San Juan Initiative Protection Assessment
Nearshore Case Study Area Characterization

Prepared for:
The San Juan Initiative; The Puget Sound Partnership
through The Surfrider Foundation

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TABLE OF CONTENTS

Table of Tables

Table of Figures

Executive Summary

The San Juan Initiative represents a unique collaboration between the Puget Sound Partnership, San Juan County, community leaders, state and local agencies, and the Surfrider Foundation. The goal of the Initiative is to improve ecosystem health in a manner that supports the prosperity of the community, builds local capacity for ecosystem protection and acts as a pilot for addressing habitat protection in Puget Sound. This San Juan Initiative Nearshore Characterization provides data on county shores and habitats to allow for assessment of the success of management programs by the Initiative. The objective of this characterization was to assess existing and potential impacts of selected shore modifications including: shore armoring, docks, mooring buoys, vegetation clearing, and development among others, and to quantify the extent to which these modifications occur in conjunction with priority habitats. San Juan Initiative Nearshore Characterization uniquely documented a wide variety of current conditions and some amount of time-series change data from 4 representative areas of San Juan County. Several new data sets were developed for this study that have not been assessed previously in any Washington jurisdiction to date and numerous summaries and comparisons are included in the report.

Four case study areas (CSAs) were selected to represent a range of nearshore characteristics and development patterns found within San Juan County. The CSAs were located on northwest San Juan Island, the West Sound area of Orcas, northeast Lopez Island, and eastern Stuart Island, totaling approximately 34 miles of shore and 636 parcels. Field data were collected on the geologic and ecologic function in March 2008 and aerial photos from 1977 and 2006 were used. Field data collection included characterizing geomorphic shoretypes, shore modifications, dock characteristics and recording the position of all mooring buoys within each of the 4 CSAs. New data collected from air photo analysis included additional characteristics of docks, overhanging marine riparian vegetation cover, the aerial extent of marine riparian vegetation cover within a 200 ft buffer of the shoreline in 2006 and 1977, and building setback distances (2006 and 1977) from the shore. New data from the field and GIS analyses were combined with existing habitat data, and results were summarized and analyzed for the entire study area, each CSA and at the parcel unit scale. Fifteen research questions developed by the Science Advisory Panel were explored to analyze relationships between shoretypes, habitats, and modifications.

Approximately 30% of the 4.5 miles of feeder bluffs in the study area were modified (predominantly with rock bulkheads or armoring) and are no longer able to supply sediment to the nearshore/drift cells. Bedrock shores were the dominant shoretype in all CSAs accounting for over 42% of the study area. Feeder bluffs were identified as the shoretype both at the greatest risk of modification and associated with many priority habitats. There was a positive correlation between potential forage fish spawning habitat and feeder bluffs. If the remaining feeder bluffs are preserved in their current (unbulkheaded) condition, it is likely that less erosion will occur along down-drift shores. The cascading benefit of leaving feeder bluffs free to erode would be to provide the opportunity for beaches in these areas to be both self-sustaining and have increased resilience to changing conditions, such as those anticipated under current sea level rise scenarios.

There was a predominance of shore modifications along not just feeder bluffs but also along transport zones, accretion shoreforms and pocket beaches, which all provide habitat for important marine species. In many cases these rarer shoretypes represented local habitat “hot spots” providing, for example, the only forage fish spawning substrate for a mile or more of shoreline. Shore modifications such as bulkheads are known to directly and indirectly degrade nearshore habitats (Johannessen and MacLennan 2007). In all four CSAs, 207 parcels had modifications (primarily riprap and concrete bulkheads), which represented 31% of all parcels. The majority of the shore modifications documented within all case study areas extended low enough on the beach to infringe on forage fish spawning habitat.

Our results suggested an inverse correlation between setback distance and the occurrence of shore modifications, which supports the largely intuitive concept that greater setback distances decrease the perceived need for shore armoring. However because of problems with the setback data that was available at the time of the study, this relationship should be reassessed when higher quality data becomes available.

Forest cover decline (1977 to 2006) was observed within roughly one-third (32%) of all parcels throughout the study area. The majority of parcels (56%) showed no change in forest cover and a small percent (11%) of parcels had an increase in cover. Parcels with shore modifications showed considerably greater declines in forest cover than unmodified parcels and reduced riparian vegetation cover (aerial extent and overhanging) was also correlated with shore modifications.

Development of parcels influenced the occurrence of shore modifications and riparian forest cover decline. A considerably higher percentage of developed parcels were modified (53%) than were undeveloped parcels (39%). Overall 58% of the parcels developed since 1977 experienced a decline in forest cover, with an average decline of 25%. This equates to a net loss of 17.5 acres of forest cover. The amount of forest cover change on individual parcels was highly variable which was likely due to a combination of natural and anthropogenic processes (forest clearing, erosion and re-growth) as well as possible inconsistencies in the application of management guidelines.

A total of 270 mooring buoys were mapped throughout the study area, with the greatest abundance along embayed shores and in association with the state and national parks. Just under one-third of the mooring buoys observed in the field were located over mapped eelgrass beds. These results suggest that more can be done to reduce impacts and protect the eelgrass beds.

A total of 207 docks were mapped in the field. Detailed data on dock, float, and pier characteristics including, dimensions, height, and materials, are included in the report. The density of docks was greatest within the San Juan and Orcas Island CSAs. Only 2% of the docks observed in the field had light-penetraing grating (excluding ramps), and grating was observed only on docks located in the San Juan Island CSA. Approximately three-quarters of the docks observed in the field had some kind of creosoted material associated with the structure and in total 1,024 creosote piles were inventoried in association with docks in the study area, excluding marinas. The greatest number of creosoted piles was documented in the San Juan and Orcas Island CSAs, where herring spawning in known to occur. Creosote has been documented as particularly toxic to herring (Vines et al 2000). Stuart and Lopez Islands had the greatest ratio of floats over eelgrass beds. Floats orientated east-west were less frequently over eelgrass beds, while those oriented SE-NW were most frequently over eelgrass beds. Incentive programs could be put in place to reduce impacts of existing docks over eelgrass.

Based on a site-specific study conducted in Mitchell Bay, it appeared that shore modifications with more negative ecological impacts were those that were (originally) constructed prior to the implementation of the Shoreline Master Program (SMP) in 1977. A comparison of shore modifications within Mitchell Bay between 1977 and 2006 was conducted to determine how many of the current shore modifications were present in 1977 and if there were differences in the waterward extent of the modifications, their length, or material. Of the 12 shore modifications assessed, at least 5 appeared to be present in 1977, and at least 3 (of the 5) appeared considerably altered since 1977. Each of the 3 altered modifications appeared to cause greater adverse impacts to nearshore resources (e.g. addition of fill material or waterward expansion into intertidal areas). Throughout the field surveys numerous similar structures were observed that appeared to pre-date the SMP, indicating this issue is more pervasive than just Mitchell Bay.

Introduction

The San Juan Initiative is a unique partnership bringing together the San Juan County Council, the Puget Sound Partnership, community leaders, state and local agencies, and the Surfrider Foundation. The Initiative is an unprecedented effort to ensure that all existing conservation efforts, both public and private, are working together to protect the rich, diverse ecosystem of the San Juan Islands.

The Initiative, which started its work in 2007, is now in Phase Two of its four-phase process. The entire effort is scheduled to be completed by February, 2009. Phase Two is an assessment of how and why current protection efforts are either succeeding or failing. The first step in the assessment was a county-wide look at what is known about the significance of existing and potential impacts from human-caused shoreline modification. It quantified the extent to which shoreline modification occurs in conjunction with priority habitats, and identified protection problems that should be investigated in more detail through tailored case studies.

The case studies inventoried shoreline modifications throughout specific geographic areas of the San Juan County (SJC) nearshore in order to determine on-the-ground conditions. The findings are currently being merged with a permit review, community interviews and protection program analysis, the outcomes of which will determine the reasons for the success or failure of various nearshore protection efforts.

Background

The San Juan Initiative Nearshore Case Study Characterization, conducted by Coastal Geologic Services Inc. (CGS), documented and characterized the geomorphic, ecologic and level of anthropogenic modification to the shores of 4 case study areas in San Juan County. The findings are currently being merged with a policy program and permit review to analyze the success of protection programs currently implemented in San Juan County.

Four case study areas (CSAs) were selected for the San Juan Initiative Case Study Characterization (Map 1). Three of the CSAs are found on the larger islands with ferry service (San Juan, Orcas and Lopez Islands). The fourth case study area selected was a potion of Stuart Island and was intended to represent the “outer islands”, which together account for roughly 94 miles of the 408 miles of shoreline in San Juan County. The four CSAs were intended to capture a broad cross-section of ecologic, geologic and sociologic conditions within the County.

A two step process was used to identify the CSAs. The first step was to identify areas within the county that had a variety of representative shoreforms (accretion beaches, bedrock shores, feeder bluffs), variable levels of exposure (both exposed and protected embayments), variable shoreline modifications types (docks, armoring and varying amounts of shoreline vegetation) and priority habitats (eelgrass, forage fish, shoreline vegetation, kelp) within an 8-10 mile stretch of shoreline. Unfortunately kelp habitat was slightly underrepresented in the final selection of CSAs, as it predominantly occurs along more exposed shores, which was an explicit part of the selection criteria. Case study areas were restricted to 8-10 miles to allow field inventories to be conducted in single day for each area. In step 2, potential CSAs were reviewed for the following characteristics: variety of parcel sizes, community connection, and a variety of ownership. Policy Group members from each island were asked about the level of community connection associated with each CSA. After comparing areas, the best locations began to rise to the top and were selected for analysis. Existing data for each of CSA were then compiled and summarized by CGS prior to collecting additional data. These initial CSA descriptions can be found in Appendix 1.

A team of local scientists were consulted throughout the data collection and analysis process to provide senior technical input and to assure that the data answered the most relevant inquiries, relating to the objectives of the Initiative, across multiple scientific disciplines. The science advisory team was comprised of the following members: Amy Windrope, San Juan Initiative, Jim Kramer, San Juan Initiative, Megan Dethier, University of Washington – Friday Harbor Labs, Kurt Fresh, Northwest Fisheries Science Center, NOAA, Jennifer Burke, University of Washington, School of Aquatic and Fisheries Sciences, Tina Whitman, Friends of the San Juans (FSJ), Joe Gaydos, SeaDoc Society, Jim Johannessen, Coastal Geologic Services, and Andrea MacLennan, Coastal Geologic Services.

Methods

CGS collected data for the case study characterization both in the field and remotely using GIS, air photo analysis and existing data sets. Field data collection included characterizing geomorphic shoretypes, shore modifications, dock characteristics and recording the position of all mooring buoys within each of the 4 CSAs. These data were then brought into GIS, and paired with existing data for analysis. New data collected from air photo analysis included additional characteristics of docks, overhanging marine riparian vegetation cover, the aerial extent of marine riparian vegetation cover within a 200 ft buffer of the shoreline in 2006 and 1977, and building setback distances (2006 and 1977). These data were integrated with existing parcel and habitat data.

Field Data Collection Methods

All field data were collected primarily by visiting the entire shore of the CSAs by small boat using GPS. Field mapping was completed in March of 2008 using an 11 ft inflatable boat with an outboard engine. The boat work was completed at mid and high tides and the small size of the boat allowed for work very close to the shore features. Specific field methods are discussed further below.

Geomorphic Shoretype Mapping

All of the shore included in each CSA was delineated into one of eight different alongshore segments: feeder bluff exceptional, feeder bluff, transport zone, modified, accretion shoreform, pocket beach, no appreciable drift and no appreciable drift - bedrock.

The **Feeder Bluff Exceptional (FBE)** classification was applied to rapidly eroding bluff segments. This classification was meant to identify the highest volume sediment input areas per lineal foot. Feeder bluff exceptional segments were characterized by the presence of recent landslide scarps, and/or bluff toe erosion. Additionally, a general absence of vegetative cover and/or portions of bluff face fully exposed are often used for this classification. Other indicators included the presence of colluvium (slide debris), boulder or cobble lag deposits on the beach, and fallen trees across the beachface. Feeder bluff exceptional segments lacked a backshore, old or rotten logs, and coniferous bluff vegetation. See Table 1 for a summary of mapping criteria.

The **Feeder Bluff (FB)** classification was used for areas of substantial sediment input into the net shore-drift system. Feeder bluff segments identified segments that had periodic sediment input with a longer recurrence interval as compared to feeder bluff exceptional segments. Feeder bluff segments were characterized by the presence of historic slide scarps, a lack of mature vegetation on the bank, and intermittent bank toe erosion. Other indicators included downed trees over the beach, coarse lag deposits on the foreshore, and bank slope.

Transport Zone segments represented areas that did not appear to be contributing appreciable amounts of sediment to the net shore-drift system, nor showed evidence of past long-term accretion. Transport zones are shore segments where net shore-drift sediment is merely transported alongshore. The segments were delineated based on the lack of erosional indicators (discussed above for feeder bluff exceptional and feeder bluff segments) and the lack of accretion shoreform indicators such as a wide backshore area or a spit. This classification was meant to exclude areas that were actively eroding; however, transport zones typically occurred along banks that experienced landsliding and/or erosion at a very slow long-term rate, such that sediment input is minimal.

The **Modified** classification was used to designate areas that have been armored or otherwise altered to a state where the natural geomorphic character of the shore was largely concealed by the modification such that the bank no longer provided sediment input to the beach system or that beach-backshore processes were altered. This included bulkheaded areas where the bulkheads were still generally intact and functional, as well as areas with substantial fill at the shore, and other areas as described below in the *Shoreline Modifications* section, along with mapping methods.

The **No Appreciable Drift** (NAD) classification was used in areas where there was no appreciable net volume of sediment transport, due to a lack of wave energy or due to a lack of sediment volume such as along bedrock shores. NAD shores were further distinguished as NAD-B if drift was precluded due to the absence of nearshore sediment associated with bedrock shores. Regular NAD shores will then denote shores where limited wave energy or sheltered conditions eliminate the process of alongshore transport of sediment.

Table 1. Current conditions field mapping criteria (adapted from Johannessen and Chase 2005).

Feeder Bluff Exceptional Mapping

Presence of (priority in order):	***Absence of:***
1. Bluff/ bank	1. Shoreline bulkhead/ fill
2. Recent landslide scarps	2. Backshore
3. Bluff toe erosion	3. Old/ rotten logs
4. Abundant sand/gravel in bluff	4. Coniferous bluff vegetation
5. Colluvium/ slide debris	5. Bulkhead
6. Primarily unvegetated or vegetated slumps	
7. Trees across beach	
8. Boulder/ cobble lag	
9. Steep bluff (relative alongshore)	

Feeder Bluff Mapping

Presence of (priority in order):	***Absence of:***
1. Bluff/ bank	1. Shoreline bulkhead/fill
2. Past landslide scarps	2. Backshore
3. Intermittent toe erosion	3. Old/rotten logs
4. Moderate amount sand/gravel in bluff	4. Coniferous bluff vegetation
5. Intermittent colluvium	5. Bulkhead
6. Minimal vegetation	
7. Trees across beach	
8. Boulder/ cobble lag	
9. Steep bluff (relative alongshore)	

Transport Zone Mapping

Presence of (priority in order):	***Absence of:***
1. Coniferous bluff vegetation	1. Visible landslide scarps
2. Apparent relative bluff stability	2. Toe erosion
3. Gentle slope bluff (relative alongshore)	3. Backshore & backshore vegetation
4. Unbulkheaded transport zone adjacent	4. Old/rotten logs
	5. Colluvium
	6. Trees across beach
	7. Bulkhead

Modified Mapping

Presence of (priority in order):	***Absence of:***
1. Bluff/bank	1. Backshore & backshore vegetation
2. Shoreline bulkhead (mostly intact)	2. Lagoon/wetland/marsh behind berm
3. Substantial shoreline fill	3. Backshore "platform"
	4. Old/rotten logs
	5. Fine, well sorted sediment (relative alongshore)
	6. Bulkhead

Accretion Shoreform Mapping

Presence of (priority in order):	***Absence of:***
1. Backshore & backshore vegetation	1. Bluff/bank in backshore
2. Lagoon/wetland/marsh behind berm	2. Toe erosion at bank
3. Backshore "platform"	3. Landslide scarps
4. Old/rotten logs	4. Boulders on beachface
5. Fine, well-sorted sediment (relative alongshore)	5. Bulkhead

Table 1 continued.

No Appreciable Drift (NAD) Mapping

Presence of (priority in order):	***Absence of:***
1. NAD mapping (Johannessen 1992) 2. Embayment/lagoon shore	1. Active beachface 2. Accretion shoreform indicators
No Appreciable Drift – Bedrock (NAD-B) Mapping	
1. Bedrock cliffs, ramps or platform with little or no mobile sediment 2. Caves, haystacks or other shoreforms characteristic of bedrock.	1. Sediment derived from glacial or other deposits supplying sediment to nearshore 2. Collection of loosely assembled sediment within intertidal profile
Pocket Beach Mapping	
1. NAD mapping (Johannessen 1992) 2. Beach contained by bedrock headlands, *often* short in length 3. Crescentric in plan view 3. Swash aligned beach	1. Active sediment sources along adjacent shores 2. Sediment sorting alongshore

NOTE: Criteria in order of importance & features present take priority over features absent.

The **Accretion Shoreform** classification was used to identify areas that were depositional in the past or present. These segments were classified based on the presence of several of the following features: broad backshore area (greater than 10 ft wide), backshore vegetation community, spit and/or lagoon landward of a spit. Additional indicators for delineating an accretion shoreform were the presence of relatively fine-grained sediment or very old drift logs in the backshore.

The additional classification of **Pocket Beach** was included to accurately document this unique shoretype that is common within San Juan County. Pocket beaches represented beaches that were contained between two bedrock headlands, essentially creating a closed system. Pocket beaches were typically not located within drift cells. Theoretically minimal exchange of sediment occurs between the pocket beach and their adjacent shores. Pocket beaches were typically swash aligned, shorter in length, crescentric in plan and display well sorted materials.

Shoreline Modifications

All shoreline modifications of any significance (generally located adjacent to the MHHW or in the intertidal and over 5 ft in size) were mapped with GPS points at either end of the modification. This mapping was performed in the field by small boat at higher tides along with geomorphic shoretype mapping. Modifications included all types of shore armoring, including those associated with stairways, boat haul out areas, groins, jetties, boat ramps, fill areas including small and large, industrial areas, marinas or ferry terminal breakwaters and shore protection, road ends extending over the beach, or residential areas with smaller amounts of fill and/or shore protection structures.

Descriptive data for each modification were also recorded in the field, including the type of modification, and the material it was composed of (e.g., rock, timber, concrete, etc). The elevation of the toe of the structure relative to Mean Lower Low Water (MLLW) was estimated using measurements and estimations of distance from water level to modification toe (field work was carried out at times with high water levels). Additional notation was made as to whether or not the modified shore was likely a source of sediment prior to alteration based on field observations (only). Field indicators of historic sediment sources included steep bluffs with erosional indicators such as landslide scarps, lack of vegetation, fallen or jack-strawed trees, and deciduous trees commonly associated with disturbance (such as Red alder and Bigleaf maple). The historic shoretype of all other modified shores was determined using GIS and oblique aerial photography, and was largely based on shore topography, the adjacent mapped shoretypes, and backshore/intertidal vegetation.

Mooring Buoy Mapping

All mooring buoys found within each of the CSAs were mapped in the field using GPS.
All mooring buoy GPS points were brought into GIS as a point shapefile and a 15 ft buffer was drawn around each point. The presence/absence of eelgrass within the buffered buoy location was then visually assessed and recorded in the attribute file.

General Field Mapping Procedure

All features were mapped from a small boat at mid to high tides with good visibility. Field mapping criteria were used to map individual segments in the field based on observed shoreline features. Positional data was recorded using a handheld Thales *MobileMapper* GPS unit in the WGS 84 (World Geodetic System or Latitude/Longitude) coordinate system. The GPS unit was WAAS (wide area augmentation system) enabled, and generally had an accuracy of +/- 9 ft. Waypoints were marked at the beginning and end of each field-mapped segment as close inshore to the position of mean high water (MHW) as possible, and at a 90-degree angle to the shoreline (shore-normal). The waypoints were correlated with segments and additional attribute data, and notes that were recorded in a field notebook.

The GPS data was downloaded using *MobileMapper Office* (Thales Corporation), and a text file of the positions and waypoints was created. The text file was then opened in Excel in order to delete header rows and unnecessary columns for import into ArcMap 9.1. The Excel file was then saved as a comma separated file and imported into ArcMap 9.1 using the “Add x, y data” under the tools menu, creating an event file. The event file was then exported from ArcMap 9.1 in the ESRI shapefile format. The shapefile was then re-projected into NAD 83 State Plane North – FIPS 4601, the preferred projection requested by the science advisory team.

Ancillary Data

Numerous ground photos were taken throughout field mapping. Field photos were taken of representative CGS shoretypes as well as at each shore modification, dock and any other anomalous feature observed during fieldwork. At each location a field photo was taken, a GPS point was also recorded. Following field data collection, the GPS points were imported into a GIS shapefile. These data could then later be hyperlinked to the appropriate ground photos, if the client determines a valuable use for this tool.

Data Collection from Air Photo Analysis

Overhanging Marine Riparian Area (MRA) Polyline Mapping

Overhanging marine riparian area line data was collected and displayed along (snapped to) the Washington State Department of Natural Resources (WDNR) Shorezone shoreline (2001). The shoreline was segmented and attributed at each change in vegetation type (see vegetation categories below), to allow the entire marine riparian vegetation type to be displayed or just the individual vegetation types. The parcel boundaries and numbers associated with each shore segment were later added to the data using a processing tool created for this utility. The length of each shoreline vegetation type was also calculated.

Each overhanging vegetation type was estimated using the 2004/2006 color infrared high-resolution vertical air photos. If active coastal erosion was occurring (feeder bluff) then the riparian vegetation cover immediately landward (e.g. along the bluff crest) was estimated. The following categories were used to characterize the overhanging MRA vegetation including: D – dune/marsh vegetation, PG – prairies/grasslands (not lawns), S - shrubs, F - forest, L – lawn, IMP – impervious material such as road/structure. Percent cover of the fringing riparian vegetation types was estimated based on vertical air photos, for example: 60-F/30-L/10-IMP, producing a total of 100% coverage.

Marine Riparian Areas Polygon Mapping

Percent-cover vegetation in the marine riparian area was estimated within a 200 ft buffer (management zone) landward of the Shorezone shoreline. The buffer (management zone) was created in ArcGIS using the buffer wizard. Breaks were added to the polygon along each parcel boundary to create individual marine riparian management areas for each shoreline parcel included in each CSA. Where the buffer extended beyond the limits of the parcel (e.g. the parcel extends only 100 ft landward of the Shorezone shoreline), the percent cover and shoreline vegetation types were estimated for the entire parcel only. The marine riparian vegetation cover of the adjacent landward parcel was not assessed, as it was the focus of this study to address issues related to waterfront parcels only.

Air photo interpretation of marine riparian cover was conducted using the high-resolution infrared images from 2004/2006 and georeferenced historic images from 1977 (courtesy of Washington Department of Ecology). Thirty-five 1977 vertical air photos were georeferenced prior to conducting this analysis. Current and historic conditions within each parcel were assessed concurrently for greater efficiency. The percent cover of each vegetation type was estimated and noted in the attribute table of each marine riparian area polygon. The vegetation assemblages found within each parcel were characterized based on representative shoreline vegetation types found alongshore within the Puget Sound. The following categories were used to characterize the MRA: D – dune/marsh vegetation, PG – prairies/grasslands (not lawns), S - shrubs, F - forest, L – lawn, IMP – impervious material such as road/structure. Percent cover of these vegetation types was estimated for each parcel's management area for example: 80-L/10-F/10-S, producing a total of 100% coverage.

Dock Polygon Mapping

Dock data was collected primarily from high-resolution infrared air photos from 2004/2006 and oblique photographs, and supplemented with new field data. Air photo interpretation was conducted at a minimum scale of 1:240 (1 inch=20 ft). Two polygons were created (digitized) for each dock structure. The "Pier" polygons encompassed both the pier and ramp structures, and started from the approximate Ordinary High Water Mark (Shorezone shoreline) and extended the entire length of the structure. Where the dock extended into the upland area landward of the Shorezone shoreline, the digitized Pier polygon was truncated at the Shorezone shoreline and the portion over land was not included in the digitized polygon. This landward area was often under tree cover making it difficult to accurately view in air photos, and was not required for analyses of the nearshore. Additionally, truncating the structure at this point enabled a more accurate calculation of the shaded intertidal area resulting from the entire pier-ramp structure.

The Pier polygon was digitized for each dock within each CSA, and the following attributes were recorded: width, length, orientation (4 orientations), and the parcel number. Floats were digitized in a separate polygon shapefile, and the following attributes were documented: float width, length, orientation (4 orientations), the number of boats moored at the time of the photo, presence or absence of (outer edge of) eelgrass waterward of the dock at the site, along with the parcel number. Where eelgrass was within 50 feet adjacent to the dock it was noted in the attribute table that eelgrass was present. Several floats were observed in the air photo analysis that were unattached to the shore and therefore not clearly associated with a parcel number. For these free floats an artificial parcel number was created in the attribute table that consisted of all 9's.

Additional dock data was collected in the field and added to the attribute table for piers and floats. Data collected in the field for piers included: the material of the structure, the approximate percentage of light-penetrating grating on the pier (not ramp), the estimated height of the pier above tidal datum, and number of creosote pilings. Field data collected for floats included: the material of the structure, the approximate percent of light-penetrating grating, the measured width of the float, and the number of creosote pilings.

Mapping Structures and Upland Setback Distances

The minimum setback distances of any major structure (primarily a house or cabin) in the upland of each parcel was measured. A point shapefile was created and the minimum setback distance location (waterward-most extent of the structure) for each parcel containing a major structure was digitized. The distance from the Shorezone shoreline to that location was measured in feet using the GIS measuring tool, and recorded in the attribute file along with the parcel number. If this distance changed between 1977 and 2004/2006, then that change was noted in the attribute table. Some structures extended beyond the Shorezone shoreline and were considered "over-water" structures. These were noted in the attribute table as having a negative setback distance.

Integration of Existing Data

Data from numerous sources were compiled for use in the San Juan Initiative assessment. As previously mentioned, all data were summarized at the parcel and case study area scales for use in the permit analysis.

A common issue with assimilating shoreline data from various sources was the contrasting spatial position of various shoreline datasets. The most contrasting shorelines in this study were the SJC parcel data shoreline and the WDNR Shorezone shoreline. To resolve the issues, some pre and post data processing in GIS was required to enable these data to translate to 1) the best available shoreline for the state and 2) the parcel unit scale.

Translation between new mapping snapped to the Shorezone shoreline and parcel shoreline was conducted by creating a processing tool in which parcel boundaries were manually created along the Shorezone shoreline. Shorezone units were dissolved prior to creating the new parcel unit breaks, and the associated parcel numbers were included in the attribute table. This processing tool enabled the alongshore datasets that were created as part of this study, such as shoretype and riparian data, to be analyzed at the parcel unit scale. Parcel unit breaks were added to each of the shapefiles necessary for the analysis by using the Identity tool in ArcToolbox, and a cluster tolerance of 5. Additional processing required to aggregate data within each parcel was later conducted using MS Excel.

Buffers also provided an invaluable tool for assimilating and resolving problems arising from contrasting shoreline locations, and buffers were used by Friends to assimilate each of the data sets below with the County parcel data (Tina Whitman, Jim Slocomb, pers. comm.). The data sets listed below (and the buffers) applied were used as interim data in the nearshore case study characterization.

- Forage fish: buffer distance 100 ft from merged Washington Department of Fish and Wildlife (WDFW)/FSJ line data (documented forage fish spawning: FSJ et al 2004, potential forage fish spawning, Moulton and Penttila 2001).
- Eelgrass: translates every eelgrass outerline to parcels located directly landward (FSJ et al, 2004 data)
- Bull kelp: 100 ft buffer distance from polygons, (FSJ and WDNR , 2007)
- Pacific herring: 1,000 ft buffer from herring spawn polygons (WDFW, 2004)

Presence/absence data that were required for each parcel were created by selecting parcels adjacent to the shapefile data of interest, quality-checking the selection manually, and creating interim parcel datasets that were later joined by parcel number, then exported it into a database. This process was conducted for all parcels with modifications, feeder bluffs, eelgrass, rocky intertidal habitat (indicated by *Fucus sp*. in Shorezone database, WDNR 2001). The data were then assimilated into the parcel database as presence/absence data.

Results

Data collected in the field and from air photo analysis were compiled in ArcMap GIS and Excel for analysis. Data were analyzed, summarized in tables and graphs, and maps were created to display findings at the case study area scale. Data were also summarized at the parcel unit scale for certain inquiries requested by the client. Specific research questions were developed for further investigation following review of initial results by the Initiative's Science Advisory Team. The data summaries and results are displayed below, followed by the research questions proposed by the Science Advisory Team and the associated results. All maps can be found in the Map Appendix (Appendix 2).

General Upland Characteristics

In total, data were collected and analyzed from approximately 34 miles of SJC shoreline extended across 4 representative case study areas (selected from 408 miles of SJC shore). Each CSA measured 8.1-8.7 miles in length and was comprised of 112-202 parcels (Table 2). In total, 638 parcels were encompassed within the case study areas. Parcel density was comparable between the San Juan Island and Lopez Island CSAs, and between the Orcas and Stuart CSAs (Table 3). Mean parcel size was very similar (4.2-5.3 acres) on all islands except Lopez, where parcel size was smaller. Additional analyses of correlates between these data performed by Dr M. Dethier showed a positive correlation between parcel acreage and width. Further information on these analyses can be found in Appendix 3. Stuart and San Juan Islands had the greatest percantage of parcels measuring under one acre in area (Table 3). Orcas Island had the greatest ratio of parcels that were larger than 5 acres.

As described in the *Methods* section, setback distances were measured from the Shorezone shoreline to the nearest structure on each parcel. This method of determining setback distance was determined to be the best approach to explore the efficacy of setback distance as a shoreline management tool based on the best currently available data sets. Ideally setback distanced should be measured from the nearest structure to the bluff crest/ top of bank, however this would require topographic data of a reasonable scale and resolution, which unfortunately does not exist in San Juan County. Unfortuantely, setback distance data quality was sacrificed due to the limited data available, which resulted in incorrect setback measures, especially at higher relief shores. Setback measures were desceptively high along these shores because the bluff face (sloping bank or bluff) was included in the setback distance, which increased the measured "setback", as the horizontal distance from the top to toe of bluff was included. LiDAR imagery may become available for San Juan County, however the data was not available for this study. When this data becomes available it is recommended that setback distances be remeasured and properly assessed to accurately determine the efficacy of setback distance as management tool and to re-evaluate this portion of the analysis with a greater level of scientific rigour.

Measured setback distances from the Shorezone shoreline were very similar except on Lopez Island, where the mean setback distance was greater than other CSAs. Stuart Island had the greatest ratio of parcels that were undeveloped (Table 4). San Juan Island and Lopez Islands had considerably more parcels with setback distances greater than 100 ft (Table 5).

Table 2. General upland characteristics of each CSA.

General Upland Characteristics	All CSAs	San Juan	Orcas	Lopez	Stuart
Shoreline length (mi)	33.8	8.7	8.6	8.4	8.1
Number of parcels	636	202	121	202	111
Mean parcel area (acres)	4	4.3	5.3	2.8	4.2
Mean setback distance (ft)	103.7	84.8	77.1	141.4	78.2
Mean parcel shoreline length (ft)	284.4	237.4	377.1	223.7	380.6
Median parcel shoreline length (ft)	140.5	122.2	291.8	126.6	127.4

Table 3. Area (acres) of parcels within each CSA.

Parcel Area (acres)	All CSAs	San Juan	Orcas	Lopez	Stuart
<1 acre	306	113	36	94	63
1-5 acres	243	73	56	84	30
5+ acres	87	16	29	24	18

Table 4. Number of parcels in different setback distance classes (measured from the Shorezone shoreline).

Setback Distance (ft)	All CSAs	San Juan	Orcas	Lopez	Stuart
No Structure	250	76	47	58	69
< 50 ft	95	36	27	19	13
50 - 100 ft	157	50	26	66	15
100 + ft	134	40	21	59	14

Coastal Geomorphic Shoretypes and Priority Habitats

Maps displaying the shoreline habitats found within each case study area are found in the Maps Appendix (Appendix 2, Maps 2a – 2d). Maps 3a – 3d display the coastal geomorphic shoretypes within each CSA.

Table 5. Number of parcels and percent of parcels with setback (from Shorezone shoreline) less than 100 ft and sensitive areas of interest.

Setbacks and Sensitive Areas	All CSAs		San Juan		Orcas		Lopez		Stuart	
Parcels with setbacks <100ft	252		86		53		85		28	
Parcels with <100 ft setback and feeder bluff	37	13%	3	3%	6	11%	24	22%	4	14%
Parcels with <100 ft setback and eelgrass	120	47%	26	30%	23	43%	57	67%	14	50%
Parcels with <100 ft setback and kelp	13	5%	0	0%	7	13%	2	2%	4	14%
Parcels with <100 ft setback and rocky intertidal	113	44%	33	38%	39	74%	19	22%	22	79%
Parcels with <100 ft setback and potential forage fish spawning habitat	119	47%	24	28%	23	43%	65	76%	7	25%
Parcels with <100 ft setback and documented forage fish spawning habitat	30	12%	8	9%	5	9%	16	19%	1	4%

The Lopez Island CSA had the greatest number (and %) of parcels with eelgrass and potential and documented forage fish spawning habitats (Table 6). Though San Juan Island had the greatest linear extent of documented forage fish spawning habitat, Lopez Island had the greatest potential forage fish spawning habitat, followed by San Juan and Orcas Islands (Table 7, Figure 1). Analyses of these data performed by Dr. Megan Dethier documented a positive correlation between forage fish spawning habitat and eelgrass (Appendix 3). Herring spawning was considerably more abundant in the San Juan CSA, relative to other CSAs.

Over the four CSAs, 207 parcels had modifications (primarily riprap and concrete bulkheads), which represented 31% of all parcels (Table 6). In total, shore modifications were mapped along 11.6% of the study area's shoreline (Table 8, Maps 4a – 4d). These included high bluff sites such as south of

Spencer Spit, Swifts Bay, the Nicholson-bank area, Mitchell Bay, Orcas Landing and isolated parcels on eastern Stuart Island. The Lopez Island CSA had the greatest number of parcels with shore modifications. Orcas Island had the greatest linear extent of shore modifications, closely followed by Lopez Island (Tables 6 and 8). The abundance of shore modifications in the Orcas Island CSA was likely influenced by the number of coastal roads and hamlets (West Sound and Orcas Landing) that occur within that CSA, while other CSAs predominantly consisted of residential development. Stuart Island had the greatest percent of unmodified parcels (Table 6) and the least length of modified shore (Table 8, Figure 2). However, San Juan had the greatest number of unmodified parcels; this discrepancy is likely due to the higher parcel density of the San Juan CSA (Tables 2 and 6).

Table 6. Parcels and percent of parcels with various shore characteristics of interest. HFB = Historic Feeder Bluff (a feeder bluff that is currently armored), FB = Feeder Bluff, Doc. FF spawn = Documented forage fish spawning habitat (surf smelt or sand lance), Pot. FF spawn (Potential forage fish spawning habitat.

Parcel Summary	All CSAs		San Juan		Orcas		Lopez		Stuart	
Number of parcels	636		202		121		202		111	
Parcels with Modifications (#, %)	207	31%	62	31%	42	33%	91	45%	12	11%
Unmodified Parcels (#, %)	429	67%	140	69%	79	65%	111	55%	99	89%
Mods that were HFB (#, %)	40	19%	3	5%	13	31%	24	26%	0	0%
Parcels with FBs (#, %)	96	15%	6	3%	16	13%	63	31%	11	10%
FBs within Doc. FF spawn (#, %)	20	21%	1	17%	2	13%	17	27%	0	0%
FBs within Pot FF spawn (#, %)	77	80%	2	33%	14	88%	56	89%	5	45%
Parcels with eelgrass (#, %)	281	44%	64	32%	50	39%	112	55%	55	50%
Parcels with kelp (#, %)	32	5%	1	0%	9	7%	5	7%	17	15%
Parcels with rocky intertidal (#, %)	313	49%	86	43%	78	61%	63	31%	86	77%
Parcels with documented forage fish spawning (#, %)	71	11%	23	11%	10	8%	34	17%	4	4%
Parcels with potential forage fish spawning (#, %)	267	42%	51	25%	55	43%	133	66%	28	25%

The contrasting geomorphic conditions of each CSA combined with the variable parcel densities likely influenced these results (Table 8, Figure 2). For example the Lopez case study area was comprised of a much greater percent of feeder bluff, transport zones and accretion shoreforms, which support the processes that create and maintain forage fish habitats and eelgrass beds. Analyses by Dr. M. Dethier showed a positive correlation between potential forage fish spawning habitat and feeder bluffs (Appendix 3). Stuart and Orcas Island CSAs had far more bedrock shores and therefore support more rocky intertidal and bull kelp than other CSAs, as well as a considerable amount of eelgrass (Figures 1 and 2). The Lopez Island case study area also had bedrock shores that support rocky intertidal habitats, though this shoretype was limited to the northern extent of the study area. The San Juan Island CSA was comprised of a larger portion of pocket beaches and areas of No Appreciable Drift. Throughout all CSAs, feeder bluffs (exceptional and regular), accretion shoreforms, transport zones and pocket beaches each represented approximately 8- 8.5% of the shore. Bedrock shores were by-far the dominant shoretype, accounting for over 42% of the shore, followed by areas of No Appreciable Drift (12.9%) and modified shores (11.6%) (Table 8, Figure 2).

Table 7. Coverage of various habitats of interest found within each CSA. Note – habitats are often overlapping, therefore do not sum to exactly 100%.

Habitat Types (%)	San Juan	Orcas	Lopez	Stuart
Rocky Intertidal (*Fucus distichus*)	36%	64%	65%	84%
Eelgrass (*Zostera sp.)*	28%	34%	54%	36%
Documented Forage fish spawning	26%	3%	11%	2%
Potential Forage fish spawning	27%	23%	57%	16%
Herring (*Clupea sp*) Spawning	54%	32%	2%	0%
Bull Kelp (*Nereocystis luetkeana*)	1%	3%	0%	14%

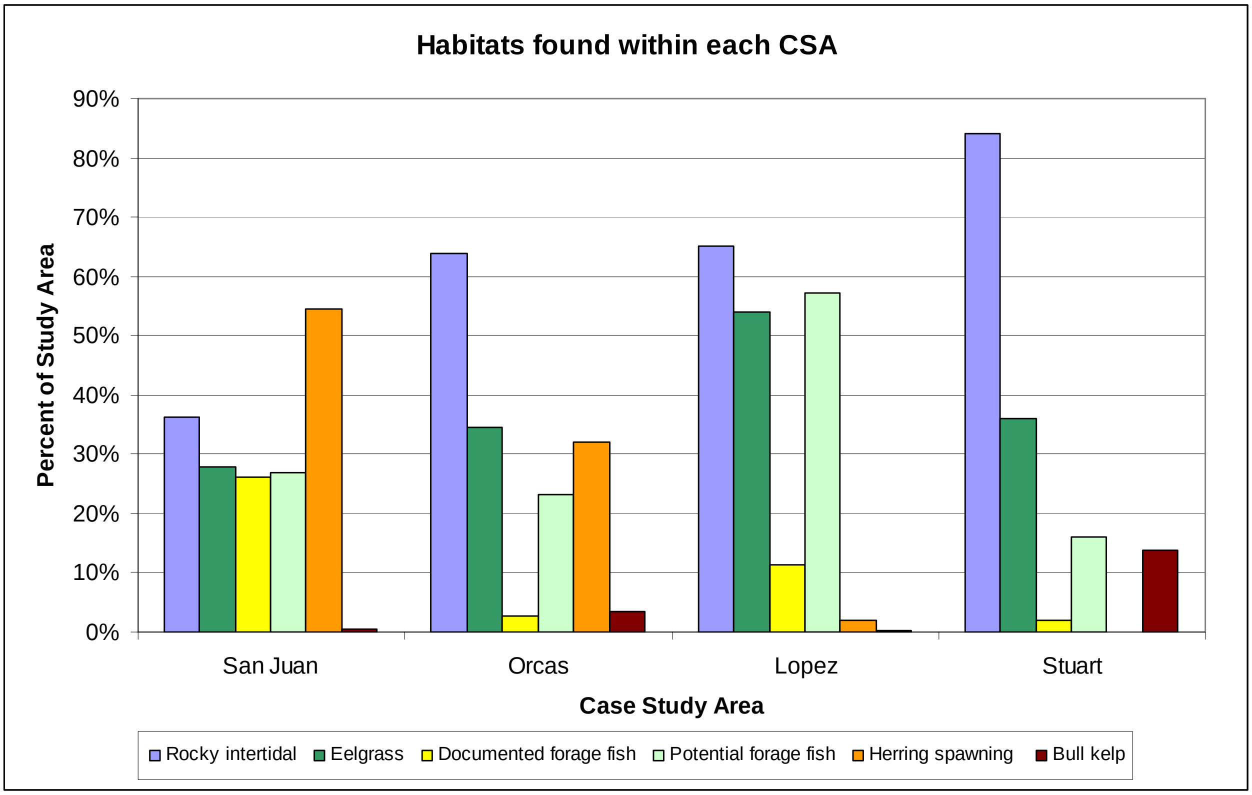

Figure 1. Percent of each CSA (shoreline length) that each habitat of interest encompassed. Habitats of interest include: Rocky intertidal habitat (indicated by *Fucus sp.*, WDNR, 2001), Eelgrass outer-line (FSJ et. al., 2004), Documented forage fish spawning habitat (WDFW, 2004), Potential forage fish spawning habitat (Moulton and Penttila, 2001), Herring spawning habitat (WDFW, 2004), Bull kelp (FSJ & WDNR, 2007).

Table 8. Shoretypes found within each CSA. FBE=Feeder Bluff Exceptional, FB=Feeder Bluff, TZ=Transport Zone, AS=Accretion Shoreform, NAD-B=No Appreciable Drift-Bedrock, NAD=No Appreciable Drift, PB=Pocket Beach, MOD=Modified.

Shoretype	All CSAs	San Juan	Orcas	Lopez	Stuart
Feeder bluff exceptional	0.4%	0.0%	0.0%	1.4%	0.0%
Feeder bluff	7.7%	1.7%	5.3%	20.1%	2.2%
Transport zone	8.4%	21.2%	1.4%	7.7%	3.2%
Accretion shoreform	8.2%	9.1%	1.6%	14.6%	6.9%
NAD - Bedrock	42.4%	6.7%	63.0%	27.5%	75.8%
NAD	12.9%	36.1%	4.3%	10.5%	0.0%
Pocket beach	8.4%	14.6%	8.2%	2.7%	8.6%
Modified	11.6%	10.5%	16.2%	15.4%	3.3%

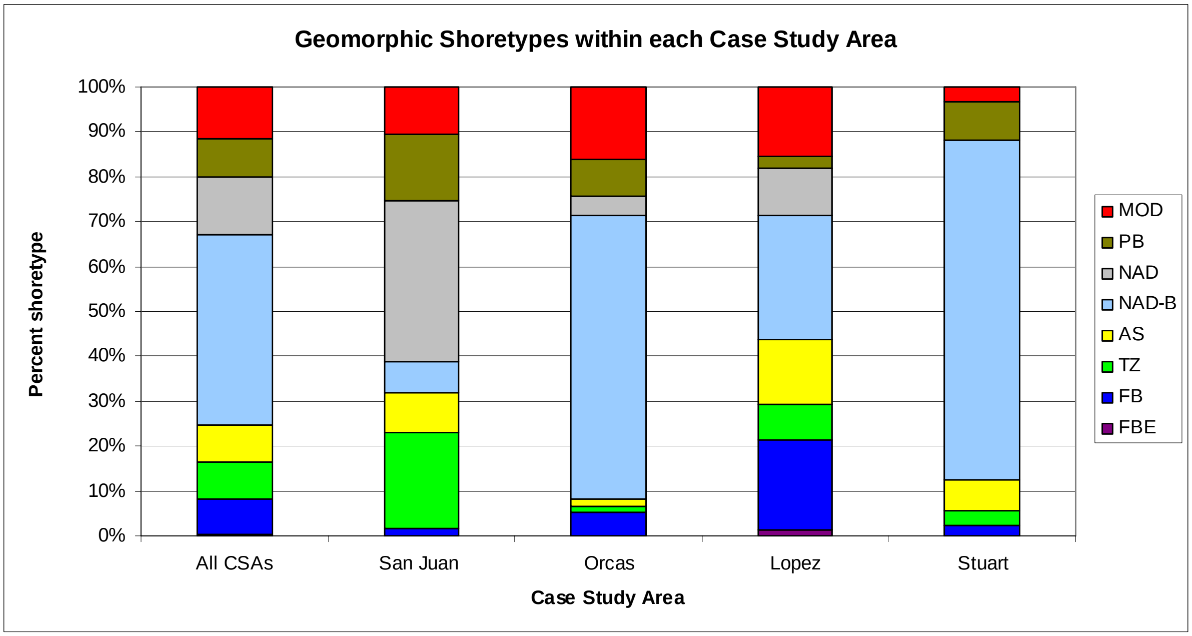

Figure 2. Geomorphic shoretypes mapped within each CSA. MOD = Modified shore, PB = Pocket Beach, NAD = No Appreciable Drift, NAD-B = Bedrock shore, AS = Accretion Shoreform, TZ = Transport Zone, FB = Feeder Bluff, FBE = Feeder Bluff Exceptional.

Table 9. Unmodified feeder bluffs (miles) and modified feeder bluffs within each case study area.

Shoretype	All CSAs	San Juan	Orcas	Lopez	Stuart
Unmodified FBs (mi)	2.9	0.2	0.5	2.1	0.2
Modified FBs (mi)	1.5	0.1	0.7	0.7	0.0

Throughout all CSAs, approximately 3 miles of feeder bluff remain intact, while another 1.5 miles have already been impounded behind shore armoring and no longer function in supplying sediment to the drift cells/nearshore (Table 9, Figure 3). The Lopez and Orcas Island CSAs have the greatest extent of modified feeder bluffs, however the Orcas Island CSA has relatively few reaches of feeder bluff as compared to the Lopez Island CSA. The greater percent of feeder bluffs within the Lopez and Orcas Island CSAs likely increases the residents' perceived risk of coastal erosion on their properties, which has likely contributed to the proliferation of shore modifications (Tables 8 and 9, Figures 2 and 3). Considerably more intact feeder bluffs remain within the Lopez Island CSA, relative to other CSAs. The large majority of intact feeder bluffs on Lopez Island sustain the important down-drift habitats such as forage fish spawning beaches, eelgrass beds, and the saltmarsh complex at and surrounding Spencer Spit State Park.

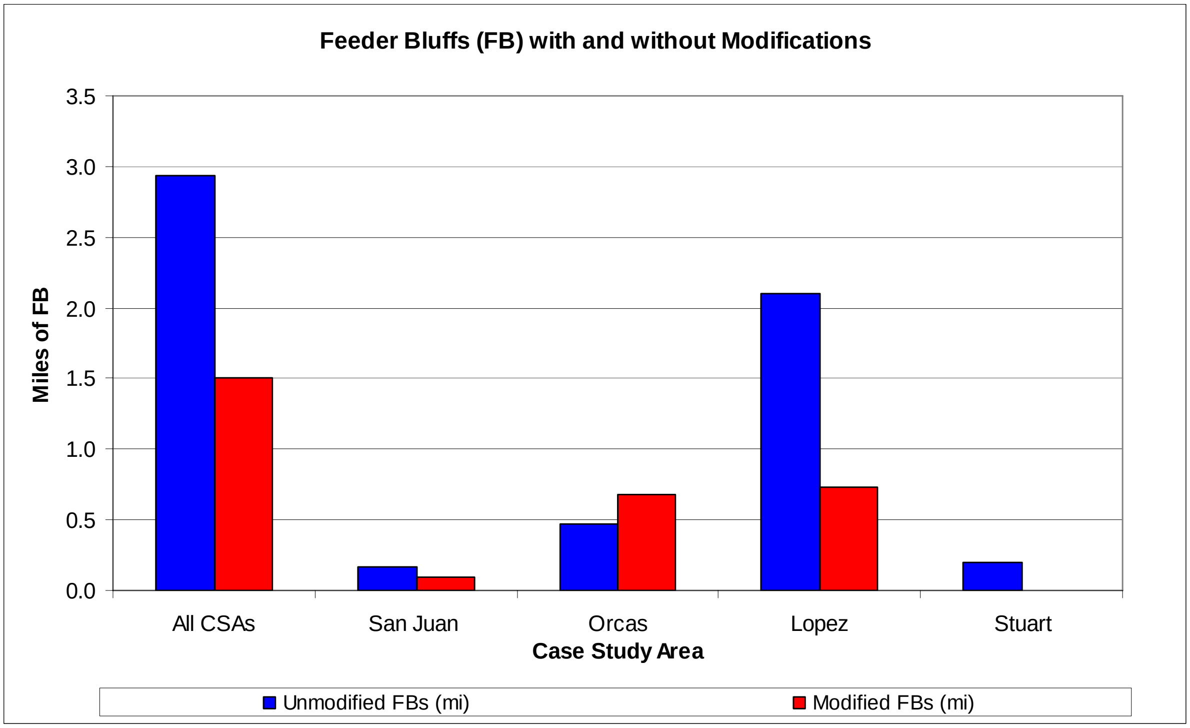

Figure 3. Linear extent of feeder bluffs with and without shore modifications, out of the total study area shore length of 33.8 miles.

The majority of the shore modifications documented within all case study areas extended low enough on the beach to infringe on the forage fish spawning habitat band, which was identified by D. E. Penttila with WDFW, as +4 to +8 ft MLLW for SJC (pers. comm 2008, Table 10, Figure 4). Only 21% of the shore modifications mapped by CGS throughout all CSAs were above the forage fish spawing band, and 35% of the shore modifications extended below Mean Sea Level (MSL), meaning that they covered virtually the entire forage fish spawning band (MSL = +4.6 ft MLLW for San Juan County, NOAA benchmark http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Bench%20Mark%20Data%20Sheets&state=Washington&id1=944). The greatest ratios of modifications that infringed on the forage fish spawning band were observed in the San Juan and Orcas Island CSAs. Within the Orcas and Lopez Island case study areas 25-30% of the shore modifications extended below MSL, which largely precludes access to the forage fish spawning band.

Table 10. Percent of length of modified shores found at various tidal elevations within each CSA. Tidal elevations of the toe of each shore modification were estimated in the field, in ft MLLW. Shaded categories indicate modifications infringing within forage fish spawning band.

Tidal Elv of Mods	All CSAs	San Juan	Orcas	Lopez	Stuart
Modified shore (mi)	4.1	0.9	1.4	1.5	0.3
8.0 ft + MLLW	21%	2%	30%	25%	16%
MSL - 8.0	44%	60%	49%	30%	44%
< MSL	35%	38%	21%	45%	40%

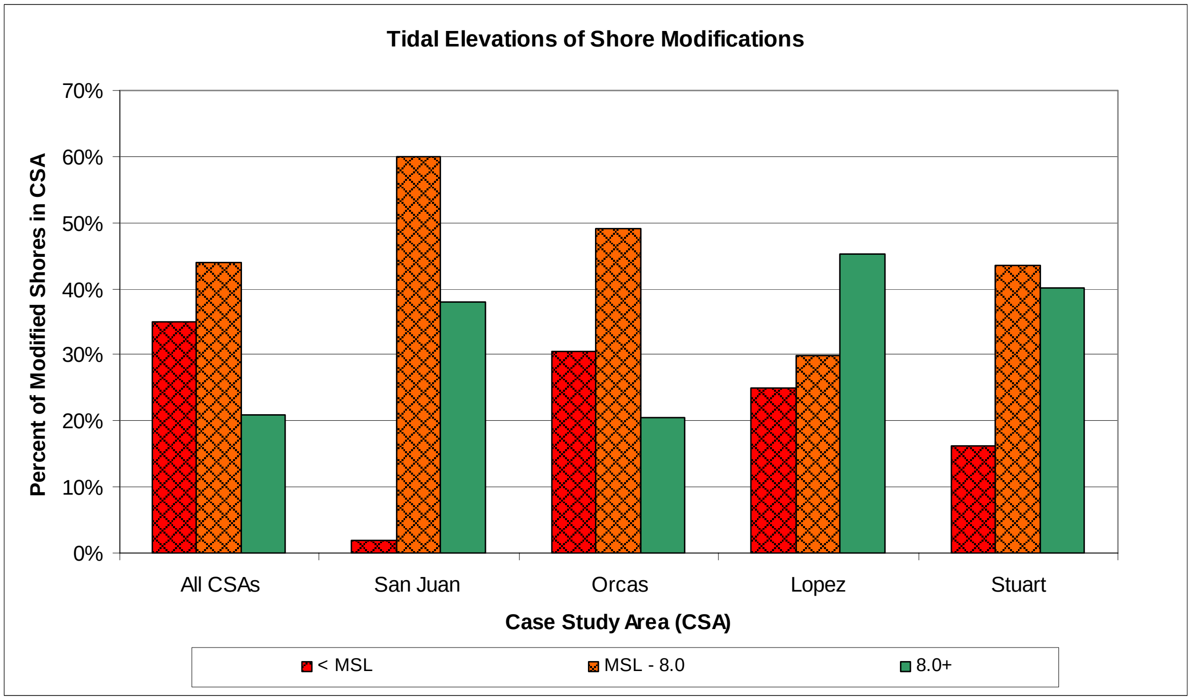

Figure 4. Tidal elevation of (the toe of structure) shore modification structures observed throughout each CSA. Cross-hatching denotes structure infringing on forage fish spawning band of 4-8 ft for SJC (pers comm. D.E. Penttila, 2008).

Marine Riparian Vegetation Summary

Overhanging marine riparian vegetation was generally consistent across the case study areas, though the forest vegetation class exhibited more variability (Table 11, Figure 5, Maps 5a – 5d). San Juan and Orcas Island CSAs had a considerably greater average of overhanging forested vegetation than Lopez Island. Stuart Island had the lowest average overhanging forested vegetation. This was likely influenced by the shoretypes found on Stuart being less condusive to forest growth close to shore, such as bedrock promintories and accretion shoreforms.

Table 11. Overhanging marine riparian vegetation – all vegetation classes and forested vegetation only (2006).

All MRA Veg Classes	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	86%	86%	87%	85%	87%
Standard deviation	29%	28%	26%	31%	30%
Forest Veg Class Only	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	56%	72%	70%	58%	10%
Standard deviation	43%	37%	36%	44%	22%

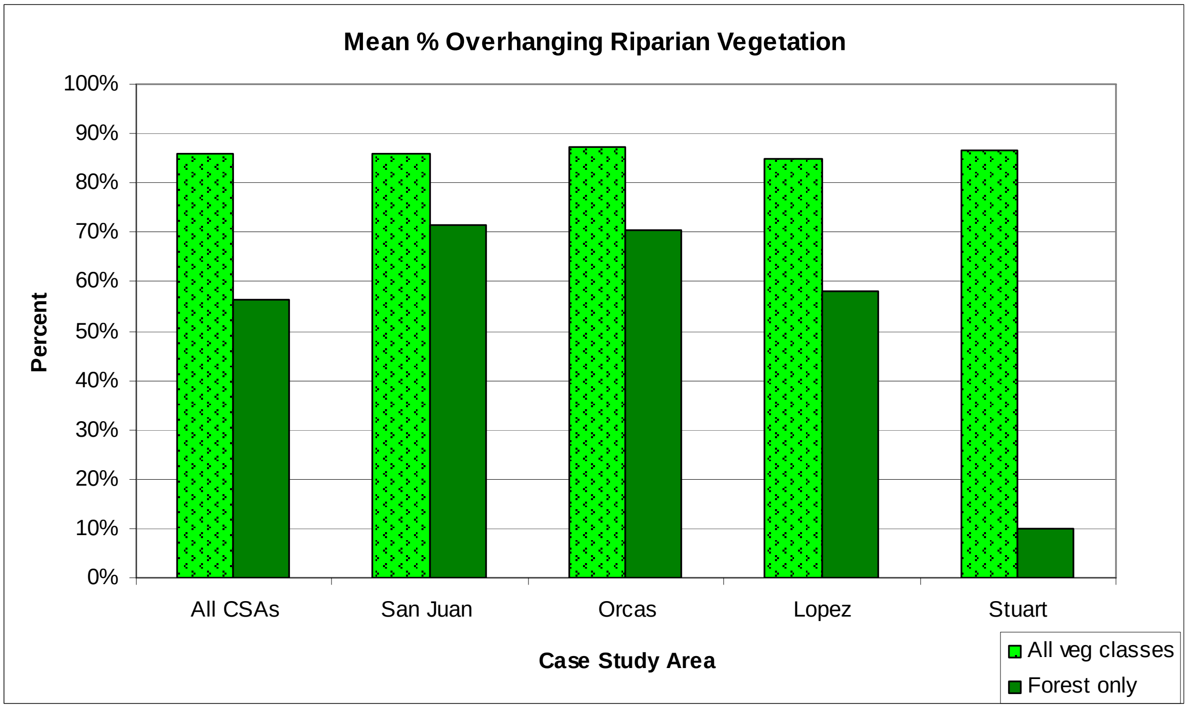

Figure 5. Mean percent overhanging marine riparian vegetation (all vegetation classes summed) and forest vegetation (only) as observed in 2006.

The average percent of forested vegetation cover within the marine riparian area management zone has incurred some decline during the period from 1977 – 2006. The greatest (average) declines have taken place within the Lopez and Orcas Island case study areas (Table 12, Maps 6a – 6d), with the greatest cumulative loss incurred to the Orcas (10.2 acres) and San Juan (9.0 acres) CSAs (Table 13). Across all case study areas marine riparian forests have declined by 26.6 acres.

Table 12. Marine riparian area forested vegetation class 1977 – 2006.

2006 Forest Cover	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	64%	71%	57%	56%	73%
Standard deviation	33%	28%	34%	35%	31%
1977 Forest Cover	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	69%	78%	62%	61%	76%
Standard deviation	34%	27%	37%	38%	30%

Table 13. Net decline in marine riparian forest cover between 1977 – 2006.

Net Loss of Forest Cover 1977- 2006	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Net loss in acres	26.6	9.0	10.2	6.2	1.2
Percent of total loss	100%	34%	38%	23%	5%

Forest cover change occurs naturally, as a result of natural disturbance such as landslides, as well as anthropogenically (e.g. land-clearing for development). In addition, forests continually re-grow (if not prevented by additional clearing and vegetation management. The interaction of these natural processes and athropogenic alteration of the landscape likely contributed to the high variability of forest cover change data.

Overall, forest cover decline was observed within 32% of all parcels assessed. Fifty-six percent of the parcels had no forest change and 11% of the parcels showed an increase in forest cover during the period of assessment, from 1977 – 2006 (Figure 6). The high variability of these data likely reflects the interaction of the natural and anthropogenic causative factors in combination with the variable interpretation and implementation of the current management tools used in an attempt to retain riparian vegetation along waterfront properties.

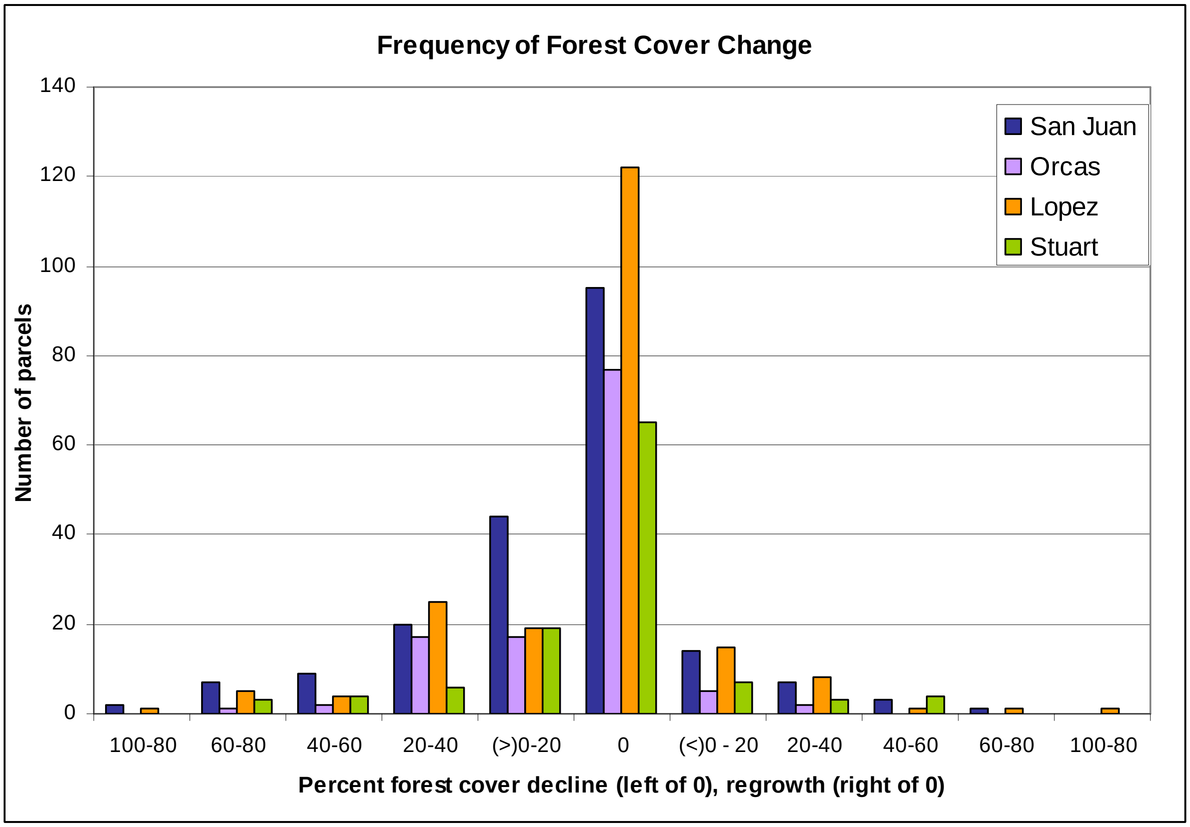

Figure 6. Frequency of forest cover change, showing percent forest cover decline (left of zero) and forest cover re-growth (right of zero) among the parcels assessed in each CSA.

Further analyses of the marine riparian vegetation data included exploring the relationship between modified (armored) shores and the occurrence of marine riparian vegetation (both overhanging and aerial extent/cover). The presence of shore modifications (predominantly shore armoring) appeared to have an effect on the quantity of overhanging marine riparian vegetation. Data showed that modified shores had 19 – 27% less overhanging riparian vegetation than unmodified shores (Table 14, Figure 7). This trend was most apparent on Lopez Island, followed by the Orcas Island case study area. A similar, although less dramatic, relationship was observed between overhanging forest vegetation along armored as compared to unarmored shores (Table 15).

Table 14. Shore modifications and overhanging marine riparian vegetation

Modified Shores	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	71%	73%	71%	70%	69%
Standard deviation	37%	35%	35%	40%	34%
Unmodified Shores					
Mean	93%	92%	96%	97%	89%
Standard deviation	20%	21%	13%	9%	28%

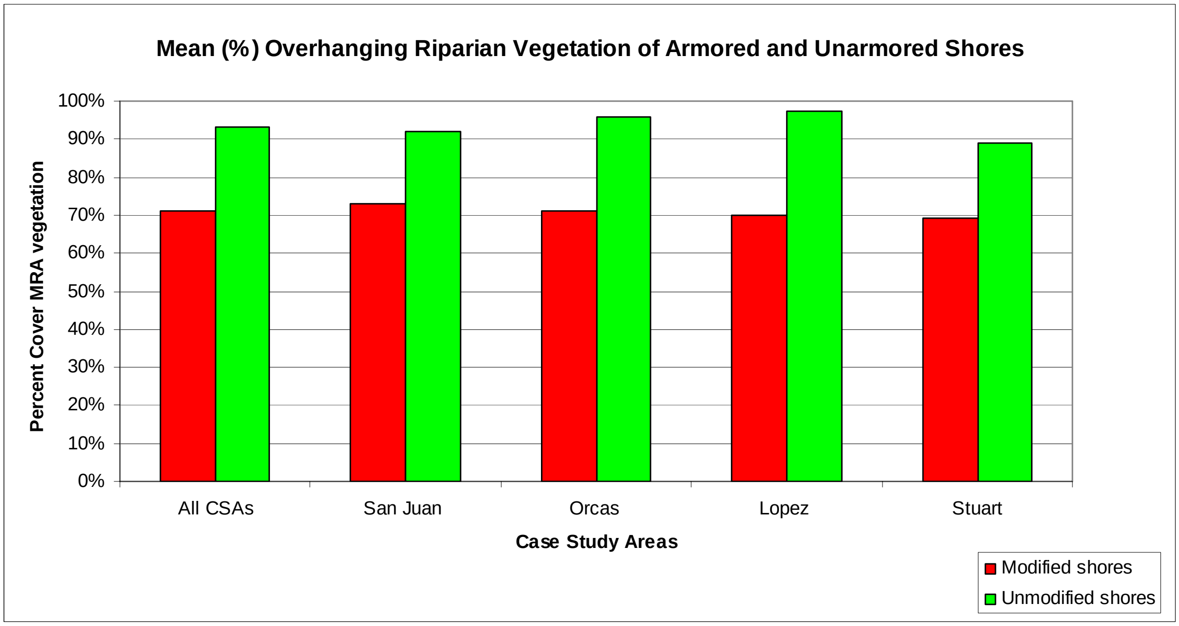

Figure 7. Mean percent overhanging marine riparian vegetation (all vegetation classes summed) of armored and unarmored shores as observed in 2006.

Table 15. Shore modifications and overhanging marine riparian forest vegetation (2006).

Modified Shores	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	53%	56%	58%	51%	35%
Standard deviation	43%	41%	39%	45%	38%
Unmodified Shores					
Mean	58%	79%	77%	64%	7%
Standard deviation	43%	32%	32%	9%	18%

A similar relationship appeared between the occurrence of shore modifications and the aerial extent of marine riparian forest cover (Table 16, Figure 8). Modified shores had on average 6 – 28% less forested vegetation cover than armored shores. This relationship was most evident within the Stuart and Orcas Island CSAs.

Table 16. Shore modifications and riparian forest cover (2006).

Modified Shores	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Mean	52%	58%	43%	53%	48%
Standard deviation	32%	30%	34%	33%	34%
Unmodified Shores					
Mean	70%	77%	64%	59%	76%
Standard deviation	31%	25%	32%	9%	29%

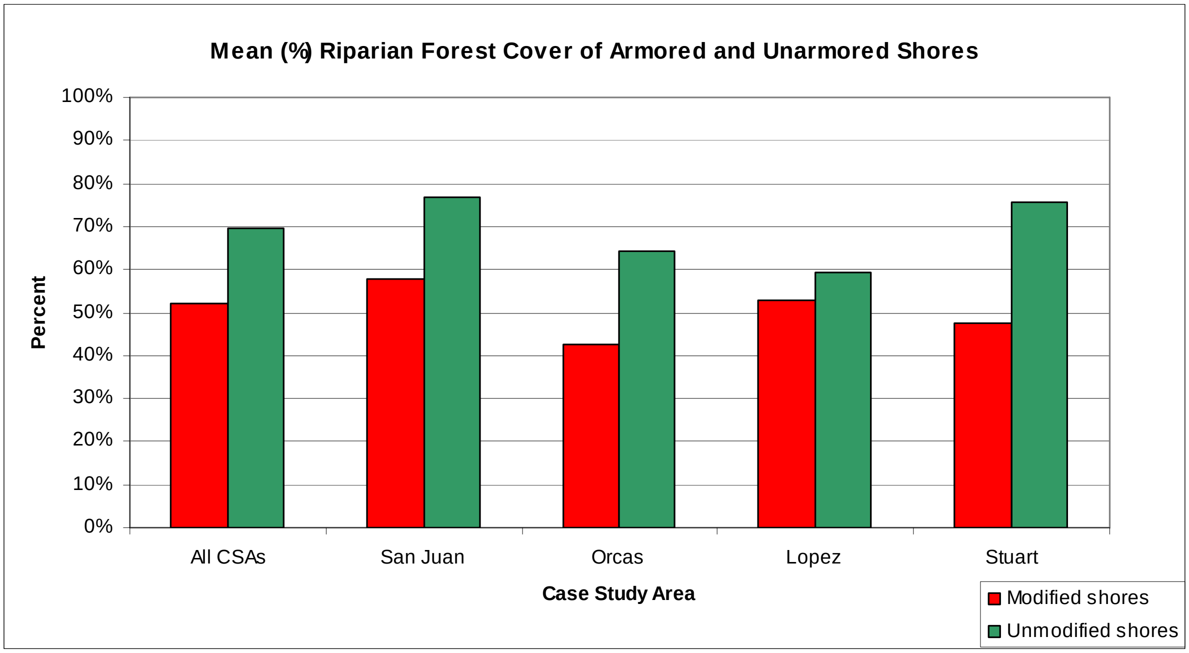

Figure 8. Mean percent marine riparian forest cover of armored and unarmored shores as observed in 2006.

Shore modifications were also associated with a greater average decline in forest cover over the period of analysis (1977 - 2006). This pattern was most evident within the San Juan and Lopez Island CSAs (Table 17, Figure 9). It was far less apparent on Orcas Island where unmodified shores also incurred substantial (average) declines in forest cover. The large range of the data is indicative of the large variability in forest cover change that occurred across all parcels throughout the study area. This variability likely decreased the apparent strength of this relationship, as all change measures were averaged, rather than only those showing a decline in forest cover.

Across the study area, a greater number of parcels with shore modifications experienced a decline in forest coverage as compared to unmodified parcels. A much greater number of unmodified parcels experienced no change in forest cover relative to modified parcels. Across all parcels, forest vegetation loss occurred at 7% more modified parcels than unmodified parcels. Ten percent more unmodified parcels showed no change in forest cover, relative to modified parcels. These results indicate that parcels with shore modification were more likely to incur changes in forest cover than those that were unmodified.

Table 17. Shore modifications and forest cover change (1977 - 2006). Negative numbers denote cover decrease and positive numbers increase.

Modified Shores	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Min	-95%	-95%	-46%	-90%	-65%
Max	70%	45%	10%	70%	55%
Mean	-8%	-13%	-4%	-7%	-5%
Standard deviation	22%	27%	11%	21%	29%
Unmodified Shores					
Min	-75%	-75%	-65%	-60%	-65%
Max	80%	65%	30%	80%	55%
Mean	-4%	-4%	-6%	-2%	-3%
Standard deviation	16%	17%	13%	15%	17%

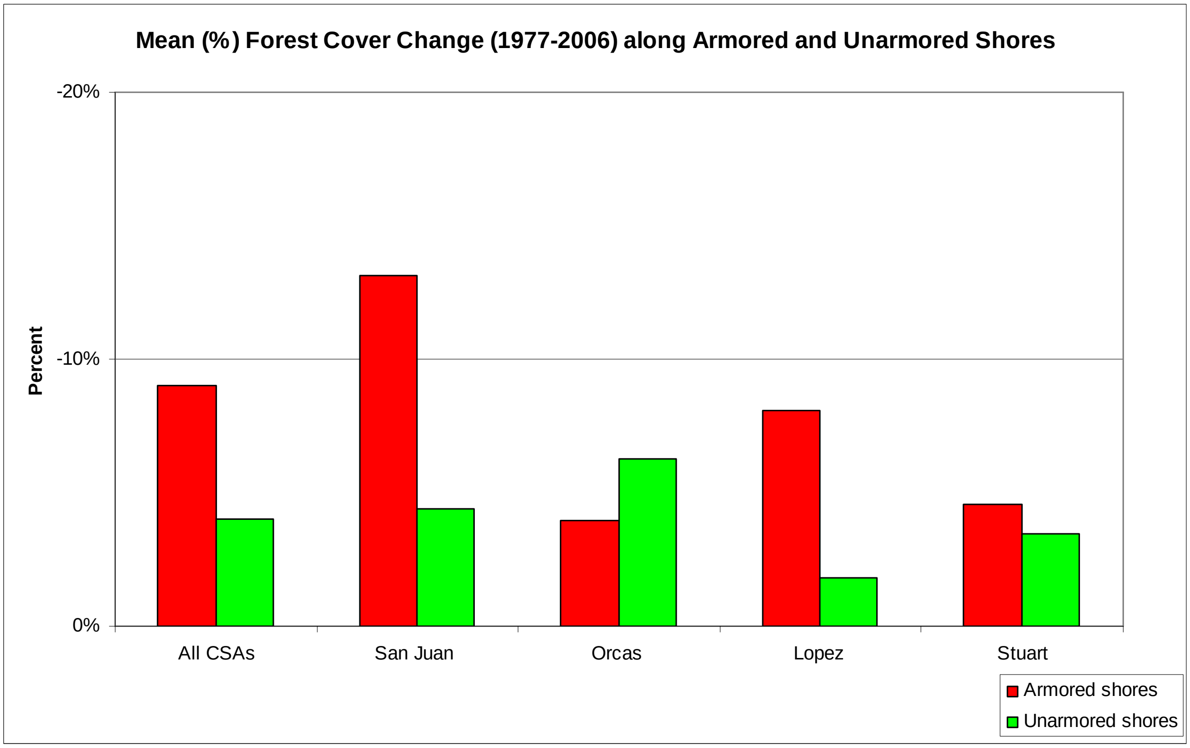

Figure 9. Mean marine riparian forest cover change from 1977 – 2006 along armored and unarmored shores. Negative value indicates decrease in forest cover.

Mooring Buoy & Dock Summaries

A total of 271 mooring buoys were mapped within all of the case study areas. Mooring buoys were most prevalent within the embayed shores and in association with the State and National Park shores of each CSA. They were most abundant on Lopez Island, followed by Stuart and San Juan Islands (Table 18, Maps 7a – 7d). Twenty-nine percent of the buoys were located within 15 ft of (previously mapped) eelgrass beds throughout all CSAs. Mooring buoys within eelgrass beds were most abundant in the San Juan Island case study area, followed by Lopez and Stuart Islands.

Table 18. Mooring buoys observed in the field and those occurring over mapped eelgrass.

Mooring Buoys	All CSAs		San Juan		Orcas		Lopez		Stuart	
Total	271		59		56		87		69	
In eelgrass	79	29%	27	46%	12	21%	20	23%	20	29%

In all case study areas combined, 207 docks were present (Table 19, Maps 7a – 7d). Docks were most abundant within the San Juan Island CSA, where 85 docks were observed, and averaged 5 docks per 0.5 mile (Table 20). Orcas Island followed San Juan Island in dock abundance with 64 docks, and averaged near 4 docks per 0.5 mile. The least number of docks were observed within the Lopez Island CSA, which may have been influenced by the higher wave exposure of the area.

Table 19. Occurrence of docks, piers and floats observed in the field and air photo analysis. Data analyzed includes only docks that were observed in the field.

Docks	**All CSAs**		**San Juan**		**Orcas**		**Lopez**		**Stuart**	
Total Number	207		85		64		16		42	
Number observed in field	160	77%	76	89%	52	81%	9	56%	23	55%
Piers	92	44%	45	53%	28	44%	8	50%	11	26%
Floats	115	56%	40	47%	36	56%	8	50%	31	74%

Table 20. Dock density within each CSA.

Dock Density	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Average Number of docks per 0.5 mile	3	5	3.8	0.94	2.5

The average pier length was greater within the San Juan Island and Orcas Island case study areas, which could be a function of the bathymetry of these areas (Table 21). Bathymetry was not available for these areas, so this potential relationship was not explored quantitatively. The average float area was comparable across all CSAs. Pier heights were predominantly +7.8 - 20 ft MLLW on San Juan and Stuart Islands and +14 - 20 ft MLLW on Lopez and Orcas Islands (Table 22). This may also be related to the topography of the shore; however this relationship was not further explored as part of this study.

Table 21. Average dock dimensions within each CSA.

Dock Dimensions (ft)	**All CSAs**	**San Juan**	**Orcas**	**Lopez**	**Stuart**
Average pier length	92	106	87	62	59
Minimum pier length	8	8	19	10	13
Maximum pier length	282	282	184	269	140
Average float length	59	66	59	42	54
Minimum float length	11	11	16	21	10
Maximum float length	218	178	162	77	218
Average float area (sf)	683	648	733	329	845
Minimum float area (sf)	66	66	296	164	288
Maximum float area (sf)	2,283	2,283	2,079	670	2,040
Average structure length (per parcel)	119	150	126	69	45
Minimum structure length	10	17	16	10	13
Maximum structure length	449	449	310	293	218
Number of structures ~60 feet (+/- 10 ft)	12	6	3	1	2
Number of structures ~120 feet (+/- 10 ft)	14	6	6	0	2

Table 22. Pier heights as measured in the field (+ft MLLW). Highest Mean Higher High Water (MHHW) for the study area is +7.8 ft MLLW.

Pier Height (MLLW)	**All CSAs**		**San Juan**		**Orcas**		**Lopez**		**Stuart**	
0 - < 7.8 ft	1	1%	1	2%	0	0%	0	0%	0	0%
+7.8 -< 14 ft	63	74%	40	98%	12	46%	1	17%	10	83%
+14 - 20 ft	21	25%	0	0%	14	54%	5	83%	2	17%

Very few (2%) of the docks observed in the field had light-penetrating grating, and grating was observed on docks only located within the San Juan Island CSA (Table 23). Creosote piles were observed extensively throughout all case study areas. The greatest number of creosoted piles was documented in the San Juan and Orcas Island CSAs. Herring spawning is known to occur in both of these areas, and creosote is known to be particularly toxic to herring (Vines et al 2000). Seventy-three percent of the docks observed had creosote piles and 7% had cresosote-treated wood used in the pier or float structure itself. In total, 1,024 creosote piles were counted in association with overwater structures within the four CSAs.

In total 26% of the overwater structures observed in this study were documented crossing mapped eelgrass beds (Table 23). Close to half of the overwater structures extended over eelgrass beds on Stuart Island (48%) and roughly one quarter of the overwater structures crossed eelgrass beds within the Orcas and Lopez Island CSAs. Floats orientated east-west were less frequently over eelgrass beds, while those oriented SE-NW were most frequently over eelgrass beds (Table 24).

Table 23. Dock characteristics pertaining to potential impacts. Data analyzed includes only docks that were observed in the field.

Dock Density	All CSAs	San Juan	Orcas	Lopez	Stuart
% with grating (ramps not included)	2%	7%	0%	0%	0%
% with creosote in structure	7%	1%	4%	11%	30%
% with creosote piles	73%	74%	77%	78%	57%
Total Number of creosote piles	1,024	529	291	59	145
Floats over eelgrass beds	26%	13%	22%	25%	48%

Table 24. Number of dock floats at various orientations. Number of dock floats over eelgrass beds reported in parenthesis. Data analyzed includes only docks that were observed in the field.

Float Orientation (number over eelgrass)	All CSAs	San Juan	Orcas	Lopez	Stuart
Floats oriented N – S	14 (2)	4 (0)	9 (2)	0	1 (0)
Floats oriented NE - SW	34 (6)	14 (1)	11 (2)	4 (1)	5 (2)
Floats oriented E - W	11 (0)	8 (0)	2 (0)	1 (0)	0
Floats oriented SE - NW	31 (11)	19 (4)	7 (4)	0	5 (3)

Top Priority Research Questions

Effect of Shoretype

1. Does shoretype influence the presence of absence of shore modifications?

Shoretype appeared to have a considerable influence on the occurrence of modifications (modifications primarily consisted of riprap or concrete bulkheads). Of all the modified shores within each of the case study areas, modifications were most abundant within the feeder bluff geomorphic shoretype, distantly followed by transport zones and then accretion shoreforms (Table 25). This may be due to the tendency of feeder bluffs to be erosional and cause a desire for the landowner to try to halt erosion. The occurrence of shore modifications within different shoretypes was also likely a function of the shoretypes that comprised each CSA, which were of considerable contrast (Table 8, Figure 2). For example, pocket beaches were less prevalent within the Lopez Island case study area, therefore few shore modifications occurred along shores that were historic pocket beaches.

Table 25. Historic shoretypes of all modified shore segments.

Historic Shoretypes	All CSAs	San Juan	Orcas	Lopez	Stuart
Feeder bluffs	37%	11%	48%	50%	0%
Transport zones	19%	14%	25%	16%	17%
Accretion shoreforms	17%	27%	12%	12%	38%
NAD - Bedrock	9%	7%	6%	21%	12%
NAD - Bedrock	5%	2%	4%	0%	0%
Pocket beaches	13%	38%	5%	1%	33%

2. What are the top 3 shoretypes at risk of modification within each CSA?

To determine what shoretypes are most at risk the historic (linear) extent of each shoretype was compared with how much is modified under current conditions. Shoretypes that are modified to the greatest degree (relative to their historic extent) are likely those that are most “at risk”. However, because the shoretypes at risk are a function of the different shoretypes that comprise the CSA or shore reach, the unmodified portions of different shoretypes are at greater risk depending on where they are found within the study area. For example, within the San Juan Island CSA, feeder bluffs (40%) were most frequently modified, relative to their historic extent, followed by accretion shoreforms (24%) and pocket beaches (21%) (Table 26, Figure 10). On Orcas and Stuart Islands the most frequently modified shoretypes were transport zones (74%, 15%; respectively). Orcas Island shoretypes that were modified to a great degree relative to their historic extent included feeder bluffs (59%) and accretion shoreforms (55%). Across all CSAs, Feeder bluffAs a result, it may be more appropriate to determine the shoretypes with the *least* risk of being modified or the least frequently modified shoretypes. These low-risk shoretypes were consistently areas of No Appreciable Drift (due to low wave energy) and bedrock shores (NAD-B).

Mapping the geomorphic shoretypes found within the entire county could prove to be a valuable management tool, since there is a finite length of shoreline that is not yet modified, and those resources demand further protection. Results of this study indicate that feeder bluffs were disproportionately modified relative to other shoretypes, and feeder bluffs were also tied to key biologic and physical functions within the nearshore environment; such as eelgrass beds, forage fish spawn areas, and nearshore sediment supply. If functioning feeder bluffs continue to decline in abundance, which will likely occur without further protection, then nearshore resources will inevitably decline and be less resilient. This would be further exacerbated under changing conditions, such as sea level rise.

Table 26. Percent of shoretype currently modified relative to the historic (linear) extent of shoretype (length of shoretype currently modified/historic extent of shoretype).

CSA	All CSAs	San Juan	Orcas	Lopez	Stuart
Feeder bluff exceptional	0%	0%	0%	0%	0%
Feeder bluff	34%	40%	59%	28%	0%
Transport zone	20%	7%	74%	24%	15%
Accretion shoreform	18%	24%	55%	12%	15%
NAD - Bedrock	2%	11%	2%	10%	1%
NAD	4%	1%	13%	0%	0%
Pocket Beach	14%	21%	9%	7%	11%

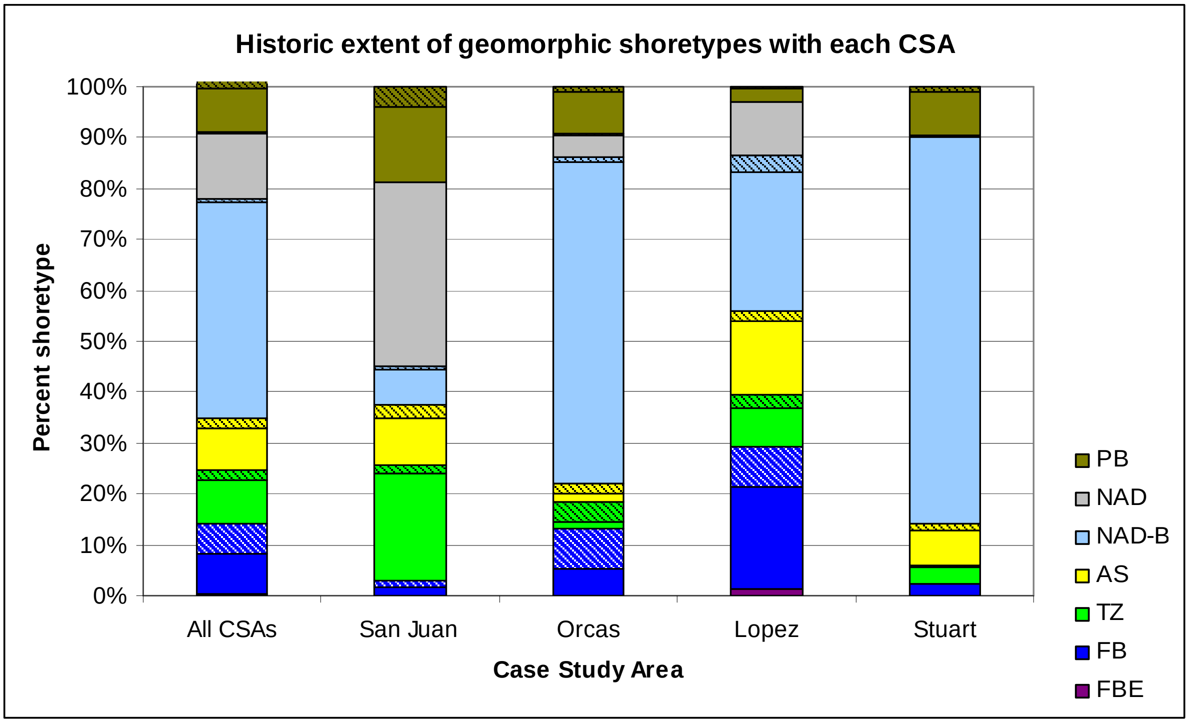

Figure 10. Historic extent of shoretypes within all CSAs. Cross-hatching denotes shores that are currently modified.

3. Does shoretype influence presence or absence of docks? What shoretype is most likely to have docks?

Shoretype did not strongly influence the occurrence of docks. Docks were slightly more abundant along bedrock shores and transport zones, where bank erosion is unlikely to occur, but docks appeared to be distributed similarly to the general occurrence of geomorphic shoretypes (Table 27).

Table 27. Distribution of (109 totatl) docks among the different shoretypes relative to the distribution of shoretypes across the study area.

Docks and Shoretypes	FBE	FB	TZ	AS	NAD-B	NAD	PB
Distribution of Docks among shoretypes	0 %	6%	17%	13%	53%	5%	6%
Distribution of shoretypes across all CSAs	1%	8%	8%	8%	42%	13%	8%

4. Does shoretype influence setback distance (mean setback distance of dominant shoretypes)?

> *As previously mentioned, setback distance used in this study was inaccurate due to data limitations. As a result, setback measures here overestimate actual setbacks from bank crests, especially at highrelief shores such as feeder bluffs. When LiDAR data is available, this evaluation should be revisited to more rigorously assess the effectiveness of setback distance as a management tool.*

Shoretype appeared to have little influence on the mean house setback distance (as measured in this study). The only shoretype that had contrasting mean setback distances was the feeder bluff shoretype, for which the setback distances were greater, but this appears to be a deceptively large difference due to the methods used to measure setbacks. Setbacks were measured from the Shorezone shoreline to the nearest structure, so these distances included the distance from the shoreline to the top of the bank. Therefore a considerable portion of the measured setback distance was essentially a function of bluff height and slope. Setback distances on feeder bluffs also exhibited a considerable range, which skewed the averages. As a result the median setback distances were calculated, and both summary tables are found below (Tables 28 and 29).

Table 28. Average setback distances along different shoretypes (ft).

CSA	FB	TZ	AS	NAD-B	NAD	PB
All CSAs	181	103	103	96	102	100
San Juan	201	81	67	86	112	86
Orcas	49	n/a	70	82	69	89
Lopez	189	133	139	144	n/a	96
Stuart	77	71	82	69	n/a	89

Table 29. Median setback distances along different shoretypes (ft).

CSA	FB	TZ	AS	NAD-B	NAD	PB
All CSAs	98	75	89	78	90	93
San Juan	77	68	79	75	86	93
Orcas	49	n/a	70	78	93	98
Lopez	98	89	95	94	n/a	64
Stuart	77	68	96	65	n/a	314

Effect of Development

5. Does development (the presence of building) influence the presence or absence of shore modifications on the shoretypes most at risk?

Parcels of a predominant shoretype at risk of being modified (*not* NAD or NAD-B) were examined to determine the influence of development on the occurrence of shore modifications. Parcels were defined as developed based on the presence of a building; typically a home. The presence of a structure on a parcel appeared to influence the likelihood that a parcel was modified. Data showed that 53% of the developed parcels assessed had some kind of shoreline modification, while 39% of undeveloped parcels were modified (Table 30). The greatest ratio of developed and undeveloped parcels with modifications was observed in the Orcas Island. Stuart Island had the least number of developed and undeveloped parcels with shore modifications, and the least number of developed parcels in general. On all islands, a considerably higher percentage of developed parcels were modified than were undeveloped parcels.

Table 30. Development and shore modifications on shoretypes at risk to modification (all shoretypes excluding NAD and NAD-B). Data displayed includes % developed of all parcels examined, % developed with shore modifications of all developed parcels, and % undeveloped with modifications of all undeveloped parcels.

	Total No. parcels	% Developed	% Developed with mods	% Undeveloped with mods
All CSAs	330	63%	53%	39%
San Juan	112	65%	52%	33%
Orcas	36	44%	88%	65%
Lopez	141	72%	51%	44%
Stuart	41	41%	35%	17%

Because a large ratio of undeveloped parcels had some kind of shore modification, additional inquiry into the types of modifications observed on these parcels was conducted. Results of this inquiry showed that a considerable number (17%) of the undeveloped parcels (parcels without buildings) with shore modifications also had docks and may represent community-owned or recreational properties. Fifteen percent of the undeveloped parcels with shore modifications were related to shore protection for a road. These coastal road parcels were exclusively located within the Orcas Island CSA, which contributes to the disproportionately high percentage of modified shores in that CSA (both developed and undeveloped). Shore modifications were predominantly comprised of rock (72%), though a single boat house, boat ramp, concrete bridge and several (5) fill areas contributed to the number of modified, undeveloped parcels.

6.-7. Does development (presence of building) influence overhanging vegetation? & marine riparian vegetation cover?

Development (or the presence of a house or cabin) appears to have only a minor influence on the abundance of overhanging marine riparian vegetation. Overhanging -vegetation was slightly more prevalent along undeveloped shores across the study area (averaging 7% more overhanging vegetation across the study area, Table 31). This trend was most evident along the San Juan and Lopez Island CSAs where 13% and 9%, respectively, more overhanging riparian vegetation was observed along undeveloped parcels when compared to developed parcels. Development appeared to have no influence on the occurrence of overhanging vegetation along the shores of the other CSAs.

Table 31. Mean overhanging marine riparian vegetation cover and mean marine riparian vegetation cover along developed and undeveloped parcels.

CSA	Mean Overhanging Vegetation		Mean MRA Cover	
	Developed	Undeveloped	Developed	Undeveloped
All CSAs	83%	90%	75%	91%
San Juan	81%	94%	77%	96%
Orcas	87%	87%	59%	82%
Lopez	82%	91%	78%	86%
Stuart	86%	87%	93%	97%

Marine riparian vegetation cover was compared amongst developed and undeveloped parcels, resulting in a more apparent pattern. Undeveloped shores in all study areas on average had 91% marine riparian vegetation cover within the 200 ft buffer from the shore, compared to just 75% of developed shores (Table 31). Contrary to overhanging riparian vegetation cover data, this pattern was most apparent at Orcas Island, where undeveloped parcels had 23% more marine riparian vegetation than developed shores. This suggests that upland vegetation clearing is being conducted farther inland, though still within the important marine riparian ecotone. The pattern was also prevalent throughout the San Juan Island CSA, where developed shores averaged 77% marine riparian vegetation cover, while undeveloped shores averaged 96% MRA cover. Both patterns were weaker throughout the Lopez Island CSA and barely visible on Stuart Island. Therefore a measureable difference appears to be present in both overhanging and MRA vegetation cover due to site development.

8. Does development (the presence of building) influence forest change?

Development, or the presence of what appeared to be a house or building of size in air photos, was examined and appears to have an effect on the degree of forest cover change. Marine riparian forest cover was assessed using vertical aerial photography from both 1977 and 2006. The presence of structures were noted within each parcel and analyzed with these data. Parcels that were undeveloped in 1977 and remained undeveloped in 2006 showed the least (average) forest cover change and the least cumulative loss of forest cover (Table 32). On Lopez Island forest cover showed a slight average increase in coverage (1%), but still experienced a net loss of forested area.

A more moderate decline in forest cover was observed within parcels that had a structure in both 1977 and 2006. On average these parcels showed a 4% decline in forest cover, which cumulatively equated to a (net) loss of 5.2 acres (226,004 sq ft) of forest cover (Table 32). The greatest decline in forest cover amongst these developed parcels was observed on Lopez closely followed by San Juan Island. The continued loss of forest cover amongst developed parcels indicates that more could be done to educate property owners on the importance of shoreline vegetation retention, and consistent implementation and enforcement of the current vegetation retention policies.

Table 32. Percent and square ft of forest cover change among undeveloped parcels, parcels developed during the period of assessment and parcels developed prior to the period of assessment. No Strctr 06 = undeveloped parcels, No Strctr 77= developed some time between 1977 and 2006, Strctr 77/06 = parcel was originally developed some time prior to 1977.

CSA	Forest Cover Change (1977-2006)					
	No Strctr 06 (%)	No Strctr 06 (net chg ft^2)	No Strctr 77 (%)	No Strctr 77 (net chg ft^2)	Strctr 77/06 (%)	Strctr 77/06 (net chg ft^2)
All CSAs	-2	-169,178	-12	-765,676	-4	-226,004
San Juan	-4	-40,105	-15	-288,062	-5	-64,583
Orcas	-3	-86,429	-14	-284,984	-3	-75,201
Lopez	1	-48,053	-10	-143,751	-4	-75,941
Stuart	-2	5,408	-8	-48,879	-3	-10,278

The most dramatic decrease in forest cover was observed along parcels that were developed during the assessment period, meaning that there was no structure present in 1977, but there was one in 2006. The average forest cover decreased in all 4 CSAs, ranging from 8 - 15% and averaging 12% across all CSAs (Table 32). This represented a cumulative loss of over 17.5 acres (765,676 sq ft) of forest cover. The greatest average percent and cumulative (net) measured loss of forest cover was observed in the San Juan Island CSA. Most parcels that were developed between 1977 and 2006 also experienced a decline in forest cover (58%: 92 of 160 parcels total developed) (Table 33). Forest cover decline (decline only; excluding parcels with no change or forest cover gains) ranged from 1 to 95%, and averaged 25%. Declines were observed within 32% of all parcels within the study area. Forest cover increased within 9% of parcels developed during the period of assessment. The average forest cover gain (gain only; excluding parcels with no change or forest cover loss) was 22%. Forests were likely harvested within these parcels prior to the period of analysis and their subsequent development, and re-growth occurred. No change in forest cover was observed within 33% of the parcels. These results suggest that management tools intended to prevent forest vegetation loss during development are less than fully effective, or perhaps effective 33 to 42% of the time, as a considerable decline in riparian forest cover is associated with the development of waterfront parcels.

Table 33. Range of forest cover change among parcels developed between 1977 – 2006.

Forest Cover Change	Min	Max	Mean	No. of Parcels	% Parcels w/ decline	% Parcels w/ no change	% Parcels w/ increase
All CSAs	-95	70	-12	160	58%	33%	9%
San Juan	-95	40	-15	53	66%	25%	9%
Orcas	-40	10	-14	22	68%	27%	5%
Lopez	-60	70	-10	60	43%	47%	10%
Stuart	-65	40	-8	25	64%	24%	12%

Effect of Parcel Shoreline Length

9. Does parcel shoreline length influence the presence or absence of shore modifications among developed parcels with a dominant shoretype "at risk" to modification?

The relationships between the presence of modifications and parcel width was explored by initially truncating the data to exclude all undeveloped parcels and parcels that had a dominant shoretype that was unlikely to be modified (NAD and NAD-B shores). A consistent trend was evident in that parcels with longer shoreline lengths (parcel width) appeared more likely to have some kind of modification present within them (Table 34). Additionally the average length of the shore modifications observed with each increasing parcel width category consistently increased. Parcels widths greater than 200 ft had an average shore modification length of 89 ft, parcels 100-200 ft in width had shore modifications that averaged 54 ft in length and parcel widths less than 100 ft had shore modifications that averaged 38 ft. Shore modification in the larger parcel width categories were predominantly comprised of rock armoring, while shore modifications along parcel widths measuring less than 100 ft were comprised of greater variety materials including rock, wood and concrete. The influence of shoreline length to shore modification is likely influenced by the increasing likelihood that a perceived erosion problem will be observed along a greater shore reach, or one that might be combined of a variety of shoretypes. It is also possible that larger parcels were platted long before narrower parcels, and narrower parcels were created by more recent subdivision. Also, older, larger parcels may have modified their shores when permits were more easily obtainable. While later developed, smaller parcels may have been subjected to more rigorous evaluations and permitting process.

It would be interesting to compare these results to the Central Puget Sound, which is both a more urban environment and is comprised of considerably less bedrock shore. The combination of smaller or narrower parcels, and the greater demand for buildable land may contrast these results from San Juan County.

Table 34. Shore modification along parcels with shoreline lengths less than 100 ft, 100-200 ft and 200 ft or greater.

CSA	Total		< 100 ft		100-200 ft		> 200 ft	
	No. Parcels	% Mod	No. Parcels	% Mod	No. Parcels	% Mod	No. Parcels	% Mod
All CSAs	209	52%	51	47%	108	51%	50	60%
San Juan	73	52%	18	67%	38	47%	17	47%
Orcas	16	88%	3	33%	4	100%	9	100%
Lopez	103	50%	30	37%	55	55%	18	56%
Stuart	17	35%	0	0%	11	27%	6	50%

10-11. Does parcel shoreline length (on developed parcels) influence marine riparian vegetation?

Parcel shoreline length appears to have little influence on riparian vegetation cover across all types. A weak relationship may exist between shoreline length and the percent of a parcel with overhanging marine riparian vegetation, as average MRA cover appears to increase with increasing parcel shoreline length (Table 35) when all case study areas are combined. However this relationship was not apparent in the Orcas Island CSA, where the average percent of overhanging riparian vegetation was greater along parcels with shoreline lengths of 100-200 ft, than those greater than 200 ft. A minor overall increase in overhanging vegetation was observed between parcels with shoreline lengths less than and greater than 100 ft. However the relationship was not of considerable strength so clear conclusions could not be made regarding these variables.

Table 35. Average % overhanging riparian vegetation (OH Veg), marine riparian area vegetation cover (MRA Cover) and change in forest cover within the marine riparian buffer area (Forest Change) along parcels with shoreline lengths less than 100 ft, 100 - 200 ft, and 200 ft or greater.

CSA	< 100 ft			100-200 ft			> 200 ft		
	OH Veg	MRA Cover	Forest Change	OH Veg	MRA Cover	Forest Change	OH Veg	MRA Cover	Forest Change
All CSAs	78%	69%	-9%	82%	75%	-7%	83%	75%	-7%
San Juan	76%	73%	-20%	77%	72%	-4%	90%	84%	-9%
Orcas	78%	48%	-9%	96%	44%	1%	85%	66%	-9%
Lopez	80%	69%	-1%	81%	80%	-10%	88%	83%	-2%
Stuart	85%	100%	-15%	83%	92%	-7%	91%	93%	-4%

Effect of Setback Distance

> *As previously mentioned, setback distance used in this study was inaccurate due to data limitations. As a result, setback measures here overestimate actual setbacks from bank crests, especially at highrelief shores such as feeder bluffs. When LiDAR data is available, this evaluation should be revisited to more rigorously assess the effectiveness of setback distance as a management tool.*

12. Does the setback distance (on developed parcels only) influence the presence or absence of shore modifications within the parcels that are most “at risk” to shore modification?

Results show a clear relationship between setback distances and developed parcels with shore modifications. This relationship was explored along developed parcels that had a dominant geomorphic shoretype likely to be modified (all shoretypes excluding NAD and NAD-B shores) and 3 setback distances classes (as measured from the Shorezone shoreline to the nearest structure). The setback distance classes were: less than 50 ft, 50-100 ft and 100 ft or greater. The percent of parcels with shore modifications decreased with increasing setback distance in 3 of the 4 case study areas. Overall, 67% of the minimal setback properties were modified verses only 40% of the maximum setback properties, with an intermediate percentage in the middle class (Table 36). The only CSA that was an exception was Orcas Island, where the lowest percent of modifications occurred in the middle setback class and all parcels in the greatest setback class were modified. For the Orcas CSA, this was likely the result of the unusually small sample size queried for analysis (only 16 parcels). The small sample size likely reflects the abundance of bedrock shores within the Orcas study area that were excluded from this analysis.

The general inverse relationship between setback distance and the occurrence of shore modification is likely a function of the “perceived risk” felt by landowners, and supports the theory that greater setback distances decrease at least the perceived need for, and the occurrence of shore armoring.

Table 36. Parcels with shore modification and setbacks distances less than 50 ft, 50 – 100 ft, and 100 ft or more.

CSA	< 50 ft Setback		50-100 ft Setback		> 100 ft Setback	
	No Parcels	% Mod	No Parcels	% Mod	No Parcels	% Mod
All CSAs	46	67%	91	54%	72	40%
San Juan	22	64%	30	53%	21	38%
Orcas	7	86%	5	80%	4	100%
Lopez	14	64%	49	55%	40	38%
Stuart	3	67%	7	29%	7	29%

13-14. Does setback distance (on developed parcels only) influence the percent of overhanging vegetation? Marine riparian vegetation cover? Or mean forest change?

Setback distance appeared to have a minor influence on the percent of overhanging vegetation, as parcels with lower setback distances had lower percentages of overhanging riparian vegetation than those with greater setback distances, with a 9% change across the 3 classes of setback (Table 37). This relationship was most apparent along the shores of Lopez Island and non-existent along Stuart Island, where the relationship appeared to be inverted. Stuart Island riparian data was likely more variable due to the prevalence of bedrock outcrops. A similar minor influence appeared between setback distance and the average marine riparian vegetation area (MRA) cover when looking at all of the case study area data; however the relationship was inconsistent among the individual CSAs. There were no apparent trends in the average percent of forest change along parcels of differing setback distances.

Table 37. Average % overhanging riparian vegetation (OH Veg), marine riparian area vegetation cover (MRA Cover) and change in forest cover within the marine riparian buffer area (Forest Change) along parcels setback distances less than 50 ft, 50 – 100, and 100 ft or greater.

CSA	< 50 ft Setback			50 - 100 ft Setback			> 100 ft Setback		
	OH Veg	MRA Cover	Forest Change	OH Veg	MRA Cover	Forest Change	OH Veg	MRA Cover	Forest Change
All CSAs	80%	72%	-6%	81%	74%	-8%	89%	79%	-7%
San Juan	77%	74%	-9%	77%	73%	-9%	90%	83%	-10%
Orcas	81%	56%	-3%	95%	66%	-9%	86%	53%	-8%
Lopez	73%	74%	-12%	76%	73%	-6%	93%	84%	-4%
Stuart	93%	95%	3%	90%	95%	-10%	75%	88%	-10%

Effect of Structures on Feeder Bluffs

15. What % of developed parcels with feeder bluffs do not have shore modifications?

Throughout the 4 case study areas, developed parcels with feeder bluffs accounted for approximately 16% of all parcels. The greatest number of developed parcels with feeder bluffs was found within the Lopez Island CSA (43 parcels or 30% of the parcels with the CSA). San Juan and Stuart Island had the least number of parcels with feeder bluffs, though on San Juan parcels with feeder bluffs accounted for a smaller ratio of case study area parcels (Table 38). Of all the developed parcels with feeder bluffs 44% had no shore modifications. The greatest number of parcels with feeder bluffs that remain unmodified were observed within the Lopez Island CSA, but all case study areas contained at least 33% of these unarmored parcels. These parcels are likely “at risk” of being modified in the future. When feeder bluffs are modified, sediment that would normally feed into the nearshore system is impounded bulkheads, resulting in negative physical and biological impacts to the down-drift portion of the respective drift cells. The largest ratio of developed parcels with feeder bluffs that are not currently modified were located within the Stuart Island CSA.

Table 38. Developed parcels with feeder bluffs and developed parcels with both feeder bluffs and shore modifications.

CSA	Developed Parcels			
	Parcels w/ FBs		Parcels w/ FB, and no mods	
All CSAs	63	16%	28	44%
San Juan	6	5%	2	33%
Orcas	8	11%	3	38%
Lopez	43	30%	19	44%
Stuart	6	14%	4	67%

16. What % of undeveloped parcels with feeder bluffs do not have shore modifications?

There are a total of 33 undeveloped parcels with feeder bluffs throughout all CSAs. These parcels are predominantly located within the Lopez Island CSA (Table 39). Twenty-three of these undeveloped parcels with feeder bluffs remain free of shore modifications and therefore represent conservation opportunities. Conserving these feeder bluffs would help to maintain ongoing sediment input to drift cells, to replace beach sediment that is continually transported alongshore by waves. Approximately half of the conservable parcels were on Lopez Island, closely followed by the Orcas and Stuart Island case study areas.

Table 39. Undeveloped parcels with feeder bluffs and developed parcels with both feeder bluffs and shore modifications.

CSA	Undeveloped Parcels			
	Parcels w/ FBs		Parcels w/ FB, and no mods	
All CSAs	33	13%	23	70%
San Juan	0	0%	0	0%
Orcas	8	17%	7	88%
Lopez	20	34%	12	60%
Stuart	5	7%	4	80%

Shore Modifications Built Prior to the SMP

A preliminary examination of shore modifications visible in the 1977 air photos was conducted within Mitchell Bay in the San Juan Island CSA. The objective of the inquiry was to determine how many of the shore modification that were present in current conditions mapping were also present in 1977 (the approximate time of the county Shoreline Master Program; SMP) and if they were present, if and how they changed over time. The examination was limited to Mitchell Bay due to time and budget restrictions as well as the need for additional air photos to provide an optimal level of certaintly. Of the 12 shore modifications assessed, at least 5 appeared to be present in 1977, and at least 3 (of the 5) appeared considerably altered since 1977. Each of the 3 altered modifications appeared to cause greater adverse impacts to nearshore resources (e.g. addition of fill material or waterward expansion into intertidal areas).

Throughout the field surveys numerous similar structures were observed that likely pre-dated shoreline management and appeared to have lasting adverse impacts on nearshore ecologic and geomorphic processes. In most cases these modifications appeared to have greater (adverse) impacts than recent structures. Whether it be resulting from precluded alongshore transport of sediment to down-drift shores, eliminated valuable (and finite) spawning areas, or 30+ years of heavy creosote piles in spawning and migratory habitats, the cumulative effect of these persistent impacts should not be underestimated and efforts should be put forth to ameliorate conditions of pre-SMP structures.

Conclusions and Recommendations

Summary of Strongest Correlations

Feeder bluffs were identified as the most vulnerable shoreforms to future modification. In addition to supplying the sediment that comprises roughly 90% of sediment input for Puget Sound regional beaches (Keuler 1988), feeder bluffs provide many other physical and ecologic functions in the nearshore (Johannessen and MacLennan 2007), and are directly correlated with potential forage fish spawning habitat and eelgrass beds. A perceived indirect association between feeder bluffs and herring spawning areas was also made (pers comm. K. Fresh 2008). Feeder bluffs were shown to be disproportionately modified and most of these modifications (predominantly shore armoring) infringed on the associated forage fish spawning habitats. This suggests that there is an actual or perceived risk that property owners are responding to given the erosive nature of these shore types. Despite the predominant occurrence of armoring along feeder bluffs, shore modifications were observed along many of the other geomorphic shoretypes, excluding NAD (no appreciable drift) and NAD-B (bedrock) shores. Many of these other shoretypes (transport zones, accretion shoreforms and pocket beaches) are also associated with habitats that are in finite supply in San Juan County due to the abundance of bedrock shores. These less common shoretypes may represent local habitat hotspots, in many cases providing the only forage fish spawning substrate for a mile or more of shoreline. Modifications were not directly proportional to the quantity of each shoreform found along the case study area shorelines.

Results documented an inverse correlation between setback distance and the occurrence of shore modifications, which supports the largely intuitive concept that greater setback distances decrease the perceived need for shore armoring. Because the data on setbacks was less than adequate this trend should be reassessed when higher quality setback data becomes available. From a systemic point of view, it should be a conservation priority to prevent further modification of feeder bluffs, which were shown to be the shoretype both at the greatest risk of modification and also associated with priority habitats. Additionally, if feeder bluffs remain unbulkheaded, it is likely that less erosion will occur at down-drift shoretypes, such as at transport zones and accretion shoreforms, which typically occur in the central and terminal ends of drift cells. This cascading benefit is both self-sustaining and offers heightened resilience of the nearshore under changing conditions, such as those anticipated with rising sea levels.

Forest cover decline was observed (from 1977 – 2006) within the waterward portions of roughly one-third of all parcels throughout the study area. The majority of parcels (56%) showed no change in forest cover and a small percent of parcels had an increase in cover (11%). Parcels with shore modifications showed considerably greater declines than unmodified parcels. Decreased riparian vegetation cover (aerial extent and overhanging) was also associated with shore modifications. Development of parcels influenced the occurrence of shore modifications and riparian forest cover decline. The amount of forest cover change on individual parcels was highly variable, which is likely due to a combination of natural and anthropogenic processes (forest clearing, erosion and re-growth) as well as inconsistent application of management guidelines. This suggests there is wide variability in how management guidelines are being applied with regard to retention of marine riparian forest cover. Management programs for marine riparian areas should be evaluated and additional incentive programs to enhance existing marine riparian vegetation should be implemented to help reverse the trends documented in this study.

Mooring buoys were most prevalent within the embayed shores and in association with the state and national parks. Just under one-third of the mooring buoys observed in the field were located over mapped eelgrass beds. These results suggest that more can be done to reduce impacts and protect the eelgrass beds, particularly in areas experiencing local declines in eelgrass meadows, such as northwest San Juan Island. One suggested approach would be to inventory all mooring buoys in SJC, determine eelgrass presence in association with each buoy, and then require those buoys over eelgrass beds to have mid-water floats.

Geomorphic shoretype did not strongly influence the occurrence of the 207 docks mapped in this study, although docks were slightly more abundant along bedrock shores and transport zones. The density of docks was greatest within the San Juan and Orcas Island CSAs. Only (2%) of the docks observed in the field had light-penetrating grating. Approximately three-quarters of the docks observed in the field had some kind of creosoted wood associated with the structure and in total 1,024 creosote piles were inventoried in docks in the study area. The greatest number of creosoted piles was documented in the San Juan and Orcas Island CSAs. Incentive programs should be considered to replace these toxic piles as herring, which are known to be vulnerable to these specific contaminants (Vines et al. 2000), spawn in both of these areas. Stuart and Lopez Islands had the greatest ratio of docks with floats over eelgrass beds. Incentive programs could be put in place to reduce impacts of existing docks over eelgrass beds to reduce existing impacts to eelgrass, along with more rigorous enforcement of existing management programs.

Recommendations for Additional Research

Additional research could be conducted using the data collected and assembled for this study. This includes data analyses and research into potential additional relationships between the variables assessed as well as their spatial patterns. Some of the potential additional research areas are:

- Where do pocket beaches occur and what priority habitats are most commonly associated with this unique shoretype?
- Revisit setback inquiries using setback distance measured from the bank crest, rather than the Shorezone shoreline
- How does shoretype influence the occurrence of marine riparian vegetation?
- Does development influence the presence or absence of nearshore habitats?
- Does setback distance influence the presence or absence of nearshore habitats?
- Does the occurrence of shore modifications on adjacent parcels influence the likelihood that a parcel is modified?
- What is the relationship between setback distances and parcel slope?

It would also be beneficial to supplement some of these data so that the datasets are county-wide, especially to increase management efficacy. The following specific research inquiries were identified during this study that could not be adequately addressed due to time and data limitations:

- What is the long-term impact of pre-SMP shore modifications? And how can we reduce those impacts?
- Does the level of wave energy/exposure influence the occurrence of shore modifications?
- What is the extent and relative significance of feeder bluffs county-wide?
- What is the habitat value of pocket beaches among shore reaches that are predominantly bedrock shores?
- Evaluate the impacts of sea level rise and climate change to the San Juan County nearshore and develop appropriate management responses.

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Appendix 1

San Juan Initiative Case Study Characterization
Descriptive summaries of selected case study areas

February 22, 2008

**Note to reader: some information contained in this summary document has been up-dated since this document was originally produced. The most current summary data is found within the report text, NOT this preliminary document.

San Juan Initiative Nearshore Case Study Area Characterization
Descriptive summaries of selected case study areas

Prepared for: Amy Windrope, Puget Sound Partnership

Prepared by: Andrea MacLennan, MS and
Jim Johannessen, Licensed Engineering Geologist, MS

February 22, 2008

Background and Objective

The San Juan Initiative is a unique partnership of the San Juan County Council, Puget Sound Partnership, community leaders, state and local agencies, and the Surfrider Foundation. The Initiative is an unprecedented effort to ensure that all existing conservation efforts, both public and private, are working together to protect the rich, diverse ecosystem of the San Juans. The San Juan Initiative Case Study Characterization is the part of an assessment of protection effectiveness that also includes a permit review and protection program analysis. The Case Study Characterization will document the extent of shoreline modifications at four case study locations in San Juan County. Upon completion of the Case Study Characterization, contractors will help merge the findings with a policy program and permit review to analyze the success of protection programs.

Case Study Areas

Four case study areas were selected for the San Juan Initiative Case Study Characterization. Three of the case study areas are found on the larger islands with ferry service (San Juan, Orcas and Lopez Islands). The fourth case study area is located on Stuart Island, and is intended to represent the "outer islands" (Figure 1). The following descriptions of each case study area were derived from existing data sources, some of which will be updated during the course of this effort. Maps of each case study area are attached as are tables displaying the parcel numbers encompassed within each area.

San Juan Island

The San Juan Island case study area is located along the northwest shore of the Island and encompasses all of Mitchell and Garrison Bays and the southwestern shore of Westcott Bay (Figure 2). The shore is comprised of a mix of shoretypes including bedrock ramps, platforms and plunging cliffs, bluffs composed of glacially derived sediment (feeder bluffs), mixed sand and gravel beaches, salt marshes and various forms of shore modifications (Washington Dept of Natural Resources (WDNR) 2001). Net shore-drift occurs along approximately 30% of the shoreline. The remaining 70% of the shore is mapped as having "No Appreciable Drift" due to low energy conditions, such as those found in the head of Mitchell Bay, *or* a general lack of sediment supply found along bedrock shores (Johannessen 1992).

Shores within the San Juan Island case study area are exposed to varying degrees. The WDNR calculated and qualified the area as: 41% protected, 35% semi-protected, 21% very protected and 3% semi-exposed (2001). The most protected shores are found within the inner embayment shores. More exposed shores include those north and south of the mouth of Garrison Bay.

Numerous valuable habitats are found within the San Juan Island case study area including documented and potential surf smelt and sand lance spawning areas, herring spawning, eelgrass beds and rocky intertidal communities. Documented surf smelt and sand lance spawning occurs along over 26% of the shore within the case study area (Washington Department of Fish and Wildlife (WDFW) 2004). Potential forage fish spawning habitat was mapped along 27% of the shore (Moulton 2000). Eelgrass was mapped by WDNR as "continuous" along 36% of the study area, and as "patchy" along another 19% of the shore. Cumulatively eelgrass was mapped as present along 55% of the San Juan case study area shore (WDNR 2001). WDFW has documented herring spawning along 54% of the study area (2004).

In total, 203 waterfront parcels encompass the San Juan Island case study area shore, representing a range of ownership types including a national park and privately owned shores. One private marina is located along the south shore of Mitchell Bay. Docks are found within at least 41 waterfront parcels (Friends of the San Juans (Friends) 2004). Shore modifications were mapped by WDNR along only 4% of the case study area, and riparian vegetation was mapped along only 14% of the shore (WDNR 2001).

Orcas Island

The Orcas Island case study area is located along the east shore of West Sound, and stretches from the north end of the inlet south and then east for a short distance along the shore of Harney Channel (Figure 3). It measures 8.6 miles and is comprised of a representative mix of the shoretypes found in San Juan County. Shoretypes encompassed within the Orcas Island case study area include bedrock ramps, cliffs and platforms, feeder bluffs, mixed sand and gravel beaches, lagoons, fill areas and various other shore modifications such as bulkheads and riprap (WDNR 2001). All shores located within this case study area were mapped by WDNR as "protected" as they are not exposed to considerable fetch. Five drift cells are included within the area cumulatively representing 33% of the shore. The remaining shore is mapped as having "No Appreciable Drift" largely due to the abundance of bedrock (Johannessen 1992).

Documented forage fish spawning has been mapped along just 3% of the case study shore (WDFW 2004), however potential forage fish spawn beaches represent 23% of the case study area (Moulton 2000). "Continuous" eelgrass was mapped by the WDNR along approximately 15% of the shore. "Patchy" eelgrass beds were documented along 42% of the shore, together representing 57% of the study area (WDNR 2001). WDFW has documented herring spawn along 32% of the shore (2004). Herring holding is known to occur 1.5 miles east of the case study area, at the east end of Harney Channel.

One hundred and twenty-eight waterfront parcels are found within the Orcas Island case study area. The Orcas Island ferry terminal is encompassed within the area, as are two marinas and at least two other community docks (each with 10 or more boats slips). One marina is located within the village of West Sound in the northeast end of the inlet; the second marina is located within a minor embayment east of the ferry terminal. Docks are found within at least 33 parcels in the case study area. Shore modifications were mapped along 14% of the shore, and riparian vegetation along just 10% of the Orcas Island case study area (WDNR 2001).

Lopez Island

Located on the northeast shore of Lopez Island, this case study area encompasses 8.4 miles from Upright Head to approximately 2 miles south of Spenser Spit (Figure 4). Shoretypes found within the area include bedrock cliffs and ramps, feeder bluffs, mixed sand and gravel beaches, lagoonal marshes, fill areas and various other shore modifications. Approximately 64% of the case study area is encompassed within 6 drift cells. The remaining shore is largely bedrock where a lack of beach material results in "No Appreciable Drift" (Johannessen 1992). Exposure along the Lopez Island case study area shores was mapped as a mix of “protected” (60%) and “semi-protected” (40%)(WDNR 2001).

Forage fish spawning has been documented along 11% of the Lopez case study area shore (WDFW 2004), though potential spawning habitat was mapped along 57% of the shore (Moulton 2000). Eelgrass beds were mapped by WDNR as “continuous” along 31%, and “patchy” along 32% of the case study area, cumulatively representing over 63% of the shore (2001). WDFW has documented herring spawn within Shoal Bay only, accounting for approximately 2% of the study area shore (WDFW 2004). Herring holding was also mapped by WDFW in the waters just north of the mouth of Shoal Bay, between Harney Channel and Obstruction Pass (2004).

Two hundred and eight parcels make up the ownership of the shoreline of the Lopez Island case study area, 9 of which are known to have docks. Parcels are in a range of ownership types including a large state park and numerous privately held properties. One private marina exists along the east shore of Shoal Bay and a shellfish farm operates within the Shoal Bay lagoon. The Lopez Island Washington State ferry terminal is also found along the northernmost shore. Shore modifications were mapped along only 8% of the shore. Marine riparian vegetation was mapped along over 17% of the case study area (WDNR 2001).

Stuart Island

Stuart Island, located in the northwest corner of San Juan County at the convergence of Haro Strait and Boundary Pass, was selected to represent the “outer” San Juan Islands with significant private ownership. The case study area includes the eastern portion of the Island, which encompasses the shore from Reid to Prevost Harbors, including John’s Pass (Figure 5). Measuring 8.1 miles, this shore is largely comprised of bedrock, where limited sediment supply precludes net shore-drift along the majority (69%) of the shore. Seven short drift cells have been mapped, together accounting for 31% of the case study area (Johannessen 1992). Shoretypes found within the area include: bedrock cliffs and ramps, feeder bluffs, pocket beaches comprised of a mix sand and gravel, fill areas and other shore modifications (WDNR 2001). The case study area shores were largely classified as “protected” (57%), with the remaining shores classified as “semi-protected” (WDNR 2001).

Forage fish spawning has been documented along only 2% of the Stuart Island study area shore (WDFW 2004). Though potential forage fish spawn habitat was mapped along 16% of the shore (Moulton 2000). Continuous eelgrass was mapped along only 2% of the shore, but patchy eelgrass beds were mapped along over 36% of the case study area (WDNR 2001). No herring holding or spawning have been documented by WDFW along the shores of Stuart Island (2004).

One hundred and twelve parcels encompass the Stuart Island case study area shoreline under a variety of ownership types, including Stuart Island State Park. One community dock is found along the east shore of Prevost Harbor. Docks are associated with 14 parcels within the case study area. Shore modifications were mapped by WDNR along less than one percent of the shore in 2001. Marine riparian vegetation was also infrequently observed, and was mapped along only 5% of the shore (WDNR 2001).

Case Study Area Data Summary

In summary, the San Juan Initiative case study areas range in length from 8.1-8.7 miles and are comprised of a representative mix of the shoretypes found within San Juan County (Table 1). The areas chosen for analysis are predominantly classified as “protected” shores. All case study areas contain both bedrock and sedimentary shores with and without net shore-drift cells. Both potential and documented forage fish spawning are known to occur within each case study area (WDFW 2004, Moulton 2000). Herring spawning has been documented in all study areas excluding Stuart Island.

Eelgrass abundance ranges from 38–63% (WDNR 2001). Marine riparian vegetation is much less frequently observed, ranging from 5-17%. Shore modifications occur along a small percentage of the shore throughout each study area (0.1-14%). However, it is likely that additional modifications have been installed since the time of the WDNR data collection and that some modification were not detected by the holicopter-based ShoreZone mapping method. The San Juan and Lopez Island case study areas have greater parcel density than Orcas or Stuart Islands. The greatest number of docks were mapped within San Juan Island, followed by Orcas and Stuart Islands. Lopez Island had the least number of docks mapped within a case study area (Friends 2004).

Table 1. Summary of case study area characteristics for San Juan Initiative

Shore Characteristics	San Juan Island	Orcas Island	Lopez Island	Stuart Island
Mileage	8.7	8.6	8.4	8.1
Number drift cells	9	5	6	7
Perecent drift/NAD	30%/70%	33%/67%	64%/36%	31%/69%
Predominant exposure	Protected (41%)	Protected (100%)	Protected (60%)	Protected (57%)
Documented forage fish spawn	26%	3%	11%	2%
Potential forage fish spawn	27%	23%	57%	16%
Herring spawn	54%	32%	2%	None
Herring holding	None	None	Yes	None
Eelgrass	55%	57%	63%	38%
Marine riparian	14%	10%	17%	5%
Modified shore	4%	14%	8%	0.1%
Number of parcels	203	128	208	112
Number parcels/mile	23.3	14.8	24.7	13.8
Parcels with docks	41	33	9	14

If you have any questions or comments about the content of this document please do not hesitate to contact us. If these tasks to not meet the desired services, then additional tasks can be added or replaced. Thank you for chosing the services of CGS.

Regards,

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Attached:
Figure 1. San Juan Initiative case study areas
Figure 2. San Juan Island case study area
Figure 3. Orcas Island case study area
Figure 4. Lopez Island case study area
Figuer 5. Stuart Island case study area

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Appendix 2 – Map Appendix

List of Maps

Appendix 3

Multi-variate analyses of shoreline parcel data from the San Juan Islands
by Dr. Megan Dethier, University of Washington

May 20, 2008

Multivariate analyses of shoreline parcel data from the San Juan Islands

Dr. Megan Dethier, University of Washington
5/20/08

Purpose:
To use multivariate analyses on the extensive shoreline data collected by Coastal Geologic Services to seek patterns linking physical and biological characteristics of shoreline parcels with various developed features, such as houses, shoreline armoring, etc.

Methods:
"Parcel characteristics" were extracted from the Coastal Geologic Services' database and transformed into numeric variables usable by Primer 6 (software for multivariate analyses). Characteristics were transformed into either presence/absence (eg presence/absence of a feeder bluff on a given parcel) or into 4 approximately equal (in terms of numbers of parcels) categories – for example, parcel size was categorized as up to 1 acre (category 1), 0.5 to 1.1 acres (2), 1.14 to 5 acres (3) or >5 acres (4).

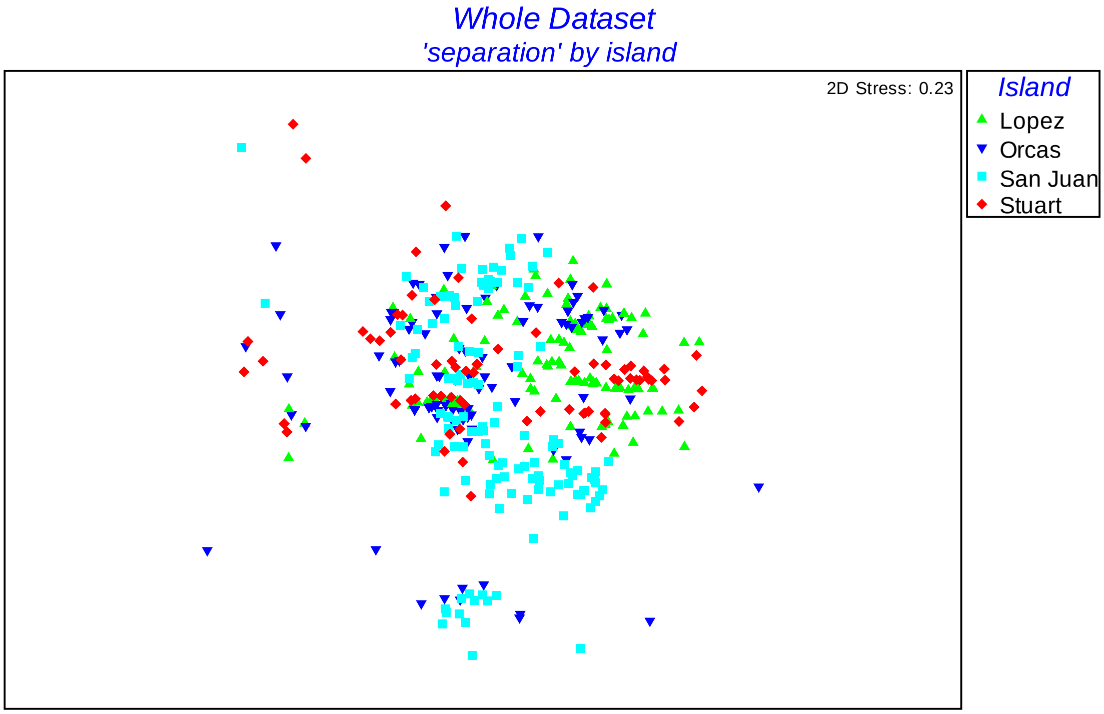
The list of characteristics used (for the 634 parcels for which all data were available) were: acreage (4 categories), shoreline width (4 categories), presence/absence of 6 shoreline types (accretionary, feeder bluffs, pocket beaches, bedrock, transport zones, no drift areas), presence/absence of 4 habitat types (rocky intertidal, *Zostera*, kelp, and potential forage fish habitat), and percent forest cover (4 categories). Within the software program, each parcel was treated as a sample, and each characteristic as a variable (corresponding to 'species' often used in these analyses). To put all the characteristic data on the same scale, the data were 'normalized' (set as relative values to the average of all values per characteristic); in this way, variables that ranged from 0 to 4 (categorical) were not weighted more heavily than variables with values of 0 or 1 (absence/presence). Resemblance matrices were calculated as Euclidian distances.

The five "factors" used for looking for patterns in the similarities of parcels were:
Island, presence/absence of a house, setback of house (<100 ft vs >100 ft), presence/absence of a dock, and presence/absence of shoreline modifications (armoring).

Results:
Some parcel characteristics, not surprisingly, were correlated (even with the data reduced to categories). Positive correlations included: acreage and parcel width, potential forage fish and *Zostera*, potential forage fish and feeder bluffs, and forest cover with Island (more forest on Stuart and Lopez parcels than on San Juan and Orcas parcels). Negative correlations included: rocky intertidal and potential forage fish, rocky intertidal and transport zones, and bedrock and accretionary zones.

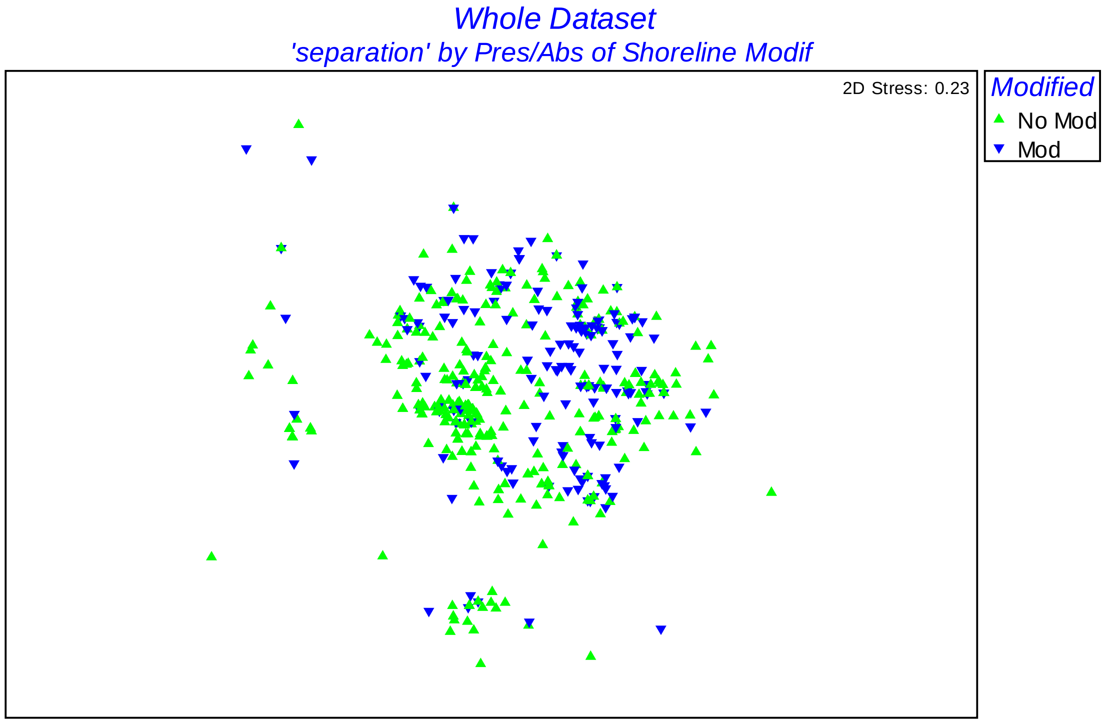
In the output from multidimensional scaling analyses, each parcel becomes represented by a "point" in the figures below; points further apart indicate that parcels were more different from each other in their overall combination of characteristics described above. The distances are relative; if an extremely different parcel was added to the analysis, all the other points would end up clustering more closely together. I sought patterns by examining if certain characteristics (such as width, or shoretype) of parcels made them more likely to (for example) have modifications built on them; if this was the case, then in the figures we should see modified parcels clustering together, and separated from unmodified parcels.

Very few patterns were seen in any of the analyses. The first figure shows that there is little pattern in terms of parcels on the different islands grouping with each other rather than with parcels from the other islands; that is, each island had a mix of parcel characteristics (this indicates good site selection work by CoastalGeo). The only apparent pattern here is that the Lopez parcels were more uniform in their characteristics (i.e. the green points cluster more closely together) than the Orcas or San Juan parcels, which were more diverse (scattered) – this relates to the stretch of shoreline chosen on each island.

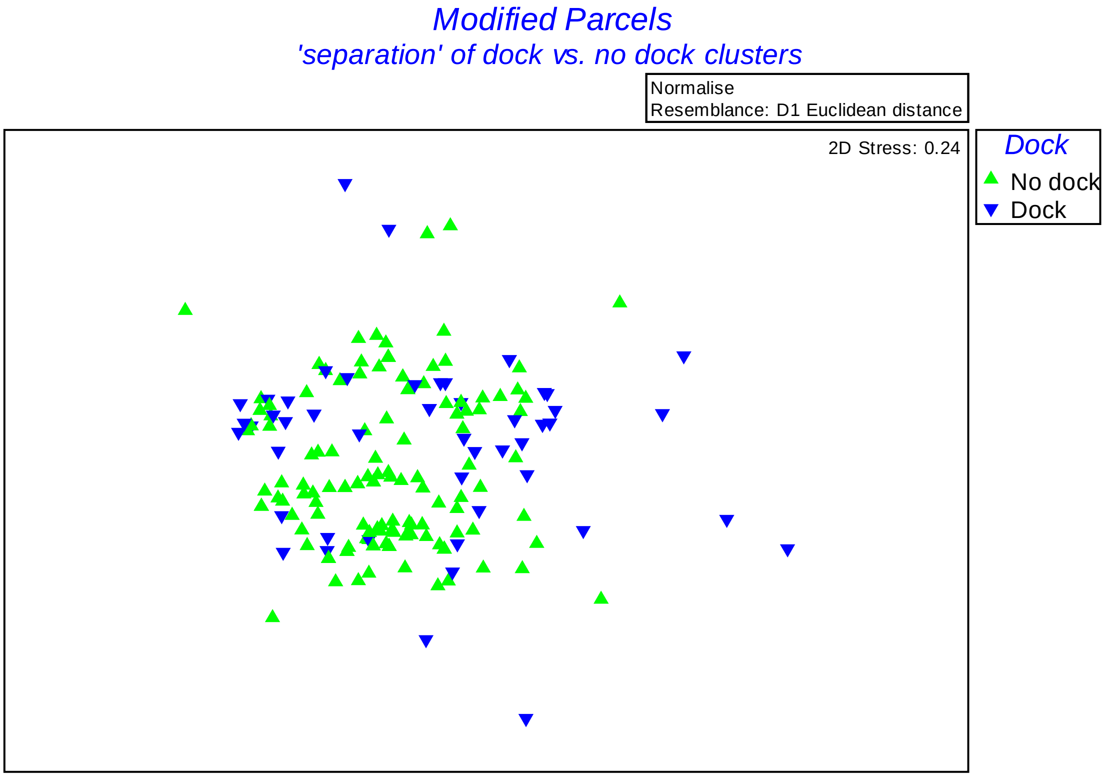


The next figure replots the same data but shows the points/parcels coded (colored) by whether or not they had shoreline modifications. Again, there is very little separation of parcels related to this factor, although the green unmodified parcels tend slightly more towards the lower left and the blue modified parcels towards the upper right. Analysis (with the SIMPER subroutine) of the characteristics that differ among these 'clusters' (i.e. that are 'pulling' the points into different parts of the graph) suggest that unmodified parcels tend to have more bedrock (not surprisingly), be wider, and have more forest cover. Modified parcels tend to be on shores with sediment (accretionary, transport, feeder bluffs, and pocket beaches), and have associated *Zostera* and potential forage fish. This pattern, although weak, confirms what we already know about the logic of building armoring on sediment rather than bedrock.

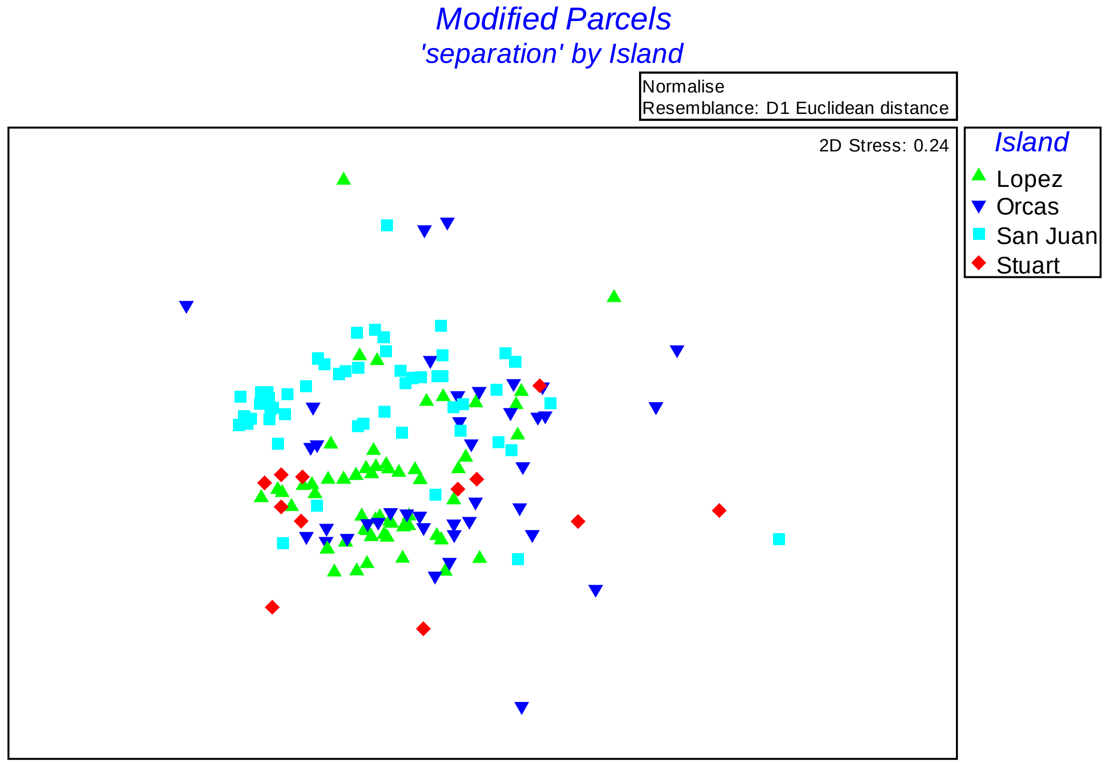
Similar analyses (not shown) looking at presence/absence of a house and degree of setback showed no patterns; i.e. parcels with houses (or large setbacks) have similar characteristics (size, shoretype, biological elements, etc.) to those without.



For the next set of analyses I filtered out all the parcels with modifications and again sought patterns relating to the factors being investigated. One of the few patterns found (still a weak one) was a slight clustering of modified parcels with docks versus without docks (Global R = .244, p = .001). Parcels with shoreline armoring but no dock tend to be associated with feeder bluffs, *Zostera*, and potential forage fish. Parcels with armoring and a dock are on diverse other shore types, including bedrock, accretionary shores, and pocket beaches. Modified parcels that include docks also tend to have more acreage and longer shoreline than those without docks.



When these data are recoded to show the island of each parcel, a weak clustering can again be seen; this grouping is statistically stronger than the grouping by dock presence/absence (R = .337). Modified parcels on Orcas tend to be in areas with pocket beaches or rocky shores, and are on larger and wider lots that those on San Juan. Modified parcels on San Juan tend to be on accretionary beaches or no-net-drift beaches. These weak patterns may simply relate to the exact shorelines used in the analyses, and are probably not subject to detailed interpretation.



In summary, in this dataset (which is very extensive) and this type of analysis, there are no clear patterns of particular types of parcels being more likely to have human modifications than other types. Houses, small setbacks, docks, and armoring appear on parcels of many different physical and biological characteristics, and on all islands. Shoreline armoring shows up most often where it is ‘needed’, i.e. on erosive shorelines, which also are those with certain biological characteristics. Overall, however, parcels get developed largely independently of their physical and biological characteristics.