Crassostrea gigas,* the Japanese Manila clam *Tapes japonica*, and the Mediterranean mussel *Mytlius galloprovincialis*, thus serving as a potential vector for invasion of local habitats by these species. Pacific oysters now are abundant in areas surrounding the aquaculture site (Klinger, unpublished data), and Dethier and Ferguson (1998) noted the presence of the introduced Pacific oyster on muddy surfaces at a low intertidal site located near the mouth of Westcott Bay (segment 72), some distance from the Westcott Bay Sea Farms. Other shellfish farmed at the site now can be found outside cultivation in Westcott and Garrison Bays.

Do et al. (2003) explored possible relationships between high oyster abundance and intertidal species diversity and abundance of key species. They did not find a significant correlation between the presence of oysters and these parameters.

The UW's Friday Harbor Laboratories Science Outreach Program, a partnership between FHL and local public and private schools, has an ongoing project that performs DNA testing of farmed and wild mussels to test for possible hybridization between native and farmed mussels. Investigators take roughly 45 samples per year; results are generally not compiled in formal reports but are available directly from the coordinator, Jenny Roberts at FHL (personal communication, Jenny Roberts, FHL, 9/12/05).

C.2.b. American Camp

The Pacific oyster *Crassostrea gigas* is abundant in rocky intertidal areas adjacent to Third Lagoon and in Fish Creek (Klinger et al. 2006 and unpublished data). This species occurs at low densities in rocky intertidal areas of Cattle Point and Eagle Cove (Copello et al 2004; Klinger, unpublished data); given this distribution, Pacific oysters likely occur in Grandma's Cove as well. The invasive seaweed *Sargassum japonica* has been reported from Griffin Bay, Fish Creek, and Cattle Point (Copello et al. 2004); this species also likely occurs in Grandma's Cove. The purple varnish clam *Nuttalia obscurata* is abundant in Griffin Bay near Third Lagoon, as indicated by the number of empty shells found on the beach there (Copello et al. 2004; Klinger, unpublished data).

C.3. Harvest and Collection of Organisms

C.3.a. English Camp

Shellfishing for clams and crabs occurs in Westcott and Garrison Bays, including on NPS property. Since 1973, harvesting has been prohibited in the area of the parade ground, but is permitted from the dinghy dock north around Bell Point up to the property line of the Westcott Bay Sea Farms year-round, in accordance with WDFW regulations. Shore-based recreational fishing is allowed throughout the park, with the exception of the historical area at English Camp, in accordance with WDFW regulations.

In addition to the direct impacts of shellfish harvest, indirect impacts can occur from habitat disturbance due to walking over the mudflat, dragging boats and gear, and digging. According to Dethier and Ferguson (1998) the most frequent human-caused threat to clams and other infaunal organisms is disruption of the natural stability of their habitat by shellfish harvesting activities, particularly from frequent digging or failure of harvesters to refill the holes they have excavated. For example, of the five sites surveyed by Dethier and Ferguson (1998), the site within English Camp exhibited the lowest abundance of the bent-nose clam, *Macoma nasuta.* This species is not targeted in the recreational fishery; consequently, Dethier and Ferguson (1998) attribute its low abundance in English Camp to indirect impacts of disturbance caused by the recreational harvest of other clam species.

At English Camp, Dethier (1993) found differences in clam abundance between areas open to clam harvest compared with a reference area closed to clam harvest, but cautions that the apparent difference could be due to physical differences between the two areas.

Dethier (1993) compared her results to a multi-year study of clam populations in Garrison Bay performed by Gallucci and Rawson and the 1970s (Galucci and Rawson 1979, cited in Dethier 1993). At that time, the beach at the parade ground area had recently been closed to harvest. Dethier concluded that both the clam and worm fauna showed evidence of recovery due to the fishery closure.

C.3.b. American Camp

Shellfishing is permitted at American Camp in compliance with WDFW regulations, but harvest is less common there because the shoreline habitats do not support harvestable populations of bivalves (with the possible exception of Pacific oysters in Griffin Bay). According to SAJH staff in 2005, limited recreational shellfishing likely occurs in the area of 4th of July Beach and in the area adjacent to Third Lagoon (Klinger, personal observation). An active commercial fishery for Dungenss crab (*Cancer magister*) exists in Griffin Bay in areas adjacent to the park; the density of crab pots is at times relatively high. Recreational pot fishing for crab also occurs in Griffin Bay. The impacts of these fisheries on the surrounding ecosystem are not known.

C4. Recreation

Recreational use of shoreline areas can impact the marine resources of SAJH. Beach walking is popular in both English and American Camps, and some visitors explore the rocky intertidal areas during low tides. Although water temperatures are cool, visitors are known to swim at the beaches on the north and south sides of American Camp (NPS 1992).

Recreational use of shorelines can cause direct harm to intertidal organisms through trampling. This is especially true on rocky platforms. Trampling can cause direct mortality of the organisms or dislodge them, cause structural damage to algae and animals that makes them more vulnerable to other stresses, or result in the loss of habitat as when sessile animals and algae are crushed or removed. Trampling impacts in rocky intertidal areas of Olympic National Park have been summarized by Erickson (2003); her findings likely are equally relevant to rocky intertidal areas within SAJH. Jenkins et al (2002) conducted an experimental study of the effects of trampling on the rocky shorelines of San Juan County Park. They found that trampling reduced the cover of *Fucus* by 30%, and that this reduction persisted through the summer season. Trampling also resulted in a short-term reduction in species diversity.

The Coastal Observation and Seabird Survey Team (COASST), a citizen-science program project of the University of Washington in partnership with the Olympic Coast National Marine Sanctuary, has collected data regarding levels of visitor use along the American Camp shoreline. Although the primary objective of COASST is to collect data regarding the incidence of seabird mortality, COASST volunteers also collect data regarding the number of humans, dogs and vehicles observed during the surveys. Data collection methodologies are described and marine bird data are available on the COASST program website (http://www.coasst.org). We obtained survey data for SAJH directly from COASST (personal communication, Kate Litle, COASST, School of Fisheries and Aquatic Sciences, University of Washington, 4/10/06). In SAJH, COASST volunteers have performed monthly surveys of South Beach (divided into two segments, east and west) since November 2000, and have surveyed Griffin Bay (4th of July Beach) since November 2004. The average number of humans and dogs per segment per month are shown in Figures 44-45 . (Average numbers are reported because some beaches are surveyed more than once per month.) Preliminary analyses performed by COASST staff indicate that when corrected for length of beach, beaches in the San Juan Archipelago show the highest rates of human use of all the beaches surveyed by COASST volunteers during summer months (personal communication, Kate Litle, COASST, School of Fisheries and Aquatic Sciences, University of Washington, 4/10/06).

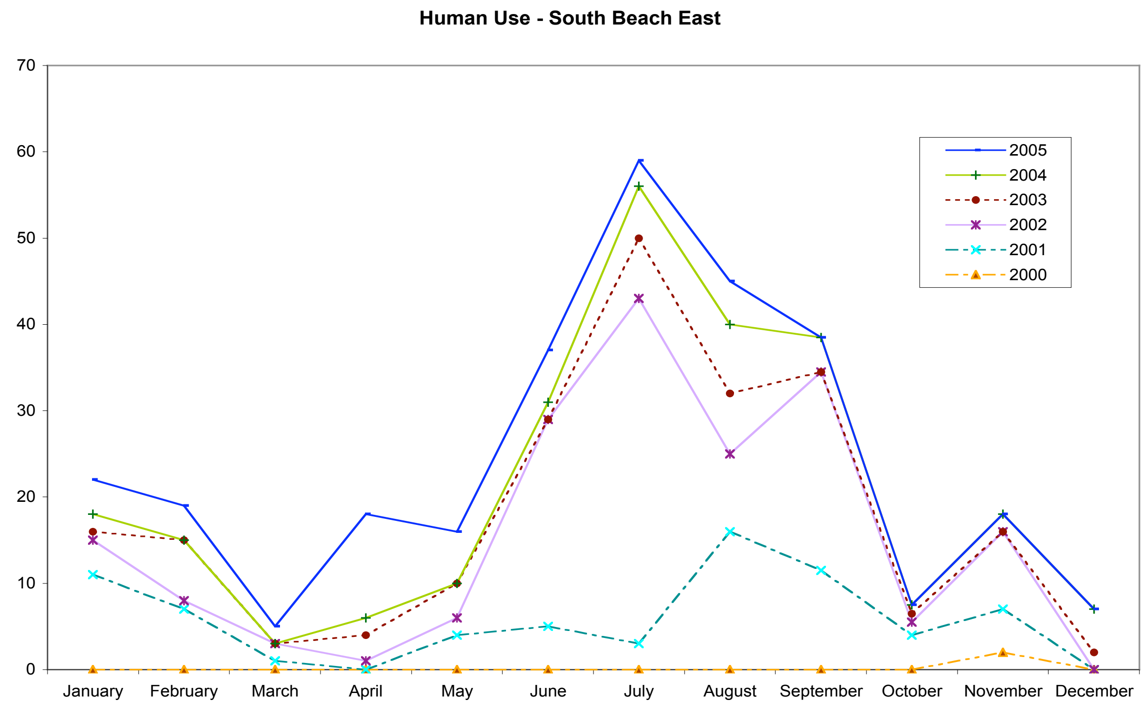


Figure 44. Human use at the eastern end of South Beach, as reported by observers for the COASST Program.

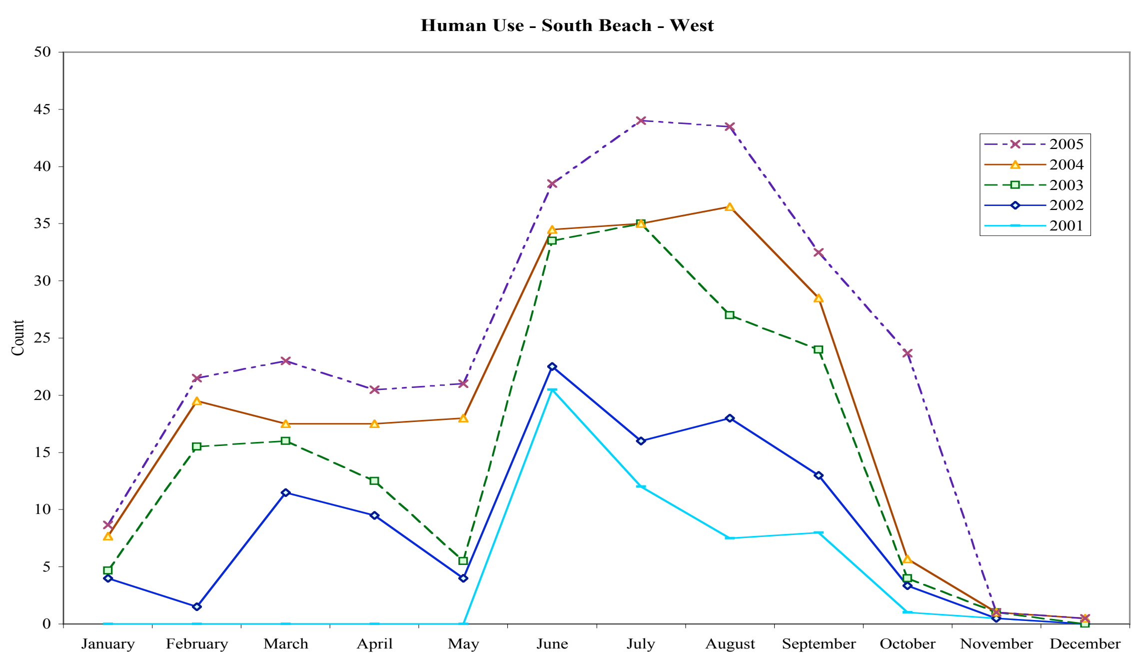


Figure 45. Human use at the western end of South Beach, as reported by observers for the COASST Program.

C.5. Shoreline Modification and Hardening

Several modifications of the shoreline have occurred in Westcott-Garrison Bay. Within the SAJH boundaries at English Camp, shoreline riparian vegetation has been removed in the area of the parade ground; a lawn of cultivated grasses now reaches to within a few feet of the water. The shoreline of the parade ground has sparse to no vegetation and is eroding in places (but note that the sparse vegetation that occurs there includes the pickleweed, *Salicornia*, a native angiosperm of comparatively high habitat value). Lack of shoreline vegetation and resultant erosion could negatively impact forage fish spawning success along this shoreline segment. A small dock and its associated access steps create an additional shoreline modification within park boundaries.

Outside SAJH boundaries, the shoreline habitats of Westcott-Garrison Bay have been highly altered by removal of vegetation associated with residential development and by construction of private docks. The construction and operation of the Westcott Bay Sea Farms shellfish aquaculture facility presents an additional modification.

Docks

Docks impact marine habitats in various ways. Dredging associated with dock construction can increase turbidity, reduce dissolved oxygen concentrations, and bury benthic organisms, and disrupt benthic habitats. Shade cast by docks can inhibit the growth of eelgrass and seaweeds, for example *Fucus*. Dethier and Ferguson (1998) found no eelgrass growing in the direct shade of any docks (including those used by the Westcott Bay Sea Farms) although they did find eelgrass growing up to the edges of the shaded areas. Construction of docks is regulated jointly by the Army Corps of Engineers, Washington Department of Natural Resources, Washington Department of Fish and Wildlife, and San Juan County via its Shoreline Master Program. The current Shoreline Master Program regulations allow the installation of one dock and one mooring buoy for each single parcel, and require that subdivisions construct joint use moorage facilities instead of individual docks for each parcel (San Juan County 2002). The SMP further states that areas with poor flushing action shall not be considered for overnight or long-term moorage facilities, but does not define ‘poor flushing’ (Larkin 1999).

Relatively few docks have been built within Westcott Bay. In 1997, San Juan County documented the presence of one large dock associated with the Westcott Bay Sea Farms and three small private floating docks. In contrast, in the same year, 13 private docks existed in Garrison Bay, in addition to the SAJH public dock (Larkin 1999). In 2004, the Friends of the San Juans conducted an inventory of docks and mooring buoys throughout the county based on aerial photos of the San Juan County shoreline and prepared a GIS layer indicating which parcels currently have docks (Figure 46). FOSJ compared their results with county records and found that the county’s inventory reflected only 40% of the current docks (FOSJ presentation to San Juan County MRC, 8/18/05).

Aquaculture operations
Westcott Bay Sea Farms produces oysters, clams and mussels at its 23-acre site in Westcott Bay. The operations rely heavily on in-water culturing systems, including a floating raft system called an upweller, which uses a submersible motor to filter seawater through barrels containing small shellfish, and a suspension culture system with stacks of plastic trays holding oysters that are hung from lines that stretch across the cultivation area. For the last 6-9 months prior to harvest, oysters are held in lantern nets that are suspended from the longlines (Westcott Bay Sea Farms 2005). Collectively, these structures may cause shading of underwater habitats.

C.6. Boating Impacts

C.6.a Recreational Boating and Mooring Buoys
Westcott-Garrison Bay and Griffin Bay are popular recreational boating areas. During the summer season, an average of 40 boats per day can be anchored or moored in Westcott-Garrison Bay (Larkin 1999; K. Evans, personal observation). Boating activities can cause impacts to water quality through intentional or accidental introduction of sewage, hydrocarbons, metals, and biocides, through increased turbidity from propeller use, and through disturbance to benthic habitats caused by anchoring or mooring. According to Larkin (1999), "in temperate climates the occurrence of planktonic embryonic and larval stages of vertebrates and invertebrates in estuaries coincides with the peak boating season. Therefore the chances of plants and organisms being affected by power boat operations appears to be substantial in shallow, heavily used boating areas."

Given the heavy boat use of Westcott-Garrison Bay particularly by vessels at anchor, the San Juan County Westcott-Garrison Bay Watershed Assessment identified physical disturbance of marine habitats due to boating activities a management issue of concern (Larkin 1999). The report highlighted the following management gaps regarding recreational boating in San Juan County:

- Lack of monitoring of habitat and water quality impacts during boating season.
- Lack of restrictions or guidance regarding the location of boat anchoring and moorage relative to sensitive habitats.
- Lack of guidance or specified traffic routes for vessels to deter heavy boat activity in sensitive habitats.
- Lack of design standards for mooring buoys to minimize habitat impacts.

Boating publications recommend Westcott-Garrison Bay as a sheltered anchoring location. Opportunities for shoreline recreation within English Camp likely add to the attractiveness of the bay among boaters. The National Park Service does not have jurisdiction over boating activities or anchoring in the bays. However, consistently high levels of recreational boat use and their likely impacts to water (and other) resources within the park suggest that NPS may wish to take steps to address boating-related impacts within the bay. Among potential actions that NPS could consider in partnership with local and state entities are 1) establish a speed limit within the bay; 2) establish a no-wake zone within the bay; 3) install mooring buoys to reduce the impacts of anchoring; 4) pursue arrangements with WDNR regarding management of bedlands adjacent to the park, for example, no-fee conservation leases of adjacent parcels; 5) amend the county permit process for private docks in Westcott and Garrison Bays to minimize impacts throughout the bay; 6) continue to recommend that San Juan County adopt the Westcott-Garrison Bay Watershed Management Plan.

Mooring Buoys

Mooring buoys can reduce impacts to the seabed associated with repeated anchoring. Washington State Parks has plans to evaluate new mooring buoy designs at nearby Sucia Island, a popular overnight boating destination. Although mooring buoys may cause less harm to aquatic resources than repeated anchoring, conventional mooring buoys can damage submerged aquatic vegetation and important macroscopic and microscopic benthic communities. They can also impact fish populations indirectly by their effects on prey species and on nursery and shallow water refuge habitats (WDNR 2005). The level of impact depends on tidal activity and currents, wind and waves, the anchoring system design and level of moorage use. Direct and indirect impacts associated with the use of mooring buoys have been studied by WDNR (Table 10).

Table 10. Sources of impacts to marine habitats from installation and use of conventional mooring buoys. Source: WDNR, 2005.

Mechanism	Direct Effects
Anchor placement	Temporary and localized increase in turbidity
Anchor/chain drag	Increase in turbidity; loss of submerged aquatic vegetation and macro-algae; destruction of benthic faunal communities
Propeller wash	Increased turbidity; loss of submerged aquatic vegetation and macro-algae
Vessel shading	Loss of submerged aquatic vegetation and macro-algae; predator refuge
Fuel spills	Localized decrease in water quality; Localized sediment contamination; Damage to submerged aquatic vegetation, macro-algae and benthic faunal communities.
Bottoming out	Loss of submerged aquatic vegetation and macro-algae; destruction of benthic faunal communities
Sewage/gray water	Shellfish closure zones; smothering of benthic faunal communities.

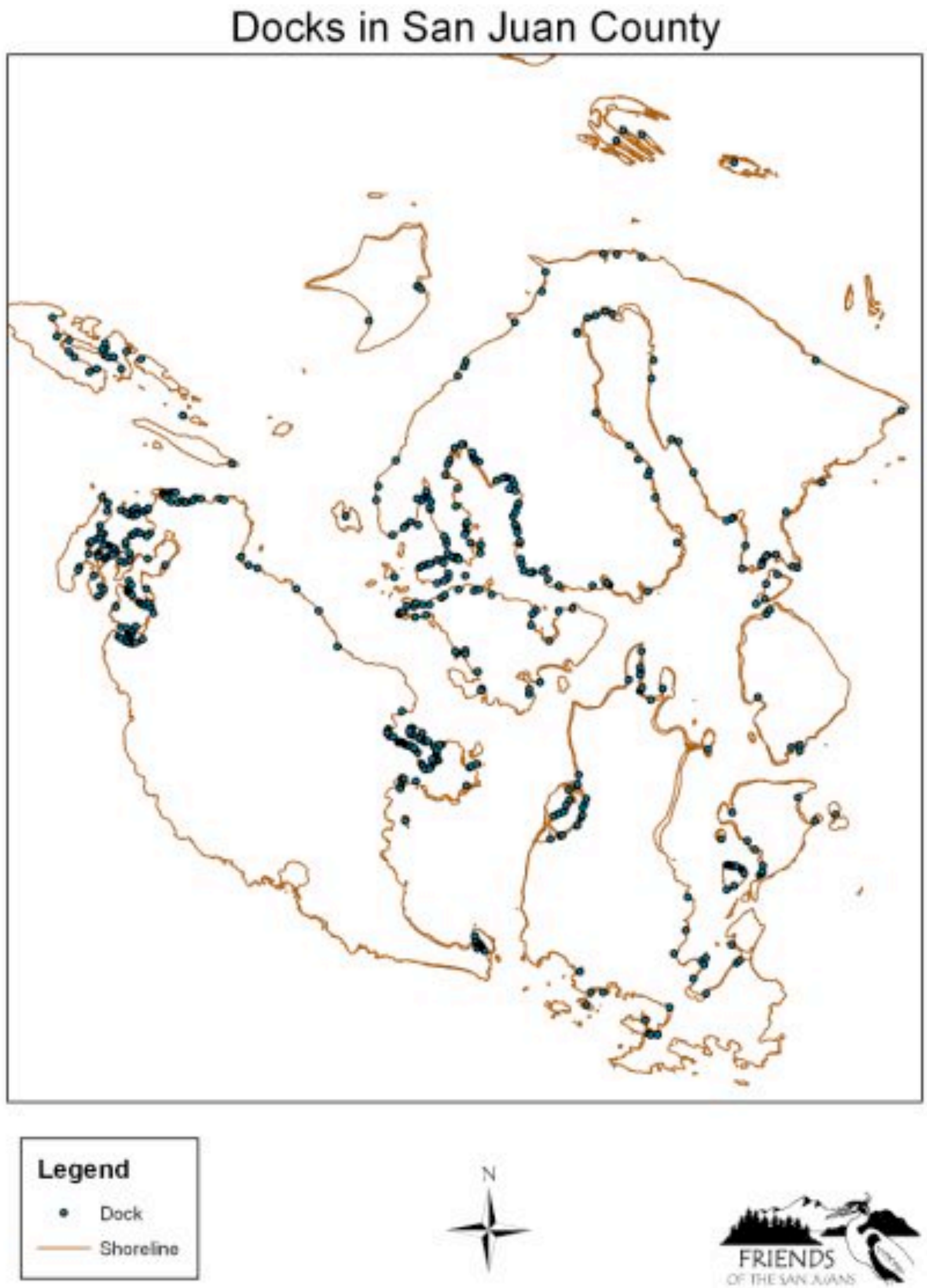


Figure 46. Locations of shoreline parcels containing docks in San Juan County. Source: Friends of the San Juans, 2005.

WDNR and San Juan County are jointly responsible for regulating the installation, placement and use of mooring buoys. The installation of a mooring buoy must be authorized via temporary licenses or more permanent leases. Licenses are easily revocable but leases may only be terminated if the lessee is in breach of the terms and conditions defined in the contract, or when mistakes, errors, or omissions need to be corrected (RCW 79.90.410). In practice, owners of mooring buoys used for recreational use per WDNR's criteria are encouraged but not required to register their buoy and are charged no fee. If the mooring buoy usage does not meet the criteria for recreational use (e.g., buoy used only for private use of a shoreline property owner, used for boats smaller than 60 feet in length, etc), the owner must apply for a license or lease (WDNR 2005). These regulations are augmented by additional and limitations placed by local government as well conditions required by federal, state and local permitting processes. San Juan County's Shoreline Master Program limits shoreline parcels to the installment of one mooring buoy per parcel (San Juan County 2002).

In summer 2004, WDNR began enforcing mooring buoy regulations in five bays in San Juan County due to increasing numbers of complaints from the public. Buoy locations were surveyed and evaluated for their distance from adjacent buoys, proximity to eelgrass beds and blockage of navigational channels. Unregistered buoys were tagged and owners were requested to register them as appropriate. A total of 111 buoys were tagged in West Sound, Barlow Bay, MacKaye Harbor, Jones Bay, and Fisherman's Bay (San Juan Islander, 9/10/04). Fish Creek, just beyond the southern boundary of American Camp on Griffin Bay, has also been identified as one of several locations with high concentrations of mooring.

C.6.b. Boating Impacts on Marine Mammals

Southern resident killer whales (*Orcinus orca*) feed in Haro Strait and the Strait of Juan de Fuca during spring and summer months. They use the waters adjacent to American Camp for transit, rest, and occasional feeding, and often are observed using the area between Alaska Packer's Rock and Eagle Point, at the western edge of the park. Southern residents were listed as endangered under the US Endangered Species Act in 2006; critical habitat has not yet been designated.

Southern resident killer whales are the target of intensive whale-watching activities by both commercial and private groups. In summer months, the number of boats engaged in whale watching can exceed 100 on some days. Boating activities associated with whale-watching are known to affect the movement of killer whales (Jelinski et al., 2002) and have been proposed to impair the ability of the animals to communicate, feed, and rest. In response to intense boating pressure along the west side of San Juan Island, a voluntary Whalewatch Exclusion Zone has been established. The zone extends from the entrance to Mosquito Pass in the north to Eagle Point in the south (www.sjcmrc.org). Within this zone, boaters are encouraged to remain 1/4 mile offshore (1/2 mile offshore in the vicinity of Lime Kiln Park) and to refrain from approaching whales. Extension of the voluntary Whalewatch

Exclusion Zone to Cattle Point, at the eastern end of American Camp, could potentially reduce the impacts of boating on whales in that area.

C.7. Shoreline Development and Zoning

In Section B, we discuss the impacts that existing shoreline development in the areas adjacent to SAJH property may have on marine water quality. Here we discuss impacts from projected future development.

C.7.a. English Camp

The Westcott-Garrison Bay Watershed Assessment Report (Larkin 1999), and the draft San Juan County Westcott-Garrison Bay Marine Habitat Management Plan and Watershed Plan (San Juan County 2001) provide excellent discussions of patterns in watershed development and land use and resultant threats to marine resources.

Land use zoning and shoreline master program designations for each parcel on Westcott-Garrison Bay are shown in Figure 41. Under the current Comprehensive Plan for San Juan County, the shorelines of Westcott-Garrison Bay are generally zoned either “Rural Residential” or “Rural Farm Forest.” The “Rural Residential” designation generally is applied to established residential subdivisions with a small-lot development pattern and allows for single-family residential uses (including home occupations); most non-residential uses are prohibited. “Rural Farm Forest” zoning is intended to provide “rural living opportunities and uses that are compatible with small-scale agriculture and forestry activities, with parcel sizes generally five to ten acres” and allows home businesses and other cottage enterprises while generally discouraging commercial and industrial uses. A large parcel encompassing the western shoreline of the small lagoon at the north end of Westcott Bay is zoned “Master Planned Resort” (Roche Harbor Resort). Most of the non-NPS shoreline of Garrison Bay is zoned “Rural Residential” with a smaller amount zoned “Rural Farm Forest”. The eastern shoreline of Westcott Bay, north of the NPS property line, is zoned “Rural Farm Forest” and the western shoreline is zoned “Rural Residential” (San Juan County 2003).

Land uses proposed to be located entirely or partly within 200 feet of the ordinary high water mark of Westcott and Garrison Bays fall within the jurisdiction of the County’s Shoreline Master Program and are also subject to additional zoning through special shoreline designations (San Juan County, 2002). Under the county’s Shoreline Master Program, the shoreline of Westcott and Garrison Bays is has dual designation as a “Rural Residential-Conservancy” shoreline. This means that the terrain landward of the ordinary high water mark is designated as “Rural Residential-Environment” while the terrain between the ordinary high water mark and the extreme low tide line is designated as a “Conservancy” shoreline. The Conservancy shoreline designation is intended to “protect natural resources and systems and/or valuable historic, educational, or scientific research areas without precluding compatible human uses natural resources and systems” and place limitations on proposed activities and uses that could degrade or deplete the physical or biological resources of the area. The Rural Residential-Environment shoreline designation is intended for residential shoreline development only, where extensive medium density residential development already exists but would not be suitable or desirable for mixed use development (San Juan County 2002).

Westcott and Garrison Bays are subject to an additional land use designation as a "Marine Habitat Management Area". The San Juan County Comprehensive Plan allows for the designation of special "Marine Habitat Management Areas" as an overlay for other shoreline designations in order to preserve and restore critical marine habitat areas. According to the Shoreline Management Plan, areas to be designated a Marine Habitat Management Area should be currently designated Aquatic, Conservancy or Natural by the Shoreline Master Program, support recreational and/or commercial shellfish growing, or be at increased risk of sedimentation and nonpoint pollution due to limited tidal flushing (San Juan County 2002). County policy encourages the simultaneous adoption of a watershed management plan when such a designation occurs. Westcott-Garrison Bay is a candidate for such designation. In 2002 a draft management plan was prepared by the San Juan County Planning Department (San Juan County 2001), but the plan has not been formally adopted nor made widely available.

C.7.b. American Camp

Land use zoning and shoreline master program designations for each parcel in the vicinity of American Camp under the current San Juan County Comprehensive Plan (San Juan County 2003) are shown in Figure 47.

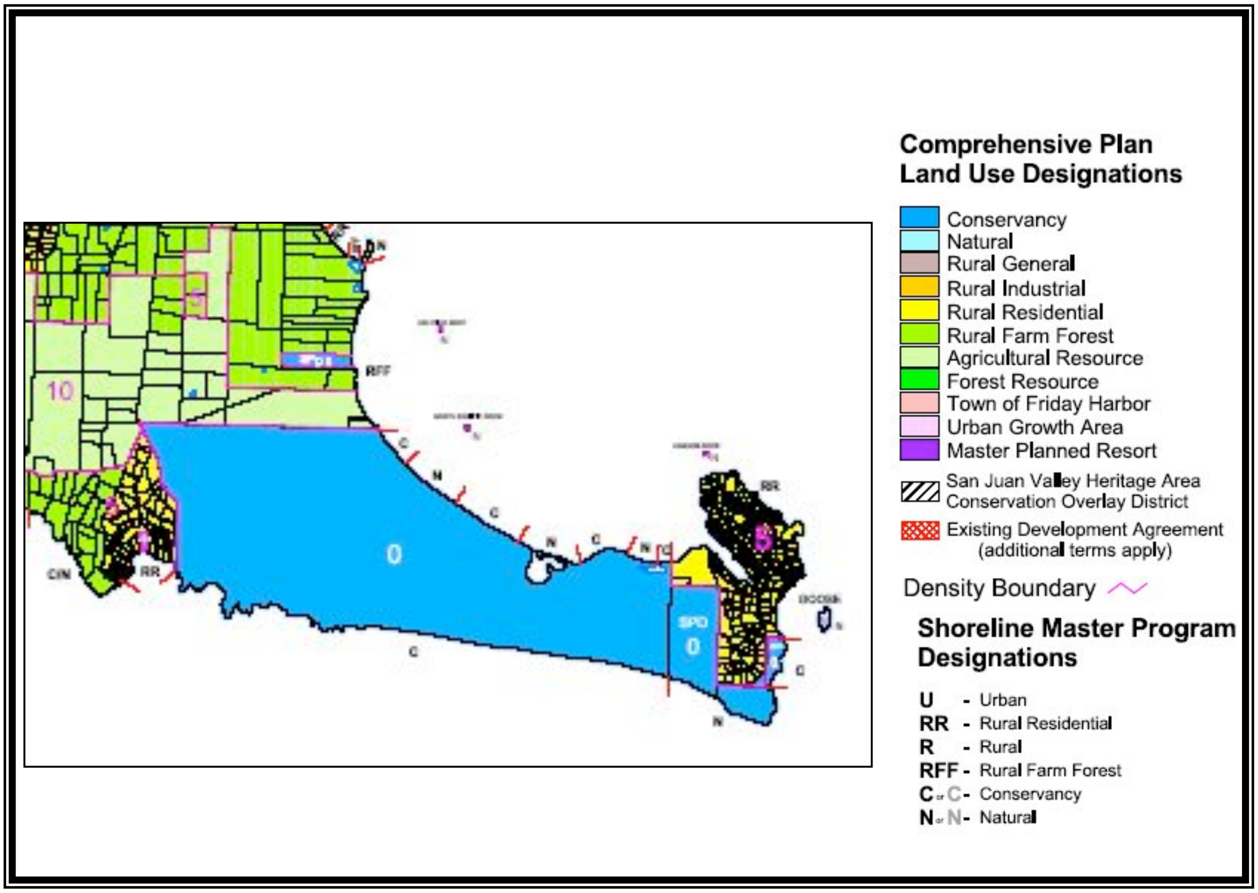


Figure 47. Shoreline zoning and land use designations in the vicinity of American Camp. (Excerpted from San Juan County, 2003)

Along the Griffin Bay side, the land immediately to the north of the park along the shoreline is zoned "Agricultural Uses" with minimum parcel size of 10 acres. Beyond this parcel, the shoreline is zoned "Rural Farm Forest" with a minimum parcel size of 5 acres. Rural Farm Forest" zoning is intended to provide "rural living opportunities and uses that are compatible with small-scale agriculture and forestry activities, with parcel sizes generally five to ten acres" and allows home businesses and other cottage enterprises while generally discouraging commercial and industrial uses. The shoreline itself is zoned as "Rural Farm Forest" as well without any more restrictive "Conservancy" overlays under the county's Shoreline Master Program. The Cattle Point and Cape San Juan communities are found to the south of the American Camp property along Griffin Bay and Cattle Pass. This area is zoned "Rural Residential" with a minimum parcel size of 5 acres, though the existing development in this area is much denser than that. The shoreline in this area is also zoned "Rural Residential" without any additional designations under the Shoreline Master Program.

Along South Beach, the land immediately to the north of American Camp is occupied by the residential development of Eagle Cove, which is zoned "Rural Residential" with a minimum parcel size of 5 acres. Part of this stretch of shoreline is designated as "Conservancy" while the remainder is designated as "Natural" shoreline under the County's Shoreline Management Program (San Juan County 2002). The Conservancy shoreline designation is intended to "protect natural resources and systems and/or valuable historic, educational, or scientific research areas without precluding compatible human uses natural resources and systems" and place limitations on proposed activities and uses that could degrade or deplete the physical or biological resources of the area (San Juan County 2002, 2003).

C.8. Water Withdrawals

San Juan County's water resources, including groundwater, are supplied by local rainfall only; aquifers are not contiguous with those on the mainland. The archipelago is located in a rainshadow created by the Olympic Mountains to the south and Vancouver Island to the west and thus receives less rainfall than most other areas in western Washington. Furthermore, the steep terrain and predominantly bedrock geology result in high runoff and discharge to marine waters, limited groundwater storage, and limited surface water particularly in the dry summer months.

Most of the streams, lakes and ponds in the County have been altered by ditching and dams for irrigation, drainage and drinking water purposes (San Juan County, 2004). Based on drilling log data, most wells in the County tend to have low recharge estimates and low average well yields (San Juan County 2004b). The NPS Water Resources Division's overview of SAJH water resources identified drinking water supplies for residential development in areas surrounding American Camp and the potential impacts of groundwater withdrawals on Jakle's, Old Town and Third Lagoons as an area of concern (NPS 1999).

San Juan County recently completed a Water Management Plan that examines issues surrounding groundwater withdrawals in the county. A county-wide water budget developed for this plan reveals that the WDOE has issued certificates and permits for groundwater equal to 57% of the amount of recharge. San Juan County estimates that the over-allocation may be as much as 174% of the amount of recharge if exempt wells are also included (San Juan County 2004b).

Well systems in shoreline areas in the county are subject to depletion; however, instead of well failure, continued operation will draw seawater into the aquifer. In 1982, a USGS study of San Juan County found that seawater intrusion was strongly suspected in nine percent of the wells studied (26 of 279), with most of these wells located in the southern parts of Lopez and San Juan islands (Larkin 1999).

Under current county policies, desalinization is permitted for individual use and community use for communities with inadequate freshwater resources, but is not allowed as a source of water for new land division (San Juan County 2004b). Growth in San Juan County is predicted to continue at a rate of 2.2% per year (San Juan County 2004b). Given the short supply of groundwater resources, apparent over-allocation of existing supply (per San Juan County 2004), and build-out potential under current land use regulations it seems likely that more desalinization facilities may be built. If this occurred, it could reduce or stabilize the rate of increase in water withdrawals, but could negatively impact marine and nearshore environments through habitat disturbance associated with the building and operation of the facilities.

C.8.a. English Camp

The San Juan County Westcott-Garrison Bay Watershed Assessment identified hydrologic alterations to wetlands, streams and riparian areas as management issues of concern for Westcott-Garrison Bay (Larkin 1999). Fourteen freshwater streams and drainage courses enter Westcott-Garrison Bays. Of these, three have had their natural flow dynamics altered by human activities.

Doe Creek, which empties into Westcott Bay, was dammed to create Briggs Lake, the reservoir serving the Roche Harbor Resort and Master Plan development. As a condition of county permits issued authorizing the expansion of the resort in the mid-1990s, the resort must update its water management plan and reservoir. As part of the plan update, the resort was required to evaluate the instream flow implications of their diversion (personal communication, Laura Arnold, private consultant and member San Juan County Marine Resources Committee, 8/1/05). This update is still in progress.

Two other altered creek systems empty into the saltwater lagoon at the north end of Westcott Bay. Of these, one crosses agricultural and pasture lands and is dammed to provide water for livestock. The second stream emptying into the lagoon drains the artificial pond which receives grey water discharge from the Roche Harbor water treatment plant (Larkin 1999).

C.8.b. American Camp

The NPS water resources baseline report for SAJH and the Vital Signs workshop both highlighted concerns over possible impacts to the lagoons of American Camp due to groundwater withdrawals by development occurring outside the park boundaries (NPS 1992; Flora and Fradkin 2004). Flora and Fradkin (2004) cite an unpublished 'Level 1' Water Quality Inventory and Monitoring Synoptic Study conducted in SAJH in 1999-2000 in which water samples were collected seasonally from five park locations. Although the results indicated that the overall quality of groundwater and surface water was good, elevated specific conductance/chloride concentrations and ammonia:nitrate ratios were found at the American Camp well, possibly indicating increasing salt water intrusion.

The residential communities to the east and west of American Camp are served by a combination of private and community wells. It is currently unknown whether the groundwater supplies serving these wells are contiguous with the groundwater resources of American Camp. Communications with SAJH staff in 2006 indicate that there exists anecdotal evidence that periodic drawdowns of the primary American Camp well may coincide with periods of heavy water use in the Eagle Cove area. According to the County's Water Management Plan, it is generally assumed that the bedrock geology is such that fractures that supply wells throughout the county have little interconnection, and that withdrawal from one well does not affect a neighboring well. In the absence of information on the subsurface geology and groundwater aquifer underlying American Camp, particularly in the area of the lagoons, it is impossible to determine whether groundwater withdrawals by adjacent communities are affecting groundwater resources within the park, including those of the coastal lagoons.

The community wells serving the Cattle Point Estates residential development have experienced saltwater intrusion and as a result the community constructed a desalinization plant in 1999 to serve as a supplementary water supply during periods of high demand and low supply in summer months. The facility operates intermittently. No monitoring program exists, so it is impossible to determine whether the facility or its effluents are impacting water quality or marine resources in the vicinity of Third Lagoon.

C.9. Coastal Erosion

The Washington Coastal Atlas, maintained by the Washington State Department of Ecology, offers some rudimentary mapping of sediment transport along the coastline (WDOE 2006c), and San Juan County has published a coarse map of erosion potential for the island (Figure 17, Section A).

Johannessen (1992) performed a study of net-shore drift in the San Juan Archipelago in the late 1970s as part of a cooperative effort between WDOE and Western Washington University. The study, available from WDOE, describes the location of drift cells, the direction of long-term net shore-drift and summarizes the basis for these determinations. Johannessen reported only one drift cell in Garrison Bay, originating at western Bell Point and moving southwest for 1 km along the English Camp shoreline, and five drift cells in Westcott Bay. In American Camp, Johannessen (1992) observed two drift cells along the shoreline of southern Griffin Bay, both originating at a headland located north of Mt. Finlayson that is a feeder bluff providing sand and gravel drift sediment to nearshore waters. He noted a long drift cell along South Beach that originates 0.8 km east of Eagle Cove and moves sediments east to a point 0.5 km west of the Cattle Point lighthouse. Because the drift cells in Westcott Bay and South Beach both originate outside park boundaries, shoreline development and armoring areas outside the park have the potential to alter sediment supply to shorelines within park boundaries.

The county road running through American Camp to the Cattle Point area communities is cut into the bluffs above South Beach and is threatened by erosion due to coastal wind and wave action at the base of the slope. San Juan County and NPS fear that the continued erosion will lead to failure of the roadway, cutting off vehicular access to the Cattle Point recreational area and residential communities. As a result, San Juan County and the National Park Service are exploring alternatives to replace the road. Concerns have been raised about the potential for the rebuilt road to affect the feeder bluffs on which it is located, thereby altering sediment transport dynamics in the area and also possibly affecting the highly productive nearshore habitats and eelgrass beds on Salmon Bank, immediately offshore. Preliminary scoping for the replacement project, co-sponsored by NPS and the Federal Highway Administration (FHWA) in collaboration with San Juan County and WADNR (across whose land the road crosses upon leaving NPS property), occurred in 2003-2004. One of the alternatives raised during the scoping period that has since been rejected would have protected the rebuilt road by armoring the foot of the bluffs. A DEIS is underway and expected to be released for public comment soon.

C.10. Marine Debris

The San Juan Lions Club and other organizations periodically organize beach cleanups including South Beach at American Camp and share tabulated results with other organizations (e.g., Friends of the San Juans). Unfortunately, the sporadic, opportunistic nature of the data and lack of consistent methods precludes any characterization of the types of marine debris found (personal communication, Tina Whitman, Friends of the San Juans, 7/13/05).

C.11. Fuel and Oil Spills

Major shipping channels exist on the south and west sides of San Juan Island. These are used by vessels in transit to the Port of Vancouver and to several ports in Puget Sound, including the major cargo ports of Seattle and Tacoma and the oil refineries near Anacortes and Bellingham. Although the Washington State ferry routes do not pass near the waters of American and English Camp, there is substantial commercial marine traffic within the islands because the ferry system serves only the five most inhabited islands; the remaining 59 inhabited islands in the archipelago are served by private ferries, barges and other vessels. State ferry regulations prohibit the transport of fuel (including propane, heating oil and fuel) on ferries, so these materials must be shipped by private barge and ferry. The shores of American Camp are particularly at risk because of 1) their location at the confluence of three significant marine traffic lanes; 2) local ocean circulation patterns that tend to accumulate floating material on the shore of South Beach (Klinger and Ebbesmeyer 2002); 3) circulation patterns that carry buoyant materials into San Juan Channel, where they can be trapped by eddies in southern Griffin Bay; 4) soft-sediment beaches, which will retain oil longer and be more recalcitrant to cleaning than rocky substrates; and 5) prevailing wind, current and wave conditions that make oil spill response logistically difficult. Westcott and Garrison Bays are at risk of small-scale fuel spills from recreational boats, and from larger oil spills that could occur in Haro Strait. Once inside Westcott and Garrison Bays, oil will tend to be trapped and could persist for very long periods. The 1995 NPS WRD's overview of SAJH water resources identified a need for oil spill contingency planning, including inventory and baseline monitoring as an area of concern (NPS 1995). Dethier performed a preliminary biological survey in 1993, but the survey has not been updated since.

As a result of a spill in winter 1985 near Westcott Bay, residents formed the Islands Oil Spill Association (IOSA), a community-based non-profit group intended to provide spill response services (www.iosa.org). Largely volunteer-driven, IOSA currently has more than 350 volunteers trained to HAZWOPER standards and providing initial assessment, containment and cleanup, and oiled wildlife rescue. From 1988 – 2005, IOSA has responded to 397 spill reports in and around the San Juan Islands. The most common spill sources include vessel groundings, collisions, sinkings and discharges from damaged fuel tanks. Eighty-three of these have involved ongoing oil and hazardous material/debris recovery, containment, booming, stopping or removing the source of oil, or wildlife rescue. IOSA records and archives data on the location and extent of spills; however, these data are not digitized at present.

Volunteer observers for the Coastal Observation and Seabird Survey Team (COASST) program record the presence, extent and type of oil (sheen, tarball or goopy) found on the beach during monthly surveys. Additional information on the methods used can be found on the COASST website at http://www.coasst.org. We obtained survey data for SAJH directly from COASST (personal communication, Kate Litle, COASST, School of Fisheries and Aquatic Sciences, University of Washington, 4/10/06). No oil was observed on South Beach during monthly surveys from 2000-2005 nor in Griffin Bay (4th of July Beach) during monthly surveys in 2005.

The National Oceanic and Atmospheric Administration (NOAA) has developed a finite-element spill trajectory model (the General NOAA Oil Modeling Environment, or GNOME). This is a free computer program that can be used to predict the path of an oil spill based on wind, currents, and other forces. The model is most useful when an actual spill has just occurred; it provides less utility in modeling spills in general. It can be accessed from the NOAA website at http://response.restoration.noaa.gov/software/gnome/gnome.html (last accessed 6/22/05).

In the event of a large oil spill, WDOE prepares Geographic Response Plans (GRP) to identify priority areas for protection and rank strategies to reduce spill impacts, generally using booms, depending on the location of the spill and resources at risk. Westcott-Garrison Bay is identified as a priority area for booming in the event of an oil spill, with several proposed boom locations at the mouth of the bay as well as within the bay. The only priority area for booming in American Camp is the outlet of Jakle's Lagoon, to prevent oil from reaching the lagoon (WDOE 2003).

Large, catastrophic oil spills due to oil tanker traffic are not the only means by which oil spills can affect marine resources within SAJH. Spills occurring during vessel-to-vessel and mobile unit (truck-to-vessel) over-water fuel transfers may also be an important source and are largely unregulated, particularly for vessels smaller than 10,500 tons. Fuel transfers occurring within San Juan County are apparently not tracked. WDOE recently completed a report on fuel transfers in Washington waterways, and intends to begin a rule-making process to define situations under which preventative measures must be implemented (WDOE 2005b).

C.12. Tsunami Hazards

Low-lying areas of Puget Sound shoreline are vulnerable to tsunami hazard generated by earthquakes that occur along the Cascadia Subduction Zone. In 2004, Washington State and the San Juan County Department of Emergency Management performed a joint risk investigation of the coastline of San Juan, Orcas and Lopez Island (San Juan County 2004b). The preliminary results suggest that due to a predominance of high-bank waterfront, most areas within San Juan County have a reduced risk of tsunami impacts. However, Cattle Point was identified as one potential localized high-risk area, due to a funneling effect increasing the height and force of the water (San Juan County 2004b).

C.13. Climate Change

SAJH is susceptible to the regional impacts of climate change. According to Canning (2002), substantial changes are anticipated over the next 50-100 years. These include

- long-term rise in sea-level
- growing frequency and magnitude of coastal erosion, shoreline retreat, and storm surge
- changes in the tidal prism and salinity of semi-enclosed bays
- inundation of low-lying coastal areas and wetlands
- sea water intrusion into coastal aquifers
- rising water tables
- increased winter rainfall and associated landsliding

Although global mean sea level rise has been on the order of 1 to 3 mm/year over the past century, recent research suggests that the rate of ice cap melting and thus the rate of sea level rise may be much more rapid that previously anticipated.

A number of factors influence actual local changes in sea level. Because of regional variations in atmospheric pressure, currents, and sea water temperature, new predictions suggest that sea level rise in the Eastern Pacific will exceed the global average by more than 20 cm over next 100 years. Local vertical land movement can also play a significant role in apparent sea level changes, particularly in tectonically active regions like Washington State. While other areas of western Washington are experience measurable uplift or subsidence, however, net vertical land movement in SAJH is close to zero. This means that SAJH will likely experience rates of sea level rise similar to the average for the Eastern Pacific.

Models from the University of Washington's Climate Impacts Group/JISAO suggest that the Pacific Northwest will see warmer, wetter winters, warmer summers, decreased flow of freshwater in summer, and increased water flow in fall and winter. Combined with land use changes and increased population, these changes could contribute to increased erosion in winter, and increased water shortages in summer. Coastal erosion may also be enhanced not only by rising sea level, but also by the increased intensity and frequency of winter storms predicted by some climate models.

Climate change may also alter species ranges and behaviors. During strong El Niño years, salmon runs that normally travel around the south end of Vancouver Island travel around the north end instead, with consequences for humans and natural communities alike. Some invasive species may benefit from climate change, enhancing their rate of spread and their competitive advantage over native species.

Sea level rise coupled with increased intensity and frequency of winter storms could cause substantial inundation and erosion in low-lying areas. Within SAJH, these forces are likely to cause inundation of shoreline areas in English and American Camps, eventually causing the coastal lagoons in Griffin Bay to disappear. Shoreline erosion along South Beach is likely to increase, particularly at the base of the cliffs at the eastern end of the beach. Regional changes in the amount and seasonal distribution of rainfall are expected to occur with climate change; these could substantially influence rates of recharge in the aquifer.

D. Recommendations

D.1. Condition Overview

We summarize the condition of water resources in SAJH in Table 11, based on our review of available data and on our best professional judgment. We rate the level of uncertainty in this estimate as fair, due to limitations of the data. We offer brief justification and rationale for our assessment in the following sections. More comprehensive treatment of specific elements is provided in Sections B and C, above.

D.1.a. Westcott and Garrison Bays

The condition of water resources in Westcott and Garrison Bays is influenced by relatively low rates of flushing, seasonally high use by recreational boaters, and by land use practices in the watershed. These combine to cause potential and actual impairments to water quality in the vicinity of English Camp.

Nitrogen has not been regularly measured in Westcott and Garrison Bays, but samples taken from the Roche Harbor Reservoir outlet stream between 1999 and 2000 (Wiseman et al. 2000) showed elevated levels of nitrate. Additional inputs of nitrogen from agricultural sources, failing septic systems, and discharge of on-board holding tanks are likely to cause levels of nitrogen to be elevated to an unknown extent. Consequently, we rate this as a potential problem.

Point estimates of fecal bacteria show that while levels tend to be acceptable under WDOH standards, they occasionally are highly elevated, causing an intermittent problem.

Algal blooms have not been reported in Westcott and Garrison Bays. However, highly elevated levels of PSP were detected on four occasions between 1992 and 1997, suggesting that algal blooms have occurred at least four times in the past. Occasional high nutrient levels and relatively low flushing rates combine to render the Westcott-Garrison system vulnerable to algal blooms, hence algal blooms are a potential problem.

Existing data are insufficient to determine whether metals currently are or could become problematic with respect to water quality. The few data that exist indicate that surface sediment concentrations of most metals approximate natural background levels in Westcott Bay. However, elevated levels of cadmium have been observed there, and a spatial correlation between elevated levels of molybdenum and the absence of eelgrass has been noted.

Toxicants are introduced into Westcott and Garrison Bays from agricultural, residential, boating, and biological sources. Although levels of toxicants are not regularly measured in Westcott and Garrison Bays, occasional reports of elevated levels of PSP (a biotoxin) have been reported. Consequently, we rate this as a potential problem for water quality.

Table 11. Potential for impairment of SAJH water resources.

Stressor / Environmental Indicator	**English Camp:** Westcott-Garrison Bay	**American Camp:** Griffin Bay	**American Camp:** Strait of Juan de Fuca	**American Camp:** Coastal Lagoons
WATER QUALITY INDICATOR				
Nutrients	**PP**	**PP**	**OK**	**PP**
Dissolved Oxygen	**PP**	**OK**	**OK**	**OK**
Fecal Bacteria	**EP**	**OK**	**OK**	**OK**
Toxic Compounds	**PP**	**OK**	**PP**	**OK**
LAND USE-RELATED STRESSORS				
Septic / Wastewater / Effluent	**PP**	**OK**	**OK**	**PP**
Water Withdrawals	**OK**	**PP**	**PP**	**PP**
Stormwater Runoff	**EP**	**OK**	**OK**	**OK**
Agricultural Runoff	**PP**	**OK**	**OK**	**OK**
Aquaculture	**PP**	**OK**	**OK**	**NA**
HABITAT MODIFICATION				
Shoreline Modification	**PP**	**PP**	**OK**	**OK**
Coastal Erosion	**OK**	**OK**	**PP**	**OK**
RECREATIONAL USAGE				
Boating	**EP**	**PP**	**EP**	**NA**
Fishing	**OK**	**OK**	**OK**	**NA**
Shellfish Harvesting	**PP**	**OK**	**OK**	**NA**
OTHER STRESSORS/INDICATORS				
Non-Native / Invasive Species	**PP**	**PP**	**OK**	**PP**
Harmful Algal Blooms	**PP**	**EP**	**OK**	**PP**
Fuel / Oil Spills	**PP**	**PP**	**PP**	**PP**
Marine Debris	**OK**	**PP**	**PP**	**OK**

Definitions: EP=existing problem, PP=potential problem, IP=intermittent problem, OK=no detectable problem, shaded=limited data

Wastewater in Westcott and Garrison Bays comes from failing residential septic systems and from the illegal discharge of holding tanks by recreational boaters, both of which are unquantified. Given the relatively high residential density in the watershed and the seasonally high use of the bays for overnight anchoring, wastewater presents a potential source of impairment in Westcott and Garrison Bays.

Stormwater quality is not monitored in Westcott Bay or Garrison Bay. Stormwater enters the bays from surrounding watersheds through sheet flow, creek flow, and stream flow, carrying nutrients, fecal bacteria, and suspended solids from agricultural and residential areas and from county roads. One unnamed creek entering Westcott Bay was designated a category 5 polluted water body under state standards due to elevated levels of fecal coliform. Logging and residential landscaping within the watershed likely have altered natural filtration capacity, and may have caused increased impacts of stormwater runoff into the bays. Consequently, stormwater presents an existing problem for water quality in Westcott and Garrison Bays.

Agricultural operations from small farms within the Westcott-Garrison Bay watershed are a likely source of elevated nutrients, biocides, and fecal coliform in Westcott and Garrison Bays. For this reason, agricultural runoff presents a potential problem for water quality in Westcott and Garrison Bays, as identified by San Juan County (2000).

Biocides are introduced to Westcott and Garrison Bays via agricultural and residential landscaping applications, and through marine applications (e.g., boating, creosote logs). The extent to which biocides impact water quality is unknown, but the intensity of agricultural, residential, and marine activities suggests that biocides could present a potential problem in Westcott and Garrison Bays.

Relatively high levels of recreational boating in Westcott and Garrison Bays increase the likelihood that small fuel spills will occur within the bays, and oil from larger spills in Haro Strait could be deposited in the bays. The highly retentive character of the bays, coupled with their soft-sediment environment, suggest that once introduced, oil or fuel could persist for long periods and be recalcitrant with respect to clean-up and remediation efforts. Consequently, we rate this as a potential problem

Logging and residential home building are the primary sources of habitat modification in the Westcott-Garrison watershed. Much of the shoreline surrounding the Westcott-Garrison Bay has been carved into small parcels designated rural residential; other parcels designated rural farm forest are used for residential purposes. Residential densities in both areas are relatively high. The loss of forest, understory, and shoreline vegetation and the loss of associated ecological function suggests that habitat modification is a potential problem in the watershed.

We note that shellfish aquaculture may affect water quality in Westcott and Garrison Bays, but we choose not to rate its impact. Shellfish aquaculture can improve water quality through biofiltration, and can reduce water quality through the addition of feces, pseudofeces, and through modification or disturbance to the benthic habitat. Aquaculturists have a strong economic incentive to maintain high water quality in the vicinity of operations. Shellfish aquaculture facilities are monitored by the Department of Health and are subject to state standards, and their continued operation is generally a sign of adequate water quality.

We also note that Table 10 fails to capture the sharp decline in eelgrass observed in Westcott and Garrison Bays since 1998. The cause of the decline has not yet been established, and cannot yet be linked to specific water quality impairments.

D.1.b. Griffin Bay

Within Griffin Bay, eddy formation and consequent entrainment of dissolved and particulate substances, recreational use of nearshore areas (e.g., boating, overnight anchoring, marina use, and fishing), and land use practices on adjacent private parcels combine to create potential impacts to water quality. However, existing data are insufficient to rate these threats for most indicators. Among the indicators that can be rated, we rate nutrients as a potential problem based on likely inputs of nitrogen from failing septic systems, horticultural and agricultural fertilizers, and anchored boats. Persistent eddies and soft sediments characteristic of south Griffin Bay We rate habitat modification as a potential problem in recognition of physical impacts associated with the marina and desalinization plant (in southern Griffin Bay) and with home building (especially in northern Griffin Bay). Although not captured in Table 11, invasive bivalve species (Pacific oysters, purple varnish clams) could have positive impacts on water quality (through biofiltration), while at the same time imposing negative impacts on benthic community structure.

We have insufficient data to assess water quality in Jakle's, Old Town, and Third Lagoons; consequently, we rate water quality in these areas similar to that in southern Griffin Bay. We caution that, because of their small size and shallow depth, the lagoons will be more vulnerable to some external stressors than Griffin Bay as a whole. For example, algal bloom formation could be more frequent or intense, salinity and other water quality parameters could fluctuate more widely, and oil and other pollutants could be more persistent in the lagoon than in Griffin Bay. Over time, the lagoons could disappear with sea level rise.

D.1.c. Strait of Juan de Fuca

The south-facing shore of American Camp is exposed to the eastern Strait of Juan de Fuca. The eastern strait is a region of vigorous mixing between oceanic and estuarine waters. Circulation in the eastern strait is more dynamic than in Westcott-Garrison Bay and Griffin Bay, and rates of flushing are higher than in the interior bays and channels of the archipelago. Although the eastern basin is favored by recreational boaters for fishing and wildlife viewing, it is not used for overnight anchoring. Residential development along the south-facing shore is relatively sparse (limited to the Eagle Cove and Cattle Point Estates developments) and it is unlikely that residential septic systems in these areas negatively impact regional water quality. There exists no commercial development in the vicinity of American Camp. Although algal blooms have occasionally been reported, and dissolved oxygen has occasionally been low, these events tend to be transitory and the overall water quality of the region remains high, leading us to rate most indicators as OK.

We note four exceptions to this rating. Tidally-generated eddies characteristic of the eastern basin cause buoyant materials to be deposited on South Beach. Consequently, in the case of an oil spill (or spill of other buoyant material) in the eastern basin or in Haro Strait, the southern shore of American Camp is likely to be highly impacted, causing a potential problem. Second, high levels of PSP have occasionally been reported from the area around Cattle Point. Consequently, PSP may constitute a potential problem of unknown frequency on the south shore of American Camp.

Third, although not captured in Table 11, sea-level rise and increased storminess (both potential consequences of climate change) could lead to increased erosion at the base of the cliff behind South Beach. This could cause changes in sediment loading and turbidity, and perhaps to alterations in beach profiles. Fourth, short-term changes in erosion and in sediment loading could accompany road-building activities on Cattle Point Road, with consequent impacts to water quality.

D.2. Recommendations

In offering recommendations, we acknowledge that moderate uncertainty exists in our evaluation of several aspects of water resource condition. This uncertainty reflects the limitations of the data. Consequently, our recommendations include suggestions for closing data gaps, especially those pertaining to water resources that could become impaired in the near-to-mid-term.

We summarize our recommendations as follows, and provide a brief rationale for each in the section below. The order in which the recommendations appear does not reflect relative importance or urgency.

Table 12. Recommendations

English Camp

- Work with San Juan County to encourage adoption and implementation of the Westcott-Garrison Bay Watershed Management Plan
- Pursue partnerships with local and state entities for collaborative management of Westcott-Garrison Bay aquatic resources
- Work with local and state entities to educe impacts of recreational boating in Westcott-Garrison Bay
- Monitor nutrients, dissolved oxygen, and fecal coliform in Westcott-Garrison Bay regularly
- Partner with others to monitor eelgrass declines in Westcott-Garrison Bay; consider eelgrass restoration
- Measure the introduction of fecal bacteria from the English Camp parade ground to Garrison Bay. Consider management options that would reduce fecal loading from the parade ground to the bay if loads exceed NPS, regional, or local standards.
-

American Camp

- Address groundwater withdrawals and saltwater intrusion in American Camp
- Develop and implement a monitoring program for the coastal lagoons and immediately adjacent areas of Griffin Bay (for example, Fish Creek)
- Partner with others to encourage responsible boating practices and wildlife viewing practices in American Camp, particularly with regard to killer whales
- Work to reduce impacts of road-building activities on the nearshore environment in American Camp

Parkwide

- Partner with the Islands Oil Spill Association to update oil spill contingency planning for English and American Camps; track the Washington State oil spill contingency plan rule update process and outcome
- Promote research into issues identified at the NPS Vital Signs workshop
- Encourage basic and applied research by University of Washington and other investigators; develop guidelines for the conduct of scientific research in park areas
- Develop management plans for aquatic invasive species, or partner with local and state agencies to manage aquatic invasives

Rationale

- ***Work with San Juan County to encourage adoption and implementation of the Westcott-Garrison Bay Watershed Management Plan***

San Juan County's Watershed Management Plan offers a comprehensive approach to planning for the Westcott-Garrison Bay watershed, but the plan has not yet been adopted or implemented by the county. Implementation of the plan is likely to provide benefits to aquatic resources through Westcott-Garrison Bay.

- ***Pursue partnerships with local and state entities for collaborative management of Westcott-Garrison Bay aquatic resources***

Partnerships between state and local entities will facilitate management of aquatic resources.

- ***Work with local and state entities to educe impacts of recreational boating in Westcott-Garrison Bay***

Westcott and Garrison Bays experience high seasonal rates of recreational boating, including overnight anchoring. This use can cause impacts to nearshore environments through damage from anchoring and from illegal discharges. Impacts of recreational boating could be reduced through 1) installation of a mooring buoy system that minimizes impacts to benthic habitats (new designs currently are being tested by Washington State Parks at nearby Sucia Island); 2) enforcement of existing regulations regarding discharge of wastewater, bilge water or grey water; 3) provision of a pump-out facility or provision of information regarding nearby pump-out facilities, e.g., at Roche Harbor; and 4) education of visitors regarding impacts of overboard disposal of garbage and other solid waste.

- ***Monitor nutrients, dissolved oxygen, temperature, and fecal coliform in Westcott-Garrison Bay regularly***

The physical characteristics of Westcott and Garrison Bays combine with recreational uses by recreational boaters and land use practices in the watershed to make the system vulnerable to eutrophication and fecal contamination. More frequent monitoring will allow better characterization of seasonal and interannual variability in factors that can cause eutrophication, algal blooms, and contamination by fecal bacteria, and could lead to management of activities that cause impairment. To achieve more regular monitoring, SAHJ could implement an independent ambient monitoring program, or could partner with others (e.g., Westcott Bay Sea Farms, WDOH) to collect data on a regular schedule. In-stream monitoring should be included in such a program to capture contributions from upland areas.

- ***Partner with others to monitor eelgrass declines in Westcott-Garrison Bay; consider eelgrass restoration***

The near disappearance of eelgrass from Westcott and Garrison Bays is of concern and could signal large or persistent changes in the nearshore environment. Investigators from the University of Washington, from state agencies, and local groups are actively considering the problem. SAJH could partner with these investigators to 1) determine eelgrass population trajectories within SAJH; 2) determine and address sources of the decline, if feasible; and 3) consider restoration of eelgrass resources within SAJH.

- ***Measure the introduction of fecal bacteria from the English Camp parade ground to Garrison Bay. Consider management options that would reduce fecal loading from the parade ground to the bay if loads exceed NPS, regional, or local standards.***

Fecal bacteria and nitrogen could be introduced to nearshore waters of Garrison Bay in runoff from the parade ground. Quantification of fecal and nitrogen loading from this source will help guide management practices on the parade ground.

- ***Address groundwater withdrawals and saltwater intrusion in American Camp***

Groundwater in the vicinity of American Camp could become limiting, especially with increasing residential growth and with changes in the hydrologic cycle associated with climate change. Management of groundwater resources will require better understanding of the size of the underlying aquifer, its recharge rate, and its connections to nearby residential water supplies and to the condition of the coastal lagoons.

- ***Develop and implement a monitoring program for the coastal lagoons and immediately adjacent areas of Griffin Bay (for example, Fish Creek)***

The coastal lagoons in American Camp represent a regionally-rare shoreline feature. The lagoons are potentially vulnerable to water withdrawals, sea level rise, biological invasion, harmful algal blooms, and pollution from oil spills and other effluents and discharges. Implementation of a monitoring program would allow detection of change within the lagoons.

- ***Partner with others to encourage responsible boating practices and wildlife viewing practices in American Camp, particularly with regard to killer whales***

The area between Eagle Point and Cattle Point sustains high levels of boating traffic, especially when killer whales are present. Impacts of boating on whales potentially could be reduced through expansion of the voluntary Whalewatch Exclusion Zone, education and encouragement regarding best boating and wildlife viewing practices, and enforcement of existing regulations.

- ***Work to reduce impacts of road-building activities on the nearshore environment in American Camp***

The construction of a road to replace the failing Cattle Point Road through American Camp could negatively impact water quality in the vicinity of South Beach. We recommend that road-building activities be closely monitored to detect and reduce such impact(s), especially those associated with changing sediment supply to shoreline areas.

- ***Partner with the Islands Oil Spill Association to update oil spill contingency planning for English and American Camps; track the Washington State oil spill contingency rule planning process and outcome***

Oil spills have the potential to significantly negatively impact aquatic resources within SAJH. Impacts could be reduced or averted by contingency and response planning. The Islands Oil Spill Association is the most appropriate local partner for this; other potential partnerships exist with state agencies.

- ***Promote research into issues identified at the NPS Vital Signs workshop***

Participants in NPS Vital Signs workshop identified existing and emerging issues of concern within SAJH, reported in Flora and Fradkin 2004. The workshop findings remain salient and should be addressed. Opportunities exist to create partnerships with other organizations and to engage in local planning processes. For example, the San Juan County Marine Resources Committee is developing a management plan for the county's Marine Stewardship Area, and the park could benefit from participating in this planning process. Other potential partners include The Nature Conservancy, Friends of the San Juans, and San Juan County Beachwatchers.

- ***Encourage basic and applied water resource research by qualified investigators; develop guidelines for the conduct of scientific research in park areas***

SAJH has been the locus for a number of scientific investigations by researchers and students from the nearby Friday Harbor Laboratories, from other departments of the University of Washington, and from other colleges and universities. Results of these investigations can help inform park managers about ecological and other processes within the park. Consequently, these investigations should continue to be encouraged. We recognize that some research activities could negatively impact park resources; therefore, we encourage the development of guidelines for research conducted in areas under park management, for example, the Cattle Point. We further encourage the development of a searchable database or other archival mechanism for research conducted in the park.

- ***Develop management plans for aquatic invasive species, or partner with local and state agencies to manage aquatic invasives***

Aquatic invasive species are conspicuous in areas within and surrounding SAJH, and the abundance and diversity of invaders is likely to increase over the coming decades. Consequently, we recommend that plans be developed for management of noxious aquatic invaders. This could be accomplished in partnership with appropriate local or state entities.

REFERENCES CITED

Aasen, Sandra, M. Dutch, K. Welch, and E. Long. 2005. Sediment Quality in the San Juan Islands, Eastern Strait of Juan de Fuca, and Admiralty Inlet. Abstract of paper presented at the 2005 Puget Sound-Georgia Basin Research Conference, Seattle, Washington March 29-31, 2005.

Canning, D. 2002. Climate change, climate variability, and sea level rise in Puget Sound: Possibilities for the future. *In* T. Droscher (ed.), Proceedings of the 2001 Puget Sound Research Conference. Puget Sound Action Team, Olympia, WA.

Cannon, G.A. (Ed.). 1978. Circulation I the Strait of Juan de Fuca: some recent oceanographic observations. NOAA Tech. Rep. ERL 399-PMEL 29.

Cannon, G.A. and D.E. Bretschneider. 1986. Interchanges between coastal and fjord circulation. Rap P-v Reun Cons int Explor Mer 186: 38-48.

Cohen, Andrew, Mills, C., Berry, H., Wonham, M., Bingham, B., Bookheim, B., Carlton, J., Chapman, J., Cordell, J., Harris, L., Klinger, T., Kohn, A., Lambert, C., Lambert, G., Li, K., Secord, D., and Toft, J., 1998. Report of the Puget Sound Expedition September 8-16, 1998. A Rapid Assessment Survey of Non-indigenous Species in the Shallow Waters of Puget Sound. Report to WDNR, Olympia, WA and US Fish and Wildlife Service, Lacey WA.

Copello S, Dean N, Evans K, Guarderas P, Laderlie L, Northern J, Outlaw R, Pajuelo M, Ribiero S, Papiez C, Weiskel H, Klinger T, Wonham M, Kappel C. 2004 A comparison of multiple biological metrics between the Point Caution research reserve and neighboring public access sites. Report, Friday Harbor Laboratories.

Crean, P.B., T.S. Murty, and J.A. Stronach. 1988. Mathematical modeling of tides and estuarine circulation. In: Lecture Notes on Coastal and Estuarine Studies, Heidelberg: Spring Verlag, 471 pp.

DeRivera, C.C.*, et al*. (undated report) Broad-scale non-indigenous species monitoring along the West Coast in National Marine Sanctuaries and National Estuarine Research Reserves. National Fish and Wildlife Foundation, unpublished report.

Determan, G. 2003. Paralytic Shellfish Poisoning (PSP) Patterns in Puget Sound Shellfish in 2001, A Report for the Puget Sound Ambient Monitoring Program. Washington State Department of Health. State of Washington.

Dethier, MN, 1993. A baseline survey and inventory of intertidal communities in San Juan Island National Historical Park. Report to San Island Juan National Historical Park, National Park Service. Friday Harbor Laboratories. Friday Harbor, Washington.

Dethier, MN and M Ferguson. 1998. The marine habitats and biota of Westcott and Garrison Bays, San Juan Island. Report to San Juan Island National Historical Park, National Park Service. Friday Harbor Laboratories. Friday Harbor, Washington.

Drahn, Daniel S. 1999. Letter to Bob Querry, San Juan County Permit Center Re: Cattle Point Desalinization Plant, Brine Discharge Sampling Results, Project #SJ-6216, dated February 25, 1999, and attachments: "Salinity Study of Desalinization Unit" and map.

Drahn, Daniel S. 2000. Letter to Bob Querry, San Juan County Permit Center Re: Cattle Point Desalinization Plant Follow-up Monitoring Report, MPD Project #SJ-5515, dated March 13, 2000.

Do, Lien, M. Masten and A. Van, 2003. Effects of the oyster Crassostrea gigas on the species diversity of rocky intertidal communities in the San Juan Islands. Unpublished class report, Zoology 430/Botany 445, Spring 2003, Friday Harbor Laboratories, University of Washington.

Ebbesmeyer, C.C. and Barnes, C.A., 1980, Control of a fjord basin's dynamics by tidal mixing in embracing sill zones. Estuarine and Coastal Mar. Science 11: 311-330.

Ebbesmeyer, C.C., Coomes, C.A., Cox, J.M., and Salem, B.L., 1991, Eddy induced beaching of floatable materials in the eastern Strait of Juan de Fuca. Puget Sound Research '91 Proceedings, Vol 1: 86-98.

Ebbesmeyer, C.C., Coomes, C.A., and Noah, E.C., 1995, Winter dispersion and intrusion of floating wooden cards released along Juan de Fuca Strait. Puget Sound Research '95 Proceedings, Vol 2: 971-978.

Erickson, A. 2003. Integrating law, science, and regulation in public lands management: An application of policy science to manage impacts of human trampling on the rocky shore of Olympic National Park, WA, USA. MMA thesis, University of Washington

Flora, MD and SC Fradkin. 2004. A conceptual model of the upland aquatic and nearshore marine habitats of San Juan Island National Historical Park (Washington). US National Park Service Technical Report NPS/NRWRD/NRTR-2004/318. National Park Service, U.S. Department of Interior.

Fradkin, SC. 2004. Intertidal Fish Inventory of San Juan Island National Historical Park. Report, Olympic National Park, Coastal Branch Program.

Friends of the San Juans. 2004. J. Slocomb, S. Wyllie-Echeverria, S. Buffum-Field, J. Norris, I. Frasier, J. Cordell. San Juan County Eelgrass Survey Mapping Project Final Report. Friday Harbor, WA. 40 pp.

Friends of the San Juans. 2004. Documented surf smelt and Pacific sand lance spawning beaches in San Juan County with a summary of protection and restoration priorities for forage fish habitat (plus companion map book). Friday Harbor, WA.

Friends of the San Juans. 2005. Friends of the San Juans Presentation to the San Juan County Marine Resources Committee 8/18/05. Friday Harbor, Washington.

Fraser, I., J. Norris, J. Slocomb, S. Wyllie-Echeverria, S. Buffum-Field, and T. Whitman. 2005. Hydroacoustic and Underwater Videographic Survey of San Juan County Eelgrass Resources. Abstract of paper presented at the 2005 Puget Sound-Georgia Basin Research Conference, Seattle, Washington March 29-31, 2005.

Griffin, D.A. and P.H. LeBlond. 1990. Estuary/ocean exchange controlled by spring-neap tidal mixing. Estuarine, Coastal and Shelf Science 30: 275-297.

Hanson, Thor. 2001. Third Lagoon Preserve Ecological Assessment. San Juan County Land Bank, Friday Harbor, WA 20 pp.

Haugerud, RA, and 5 others. 2003. High-resolution Lidar topography of the Puget Lowland, Washington—A bonanza for Earth Science. GSA Today 13: 4-10. doi: 10.1130/1052-5173(200313<0004:HLTOTP>2.0C);2

Holbrook J.R., R.D. Muench, D.G. Kachel, and C. Wright. 1980. Circulation in the Strait of Juan de Fuca: Recent Oceanographic observation sin the Eastern Basin. NOAA Tech. Rep. ERL 412-PMEL 33.

Holbrook, J.R.and D. Halpern. 1982. Winter-time near-surface currents in the SJDF. Atmos-Ocean 20: 327-339.

Holmes, R.E. 1998. San Juan Island National Historical Park Wetland Inventory – 1998. San Juan Island National Historical Park, Friday Harbor, WA 18 pp + app.

Horner, R.A, D.L. Garrison, and F.G. Plumley. 1997. Harmful algal blooms and red tide problems on the US west coast. Limnology and Oceanography 42(5, part2), 1076-1088.

Jelinski, D.E., C.C. Krueger, and D.A. Duffus. 2002. Geostatistical analyses of interactions between killer whales (*Orcinus orca*) and recreational whale-watching boats. Applied Geography 22: 393-411.

Jenkins, C., M.E. Haas, A. Olson and J.L. Ruesink. 2002. Impacts of trampling on a rocky shoreline of San Juan Island, Washington. Natural Areas Journal 22(4):260-269.

Johannessen, Jim. 1992. Net shore-drift in Washington State, Volume 6: San Juan, and parts of Jefferson, Island and Snohomish Counties. Ecology Report 00-06-35. Shorelands and Environmental Assistance Program, Washington Department of Ecology, Olympia, Washington.

Johansen, D. and C. Gates 1957. The Empire of the Columbia: A History of the Pacific Northwest. Harper and Brothers, New York.

Karlson, Kristine. 2000. Physical characteristics and benthic community composition surrounding the outfall of Cattle Point desalination plant in Griffin Bay, San Juan Island, WA. Unpublished report for Zoology 430/Botany 445, Spring Quarter 2000, Friday Harbor Laboratories.

Klinger, T. and C. Ebbesmeyer. 2002. Using Oceanographic Linkages to Guide Marine Protected Area Network Design. *In* T. Droscher (ed.), Proceedings of the 2001 Puget Sound Research Conference. Puget Sound Action Team, Olympia, WA.

Larkin, Lori. 1999. Draft Westcott-Garrison Bay Watershed Assessment Report and Critical Marine Habitat Issues of Concern. San Juan County Planning Department. Friday Harbor, Washington.

LeBlond, P.H., D.A. Griffin and R.E. Thomson. 1994. Surface salinity variations in the Juan de Fuca Strait: a test of a predictive model. Cont. Shelf. Res. 14: 37-56.

Lubchenco, JA, W Milsom, SA Woodin. 1970. The Jackle's Lagoon Story: Some effects of blocking and reopening the connecting channel to Griffin Bay on physical conditions, flora and fauna. Unpublished class report, Zoology 576, Friday Harbor Laboratories.

Lukes, Jerry. 2002. Washington State Department of Health Office of Food Safety and Shellfish Programs Annual Growing Area Review for Westcott Bay. State of Washington Department of Health. Olympia, Washington.

Masson, D. and P.F. Cummings. 2000. Fortnightly modulation of the estuarine circulation in Juan de Fuca Strait. *Journal of Marine Research* **58**:3: 439-463.

Matsuura, H., and G.A. Cannon. 1997. Wind effects on sub-tidal currents in Puget Sound. Journal of Oceanography 53: 53-66.

Mills, C.E. 2003. Marine research study-sites in the San Juan Islands, Washington, USA Website. http://faculty.washington.edu/cemills/studysites, last accessed 9/25/2005.

National Climate Data Center (NCDC). 2006. Quality Controlled Local Climatological Data, Friday Harbor WA. http://cdo.ncdc.noaa.gov/ulcdsw/ULCD?prior=N&callsign=FHR last accessed 4/6/06. National Oceanic and Atmospheric Administration. Washington DC.

Newton, JA, S.L. Albertson, K. Van Voorhis, C. Maloy, and E. Siegel, 2002. Washington State Marine Water Quality, 1998 through 2000. WA Department of Ecology Publication No. 02-03-056

Newton, Jan A., Eric Siegel and Skip L. Albertson. 2003. Oceanographic Changes in Puget Sound and the Strait of Juan de Fuca During the 2000–01 Drought. Canadian Water Resources Journal 28(4): 715-728.

NPS. 2006. San Juan Island National Historical Park Website. http://www.nps.gov/sajh/pphtml/subenvironmentalfactors22.html, last accessed 4/1/06.

NPS. 2005. San Juan Island National Historical Park Website. http://www.nps.gov/sajh/Come_by_boat.htm, last accessed 9/9/05.

NPS. 2004. Annual Performance Plan 2004. SAJH Website http://www.nps.gov/sajh/annual_performance_plan.htm, last accessed 3/1/2006.

NPS. 1995. Baseline Water Quality Data Inventory and Analysis San Juan Island National Historical Park. Technical Report NPS/NRWRD/NRTR-95/62. Water Resources Division. National Park Service. Fort Collins CO.

NPS. 1992. Water Resources Overview and Recommendations for San Juan Island National Historical Park, Appendix B. Unpublished report to the Superintendent, San Juan Island National Historical Park from Water Resources Division, National Park Service. Fort Collins, CO.

Northwest Straits Commission. 2005. Northwest Straits Commission Website. http://www.nwstraits.org/projects-creosote.html, last accessed 9/23/05.

Orr LA, HH Bauer, JA Wayenberg. 2002. Estimates of ground-water recharge from precipitation to glacial-deposit and bedrock aquifers on Lopez, San Juan, Orcas, and Shaw Islands, San Juan County, Washington. US Geological Survey Water Resources Investigation Report 02-4114 (http://pubs.usgs.gov/wri/wri024114/

Parker, B.B. 1977. Tidal hydrodynamics in the Strait of Juan de Fuca-Strait of Georgia. NOAA Tech. Rep. NOS 69.

Pashinski, D.J., and R.L. Charnell. 1979. Recovery record for surface drift cards released in the Puget Sound-Strait of Juan de Fuca system during calendar years 1976-1977. NOAA Technical Memorandum ERL PMEL-14.

San Juan County. 2004a. San Juan County Water Resource Management Plan (WRIA 2). Public Review Draft, June 23, 2004. San Juan County. Friday Harbor, Washington.

San Juan County. 2004b. San Juan County/Town of Friday Harbor Hazardous Incident Vulnerability Assessment (HIVA). San Juan County Department of Emergency Management. Friday Harbor, Washington.

San Juan County. 2003. Map of Comprehensive Plan Land Use and Shoreline Master Program District 1, San Juan County. Prepared January 2003, incorporates amendments through December 2002. San Juan County. Friday Harbor, Washington.

San Juan County. 2002. Comprehensive Plan Section B, Element 3: Shoreline Master Program. Adopted by ordinance 13-2001; amendments approved by the Washington Department of Ecology, 2-14-2002. San Juan County. Friday Harbor, Washington.

San Juan County. 2001. Draft Summary Westcott-Garrison Bay Marine Habitat Management Area, Marine Habitat Management Plan and Watershed Plan. San Juan County. Friday Harbor, Washington.

San Juan County. 2000. San Juan County Watershed Management Action Plan and Characterization Report. Published online at http://www.co.san-juan.wa.us/health/wtrshdpln. Last accessed 7/7/05.San Juan County Department of Health and Community Services. Friday Harbor, Washington.

San Juan Islander. 2004. "111 buoys tagged, more may be tagged next year." Online newspaper article published 9/10/2004. http://www.sanjuanislander.com/state/dnr/buoys.shtml. Last accessed 9/13/05. Friday Harbor, Washington.

Staude, Craig. 1997. Letter to San Juan County Hearing Examiner regarding shoreline substantial development permit application #97SJ0017. August 25, 1997. Friday Harbor Laboratories, University of Washington. Friday Harbor, Washington.

Stein, J. 2000. Exploring Coast Salish Prehistory: The Archaeology of San Juan Island. University of Washington Press, Seattle.

Takesue, Renee K., RJ Rosenbauer, EE Grossman and S. Wyllie-Echeverria, 2005a. Sedimentation and contaminant loading: impacts on eelgrass (Zostera marina) bed health in northern Puget Sound. Abstract of paper presented at the 2005 Puget Sound-Georgia Basin Research Conference, Seattle, Washington March 29-31, 2005.

Takesue, Renee K., J Rosenbauer and EE Grossman. 2005b. Sedimentation and contaminant loading: effects on eelgrass (Zostera marina) bed health in northern Puget Sound. Proceedings of the 2005 Puget Sound-Georgia Basin Research Conference. Seattle, Washington.

Thomson, R.E. 1981. Oceanography of the British Columbia Coast. Can. Special Publ. Fisheries and Aquatic Sciences 56: 1-291.

WDNR. 2005. Aquatic Resources Program Activity Summary: Mooring Buoys. Draft report prepared for NOAA Fisheries and US Fish and Wildlife Service, January 2005. Available online at http://www.dnr.wa.gov/htdocs/aqr/esa/pdf/mooring_buoysv17.pdf ; last accessed 9/13/05. Washington State Department of Natural Resources. State of Washington.

WDOE. 2006a. Marine Water Monitoring Program Website. http://www.ecy.wa.gov/apps/eap/marinewq. Last accessed 3/12/06. Washington State Department of Ecology. State of Washington.

WDOE. 2006b. Washington State's Water Quality Assessment [303(d) & 305(b) Report] Final 2004 Submittal. Washington State Department of Ecology Water Quality Program Website. http://www.ecy.wa.gov/programs/wq/303d/2002/2002-index.html. Last accessed 4/1/06. Washington State Department of Ecology. State of Washington.

WDOE. 2006c. Washington Coastal Atlas Website. http://apps.ecy.wa.gov/website/coastal%5Fatlas/viewer.htm. Last accessed 4/10/06. Washington State Department of Ecology. State of Washington.

WDOE. 2005a. Marine Sediment Monitoring Program Website. http://www.ecy.wa.gov/programs/eap/mar_sed/msm_intr.html. Last Accessed 4/1/06. Washington State Department of Ecology. State of Washington.

WDOE. 2005b. Oil and Fuel Transfer Over Waters of the State of Washington: A Report to the Legislature. Washington State Department of Ecology. State of Washington.

WDOE. 2003. Northwest Area Committee San Juan Islands/North Puget Sound Geographic Response Plan. Washington State Department of Ecology Publication No. 95-201 (Rev. 3/03).

WDOE. 1998. Final 1998 Section 303(d) List – WRIA 2. Washington State Department of Ecology Water Quality Program webpage. http://www.ecy.wa.gov/programs/wq/303d/1998/wrias/wria2.pdf. Last accessed 4/6/06. Washington State Department of Ecology. State of Washington.

WDOH 2006. Washington Department of Health, Division of Environmental Health Food Safety and Shellfish Programs: Biotoxin Program website. http://www.doh.wa.gov/ehp/sf/BiotoxinProgram.htm. Last accessed 3/11/06. Washington State Department of Health. State of Washington.

Westcott Bay Sea Farms. 2005. Westcott Bay Sea Farms website URL: www.westcottbay.com, last accessed 9/9/05.

Wonham, M.J. and J.T. Carleton. 2005. Trends in marine biological invasions at local and regional scales: the Northeast Pacific Ocean as a model system. Biological Invasions 7: 369-392.

Wiseman, Chad, R. Mathhews and J. Vandersypen, 2000. San Juan County Monitoring Project Final Report. Report to San Juan County Health and Community Services Department. Institute for Watershed Studies, Huxley College of the Environment, Western Washington University.

Woolrich, Bob. 2004. Letter to Jim Slocomb, Chair of San Juan County Marine Resource Committee *(ibid)* transmitting Washington Department of Health 2004 (*ibid)* Early Warning System Summary for Shellfish Growing Areas in San Juan County and Annual Growing Area Reviews. State of Washington Department of Health. Olympia, Washington.

Woolrich, Bob. 2005. Letter to Jim Slocomb, Chair of San Juan County Marine Resource Committee *(ibid)* transmitting Washington Department of Health 2004 Early Warning System Summary for Shellfish Growing Areas in San Juan County and Annual Growing Area Reviews. State of Washington Department of Health. Olympia, Washington.

Wyllie-Echeverria, S., T. Mumford, J. Gaydos and S. Buffum, 2003. "*Zostera marina* declines in San Juan County, WA." Report from the Westcott Bay Taskforce Mini-Workshop, 26 July 2003.

Wyllie-Echeverria, Sandy, T. Mumford, N. Hu, 2005. Retrospective analysis of eelgrass (Zostera marina L.) abundance in small embayments within the San Juan Archipelago, Washington. Abstract of paper presented at the 2005 Puget Sound-Georgia Basin Research Conference, Seattle, Washington March 29-31, 2005.

Appendix A. National Wetlands Inventory Land Type Size and Distribution

Table A1. NWI Class Codes and Acreage

NWI Land Types	Area (acres)
American Camp	
Marine and coastal	18.47
Wetland	12.88
Stream and Riparian	0
Upland	1217.73
English Camp	
Marine and coastal	0.94
Wetland	2.78
Stream and Riparian	0
Upland	503.52

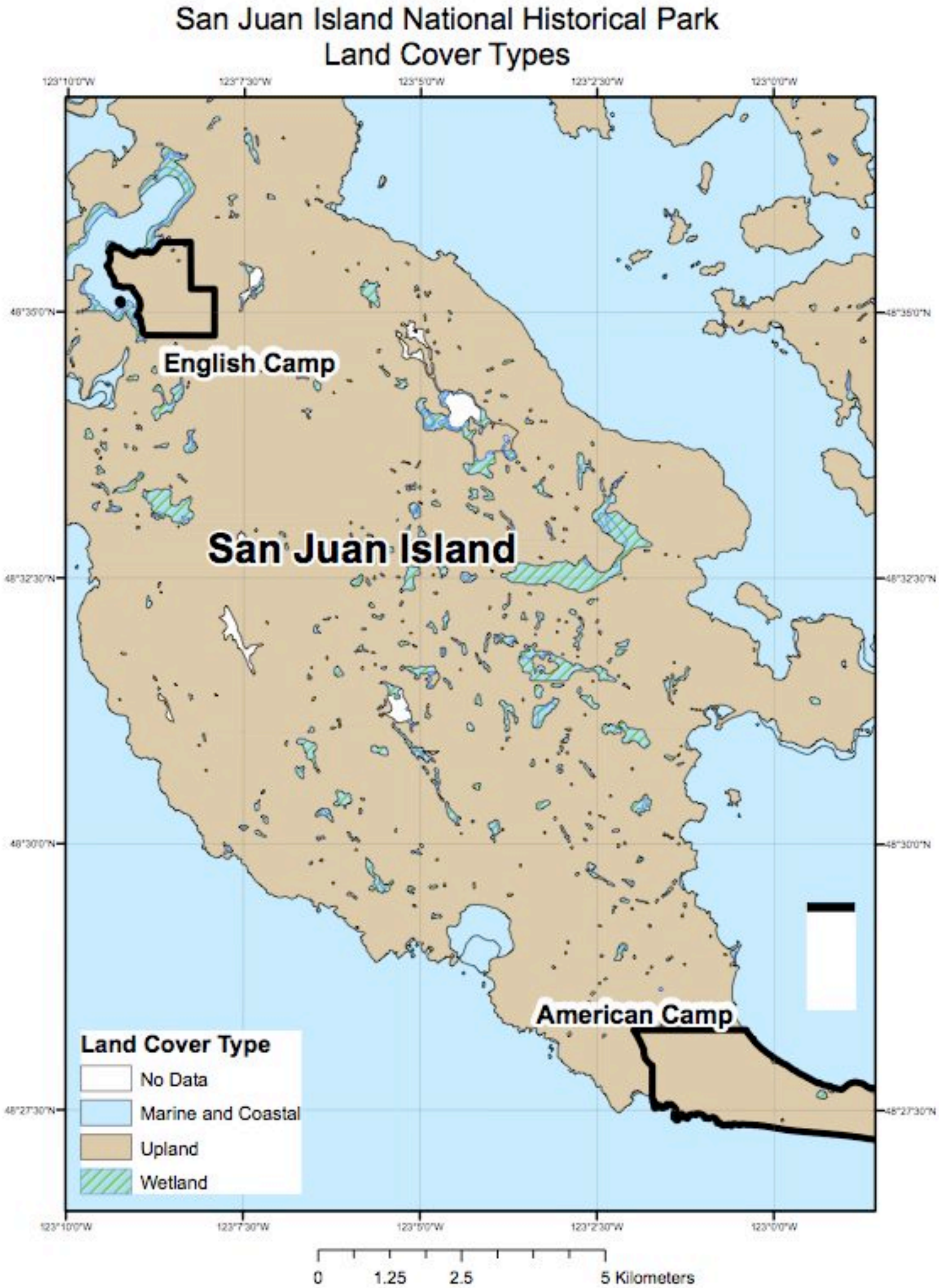


Figure A1. Land Cover Types, San Juan Island.

Land Types in San Juan National Historical Park
English Camp

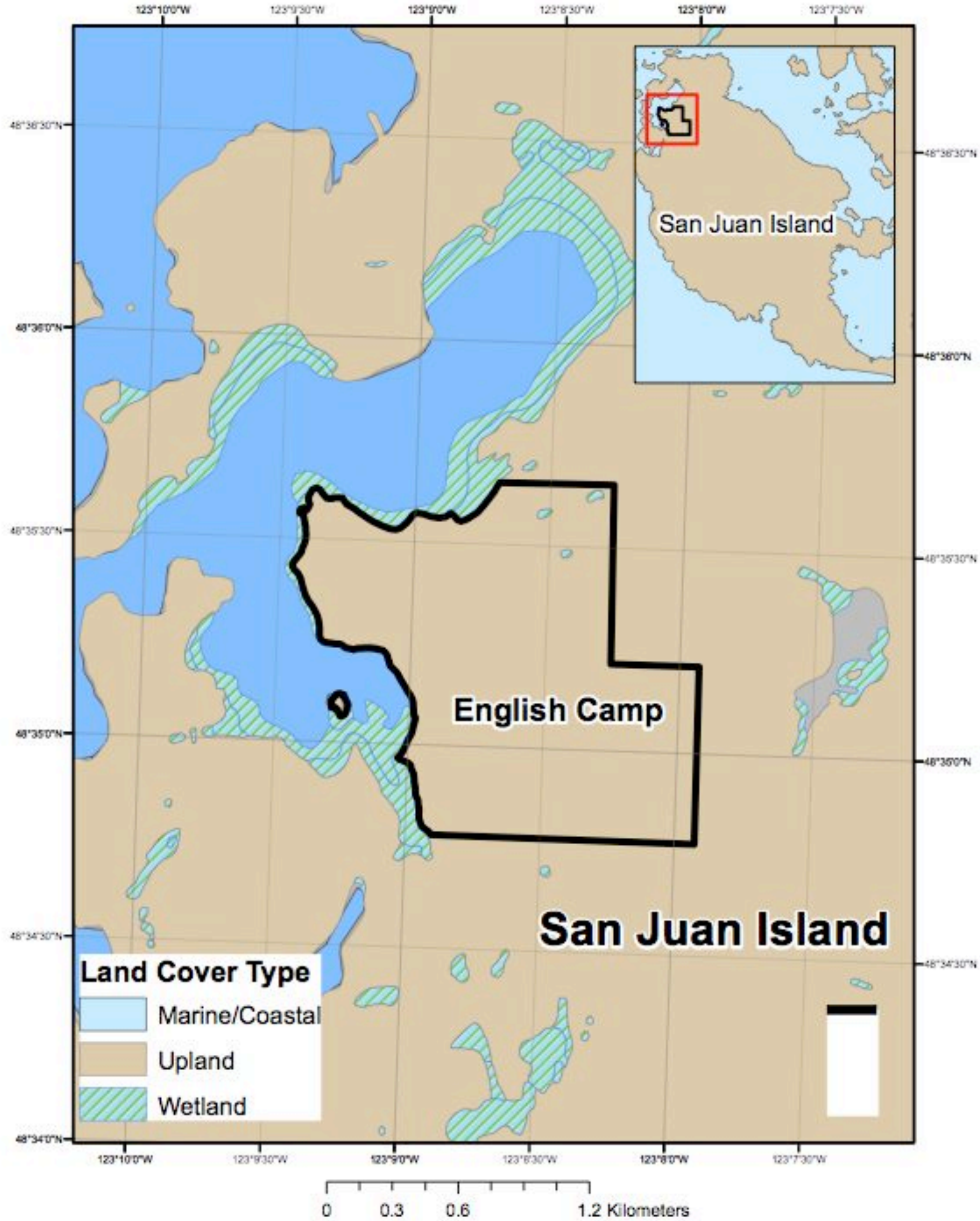


Figure A2. Land Cover Types, English Camp.

Figure A3. Land Cover Types, American Camp.

Appendix B. Water Quality Standards

Table B1. EPA Water Quality Standards for Marine Waters

EPA Water Quality Standards for Marine waters		Source
Dissolved Oxygen (DO)	Criteria evaluated for freshwater levels only. Coldwater values were used because the EPA identifies the presence of salmonid species to be indicative of coldwater areas. The acute lethal limit for salmonids is at 3 mg/L, but the coldwater minimum has been established at 4 mg/L due to more sensitive insect populations. Because the criteria are generalized, it is required that states evaluate the species in their own waters to establish appropriate minimum levels of dissolved oxygen.	U.S. EPA. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003; EPA Gold Book
Temperature	For marine aquatic life, the maximum increase in the weekly average temperature due to artificial causes is 1°C (1.8°F) during all seasons of the year, and daily temperature cycles of a body of water are not to be altered, neither in amplitude nor frequency.	EPA Gold Book
pH	Shall fall between the range of 6.5-8.5	EPA Gold Book
Turbidity		
Toxic Substances		
Primary Contact Recreation		Source
Fecal Coliform	The median value for a fecal coliform standard is 15 per 100mL and the 90th percentile should not exceed 43 for a 5-tube, 3-dilution method.	EPA Gold Book

Appendix B, cont. Water Quality Standards

Table B2. Washington State Water Quality Standards and recommended threshold values

Water Quality Parameter	Freshwater Standard	Marine Water Standard
Fecal Coliform	a geometric mean £ 50 cfu/100 mL, with less than 10% of samples exceeding 100 cfu/100 mL	a geometric mean £ 14 cfu/100 mL, with less than 10% of samples exceeding 43 cfu/100 mL.
Dissolved Oxygen	> 9.5 mg/L.	> 7.0 mg/L.
Total Dissolved Gas	< 110 percent of saturation at any point of sample collection	
Temperature	£ 16° C	£ 13° C
pH	6.5 - 8.5	7.0 - 8.5
Turbidity	< 5 NTU over background, with a background of < 50 NTU. If background is > 50 NTU, shall not exceed a 10% increase	
Toxic, Radioactive and Deleterious Materials	concentration below those that adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota or adversely affect public health.	
Aesthetic Value	shall not be impaired (including senses of sight, smell, touch or taste	

Water Quality Parameter	Recommended threshold values
Nitrate (N)	< 1.25 mg/L
Total Suspended Solids (TSS)	£ 50 mg/L

Source: San Juan County Water Action Plan and Characterization Report

Appendix C. Species reported from SAJH, reproduced from Dethier 1993; Dethier and Ferguson 1998; Cohen et al 1998; and deRivera (unpublished).

Appendix C1. Species reported by Dethier 1993.

Abbreviations:
GCS – Grandmother's Cove Sand
SB – South Beach
4JB – 4th of July Beach
BCO – British Camp (ibid) Open
BCC – British Camp Closed
JKL – Jakle's Lagoon
ACPR – American Camp Protected Rock
ACER – American Camp Exposed Rock
C – Common
O – Occasional
R – Rare

UNCONSOLIDATED SUBSTRATES

Species	GCS	SB	4JB	BCO	BCC	JKL
Vascular Plants						
Zostera marina			C	C	C	
Spergularia canadensis						C
Atriplex patula						C
Salicornia virginica						C
Cuscuta salina						O
Distichlis spicata						C
Lepidium virginicum						O
Galium sp.						C
Plantago maritima						O
Jaumea carnosa						O
Polygonum fowleri						R
Lathrys japonicus						O
Holcus lanatus						R
Ambrosia chamissonis						R
Soncus sp.						R
Poa confinis						C
Unid. Poaceae						R
Hordeum branchyantherum						R
Algae						
Ulva spp.			C	C	C	
Fucus spp.				O		
Rhizoclonium sp.				O	C	

Collinsiella tuberculata					O	
Ralfsia pacifica					O	
Animals						
Phylum Cnidaria						
Haliplanella lineata				C	O	
Phylum Nemertea						
Paranemertes peregrina					C	
Phylum Arthropoda						
Excirolana spp.	C					
Exosphaeroma ?crenulatum (ibid)					O	
Gnorimosphaeroma oregonense				O	C	
Gnorimosphaeroma noblei					C	
Idotea wosnesenskii				O		
Limnoria spp.						O
Eohaustorius brevicuspis	C					
Eohaustorius washingtoniensis	C					
Grandifoxus grandis	O					
Heterophoxus oculatus			O			
Foxiphalus obtusidens			O			
Traskorchestia traskiana	C					
Traskorchestia californiana	C					
Megalorchestia californiana			O			
Allorchestes sp.			O			
Paramoera mohri		C				
Ampithoe lacertosa			O			
Corophium spp.			C	C		
Unid. Amphipods						O
Caprella laeviuscula			O			
Hemigrapsus nudus				C	O	
Hemigrapsus oregonesis				C	O	R
Cancer productus				C		
Pagurus spp.					O	
Balanus glandula				C	C	
Mites			O	C	C	
Unid. Insects (beetles & flies)	O	R	O			O

Phylum Annelida						
Notomastus variegatus			O		C	O
Unid. Capitellids			C	C		
Capitella capitata					C	O
Cirratulus cirratus				R		
Tharyx parvus					O	
Cirriformia spirabranchia				O		
Schistomeringos annulata				C		O
Schistomeringos rudolphi					C	
Glycera sp.					O	
Hemipodus borealis	O		O			
Glycinde ?polygnatha (ibid)				C	C	
Ophiodromus pugettensis				C	C	
Podarkeopsis brevipalpa				O		
Lumbrineris sp.				O		
Lumbrineris zonata			C	C		
Lumbrineris inflata				C	C	
Lumbrineris luti					C	
Nephtys brachycephala			O			
Nephtys caeca				O		
Nephtys longosetosa				O		
Platyneris bicanaliculata			O			
Nereis procera				O		
Nereis vexillosa				C		
Nereis sp.				O	O	
Armandia brevis			O	C	C	
Naineris dendritica				C	C	
Naineris quadricuspida					C	
Scoloplos armiger				C		
Eteone tuberculata			R			
Eteone californica					R	
Eulalia tubiformis				R		
Phyllodoce mucosa			R		R	
Laonice sp.	O					
Polydora proboscidea				C		
Polydora cardalia					C	
Polydora ?quadrilobata (ibid)					O	
Unid. terbellids			C			
Lanice sp.				O		
Pista cristata				O		
Pista brevibranchiata					O	

Thelepus crispus					C	
Phylum Phoronida						
Phoronopsis harmeri			O			
Phylum Mollusca						
Macoma nasuta			C	C	C	
Tellina modesta			R			
Macoma balthica			O			
Protothaca staminea				C	C	
Tapes philippinarum				C	C	
Mya arenaria				C	C	
Clinocardium spp.				O	C	
Unid. small clams			O	O	O	
Transennella tantilla				O		
Mytilus edulis				O	C	
Lottia pelta				O	C	
Lottia strigatella				O	C	
Tectura persona					O	
Littorina scutulata				O	C	
Littorina sitkana					C	

CONSOLIDATED SUBSTRATE (ROCK)

Species	ACPR	ACER
Vascular Plants		
Phyllospadix scouleri	O	C
Lichens		
Arthropyrenia orustensis	C	C
Verrucaria spp.	C	C
Algae		
Ulvoids	C	C
Acrosiphonia spp.	O	O
Prasiola meridionalis	O	O
Codium fragile		R
Fucus gardneri	C	C
Egregia menziesii	O	R
Alaria marginata	C	R
Hedophyllum sessile	C	C
Costaria costata	O	R

Laminaria spp.	R	R
Desmarestia ligulata	C	R
Desmarestia viridis	O	R
Ralfsia pacifica	C	C
Leathesia difformis	O	R
Endocladia muricata	O	C
Mastocarpus papillatus	O	O
Hildenbrandia rubra	C	C
Odonthalia floccosa	C	O
Microcladia borealis	C	O
Mircocladia coulteri		R
Polysiphonia pacifica	C	R
Callithamnion pikeanum	O	R
Ceramium spp.	O	R
Halosaccion glandiforme	O	O
Porphyra spp.	O	O
Iridaea splendens	C	R
Cryptopleura sp.	R	O
Antithamnion kylinii	R	
Prionitis lyallii	O	O
Smithora naiadum		O
Corallina vancouveriensis	O	C
Bossiella plumose	O	C
Encrusting corallines (3-5 spp.)	C	C
Animals		
Phylum Porifera		
Ophlitaspongia sp.	R	O
Haliclona permollis	O	O
Halichondria panicea	O	O
Phylum Cnidaria		
Anthopleura elegantissima	C	C
Anthopleura xanthogrammica		R
Urticina spp.	C	C
Aulactinia incubans		O
Unid. Hydroids		O
Metridium senile		O
Phylum Nemertea		
Paranemertes peregrine	R	O
Emplectonema sp.	O	O
Amphiporus sp.	O	O

Phylum Annelida		
Schizobranchia sp.	O	
Nereis sp.	O	R
Dodecaceria fewkesi		O
Eudistylia vancouveri		O
Laonome kroyeri		O
Unid. Terebellids		O
Phylum Arthropoda		
Balanus glandula	C	C
Semibalanus cariosus	O	C
Chthamalus dalli	C	C
Pollicipes polymerus		O
Idotea spp.	O	O
majid crabs	C	O
amphipods	C	C
Pagurus spp.	C	C
Cancer oregonensis	O	O
Cancer gracilis		O
Hemigrapsus nudus	O	O

Appendix C2. Epibenthic and infaunal taxa reported from soft-sediment transects in Westcott-Garrison Bay (Dethier & Ferguson 1998).

ANIMALS

Annelida (polychaete worms)

Abarenicola pacifica
Dorvillea (=Shistomeringos) annulata
Euclymene sp.
Glycinde picta
Hemipodus borealis
Harmothoe imbricata
Misc. hesionids
Lumbrineris inflata
Lumbrineris zonata
Nephtys caecoides
Notomastus tenuis
Naineris quadricuspida
Nereis brandti
Nereis vexillosa
Misc. nereids
Ophiodromus pugettensis
Owenia fusiformis
Polydora cornuta (=P. ligni)
Polydora kempi japonica
Polydora proboscidea
Podarkeopsis glabrus (=P. brevipalpa)
Misc. polynoids
Scoloplos armiger
Small capitelids
Syllis adamantea
Misc. terebellid tubes
Thelepus crispus

Arthropoda

Americorophium (=Corophium) salmonis
Balanus glandula
Chthamalus dalli
Misc. corophiid amphipods
Eogammarus confervicolus
Hyale plumulosa
Pagurus spp.
Traskorchestia traskiana

Cnidaria

Haliplanella lineata

Mollusca
egg masses of *Melanochlamys*
Clinocardium nuttallii
Cryptomya californica
Lottia strigatella
Littorina scutulata
Littorina sitkana
Bivalve holes
Lirularia parcipicta (Q)
Macoma inquinata
Macoma nasuta
Unid. *Macoma*
Melanochlamys diomedea
Mya arenaria
Mytilus trossulus
Crassostrea gigas
Protothaca staminea
Saxidomus giganteus
Tapes japonica = T. philippinarum
Transenella tantilla
Tresus capax

Nemerta (other worms)
Lineus vegetus
Unid. Nemertean

PLANTS AND ALGAE
Encrusting green algae
Enteromorpha spp.
Fucus gardneri
Endocladia muricata
Mastocarpus papillatus
Polysiphonia spp.
Misc. encrusting algae
Salicornia virginica

Appendix C3. Non-native invasive species reported by Cohen et al. 1998.

Cohen et al. 1998 conducted a rapid assessment survey for non-indigenous marine organisms in Puget Sound over a six day period in September 1998. The assessment team surveyed fouling organisms on docks and adjacent shallow water benthic habitats at a total of 32 stations (23 primary, 9 secondary), including two locations on San Juan Island: the FHL docks and Argyle Lagoon. Thirty-nine non-indigenous species were collected and identified, eleven of which are new records for Puget Sound (listed below). Results were not tabulated by location; however, the notes for the two San Juan Island stations indicate:

- Argyle Lagoon (San Juan Island): The beach and lagoon were surveyed for *Spartina* sp. and *Nuttallia obscurata.* The marsh gastropod *Myosotella myosotis* was common under pieces of wood in the *Salicornia virginica* marsh (secondary site).

Based on the data developed by the Puget Sound Expedition, and a brief review of the extant lists of non-indigenous species that include the Puget Sound area (including reviews of the Cnidaria by Claudia Mills and Polychaeta by Leslie Harris), we offer a provisional list of 52 non-indigenous species that have been collected from and appear to be established in the salt or brackish waters of Puget Sound…This list of species is provisional pending further taxonomic work and review by expedition members and associates. For the purposes of this list, Puget Sound is defined as the inland marine waters of Washington State east of Cape Flattery." (Cohen et al. 1998) * = species reported by J. W. Chapman from Mud Bay near Olympia after the Puget Sound Expedition.")

Phaeophyceae
Sargassum muticum

Anthophyta
Spartina alterniflora
Spartina anglica
Spartina patens
Zostera japonica

Foraminifera
Trochammina hadai

Cnidaria: Hydrozoa
Cladonema radiatum
Cordylophora caspia (= *C. lacustris*)

Cnidaria: Anthozoa
Diadumene lineata (= *Haliplanella luciae*)

Platyhelminthes
Pseudostylochus ostreophagus

Annelida: Polychaeta
Hobsonia florida
Neanthes succinea *
Pseudopolydora sp.
Pygospio elegans
Streblospio benedicti *

Mollusca: Gastropoda
Batillaria attramentaria (= *B. zonalis*, = *B. cumingi*)
Ceratostoma inornatum (= *Ocenebra japonica*)
Crepidula fornicata
Crepidula plana
Myosotella myosotis (= *Ovatella myosotis*)
Urosalpinx cinerea

Mollusca: Bivalvia
Crassostrea gigas
Musculista senhousia (= *Musculus senhousia*)
Mya arenaria
Mytilus galloprovincialis
Nuttallia obscurata
Venerupis philippinarum (= *Tapes japonica*)

Arthropoda: Crustacea: Copepoda
Choniostomatid copepod
Mytilicola orientalis

Arthropoda: Crustacea: Cumacea
Nippoleucon hinumensis

Arthropoda: Crustacea: Isopoda
Limnoria tripunctata

Arthropoda: Crustacea: Amphipoda
Ampithoe valida
Caprella mutica (= *C. acanthogaster*)
Corophium acherusicum
Corophium insidiosum
Eochelidium sp.
Grandidierella japonica
Jassa marmorata
Melita nitida
Parapleustes derzhavini

Bryozoa
Bowerbankia "gracilis"
Bugula stolonifera
Bugula sp. 1
Bugula sp. 2
Cryptosula pallasiana
Schizoporella unicornis

Entoprocta
Barentsia benedeni

Urochordata
Botryllus schlosseri
Botrylloides violaceus
Ciona savignyi
Molgula manhattensis
Styela clava

Appendix C4. Non-native invasive species reported by DeRivera et al. (unpublished) from Padilla Bay National Estuarine Research Reserve. Species are listed alphabetically within each class. NIS designates a confirmed nonindigenous species.

Cnidaria, Hydrozoa
Campanulariidae
Clytia hemisphaerica
Clytia sp.
Eudendrium sp.
Gonothyraea sp.
Laomedea sp.
Obelia longissima
Obelia sp.

Mollusca, Gastropoda Nudibranchia
Cumanotus sp.
Dendronotus frondosus
Eubranchus rupium
Hermissenda crassicornis

Crustacea, Cirripedia
Balanus crenatus
Balanus glandula
Balanus improvisus ***NIS***

Urochordata, Ascidiacea
Botrylloides sp.
Botrylloides violaceus ***NIS***
Botryllus schlosseri ***NIS***
Corella inflata
Corella willmeriana
Molgula manhattensis ***NIS***
Styela sp.

Bryozoa
Bowerbankia sp.
Bugula pacifica
Bugula sp.
Celleporella hyalina
Cribrilina corbicula
Cryptosula pallasiana ***NIS***
Membranipora villosa
Schizoporella sp.
Schizoporella unicornis ***NIS***
Tubulipora tuba

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.

NPS D- 82, December 2006