



Marine Shoreline Management—A 35-Year Evaluation of Outcomes in San Juan County, Washington, US

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ABSTRACT

In 1976, Washington became the first state to implement the federal Coastal Zone Management Act (CZMA) primarily through the 1971 WA Shoreline Management Act (SMA). However, there has been little effort in Washington to evaluate outcomes of shoreline protection programs post SMA. In 2006–2008, we characterized shoreline conditions in San Juan County over three time periods spanning pre and post SMA and engaged community members to improve effectiveness of shoreline protection. We found modest improvements in forest retention on marine shorelines between pre and post 1977, but few other improvements through time. While we could not measure shoreline construction rates, construction practices for shore armor and overwater structures (docks) have changed very little, despite the increased regulatory standards. The vast majority of shore armor constructed post SMA occurred without mandatory county or state permits likely due to: widespread perception that permits were unnecessary and that permit standards were arbitrary and inconsistently applied; poor understanding of shoreline ecology by community members; lack of county or state enforcement authority and shoreline monitoring programs; and poor permit tracking systems.

KEYWORDS

armoring; Coastal Zone Management Act; marine shoreline permit compliance; public policy; Shoreline Management Act

Introduction

The State of Washington passed the Shoreline Management Act (SMA) in 1971 in response to increasing awareness that coastal areas were experiencing dramatic growth pressures that threatened their sustainability. This same realization at the federal level resulted in the federal Coastal Zone Management Act of 1972 (CZMA; Clark 1995). In 1977, Englander, Feldmann and Hershman (1977) organized a list of 15 shoreline management challenges into two categories: resource outcomes, i.e., conditions of coastal natural resources; and organizational issues, i.e., problems that inhibit organizations from achieving policies for protecting shorelines.

Since 1977, most research aimed at evaluating effectiveness of federal coastal programs has focused on organizational issues and policies (Lowry 1980, 1985), with little

work on evaluating the implementation of those policies (Born and Miller 1988; Chasis 1980; Deyle and Smith 1998; Ehler 2003; Godschalk 1992; Hershman et al. 1999; Lowry 1985; Tang 2008; but see Good 1994). For example, the National Oceanic and Atmospheric Administration (NOAA) limited their periodic evaluation of CZMA performance to policy and planning elements as opposed to implementation outcomes (NOAA 2010). Consequently, some (Bernd-Cohen and Gordon 1999; Chasis 1980; Hershman et al. 1999) have concluded that there are insufficient studies to determine outcomes of the CZMA.

Assessments of effectiveness of local coastal programs in Washington state have also focused on organizational issues. Recent studies highlighted the following issues: poor coordination between state and local government regulators (Dionne et al. 2015), a lack of compliance and enforcement programs (Dionne et al. 2015; Patterson, Trim, and Trohimovich 2014), and the absence of essential information necessary to determine permit compliance (Quinn et al. 2006). An analysis of permit provisions (but not outcomes) in San Juan County between 1992 and 2005 suggested that more protective land-use codes (passed in 1993) did not translate into better protection for important nearshore habitat (Friends of the San Juan 2007).

In 1976, Washington became the first state with an approved CZMA coastal program. The State chose to use existing laws to protect coastal areas through a networked approach, i.e., the SMA and other related land-use laws, to meet the goals of CZMA. The SMA required local governments to enact Shoreline Master Programs (SMP), which are a combination of comprehensive plans, zoning ordinances, and regulations to protect shorelines. Current land-use codes also include provisions required by the Washington State Growth Management Act (GMA) for protection of fish and wildlife.

Recognizing that existing shoreline management might not protect federally listed Chinook Salmon (*Oncorhynchus tshawytscha*), the Puget Sound Partnership, Surfrider Foundation, and San Juan County formed the San Juan Initiative (Initiative) in 2006. The goal of the Initiative was to provide a scientifically defensible, community-based process to evaluate and improve shoreline protection through citizen-supported changes to local and state policy. The Initiative was led by a Policy Group, supported by a small staff, a Science Team, a Technical Policy Team (local planners and policy experts), and a Trades Work Group (contractors, realtors, landscapers). The Policy Group included 12 San Juan County Council-appointed citizens and policy leaders from agencies with regulatory purview in the coastal zone including NOAA; Washington Departments of Natural Resources, Fish and Wildlife (WDFW), and Ecology; and the Army Corps of Engineers.

We describe how state and local policies were implemented in San Juan County, Washington, particularly how ecological outcomes relate to organizational effectiveness. Because counties must comply with the GMA (as of 1990) and SMA, we did not differentiate between the requirements of the two acts. We report on five elements of the Initiative: 1) Characterizing shoreline construction activities during three periods reflecting three different regulatory regimes; 2) Reviewing policy, regulations, and permitting processes; 3) Evaluating the affected publics' perceptions on shoreline protection; 4) Documenting actions taken by the San Juan County Council in 2008 in response to Initiative findings; and 5) Measuring changes in shoreline management in 2012 after implementation of Initiative recommendations in 2008.

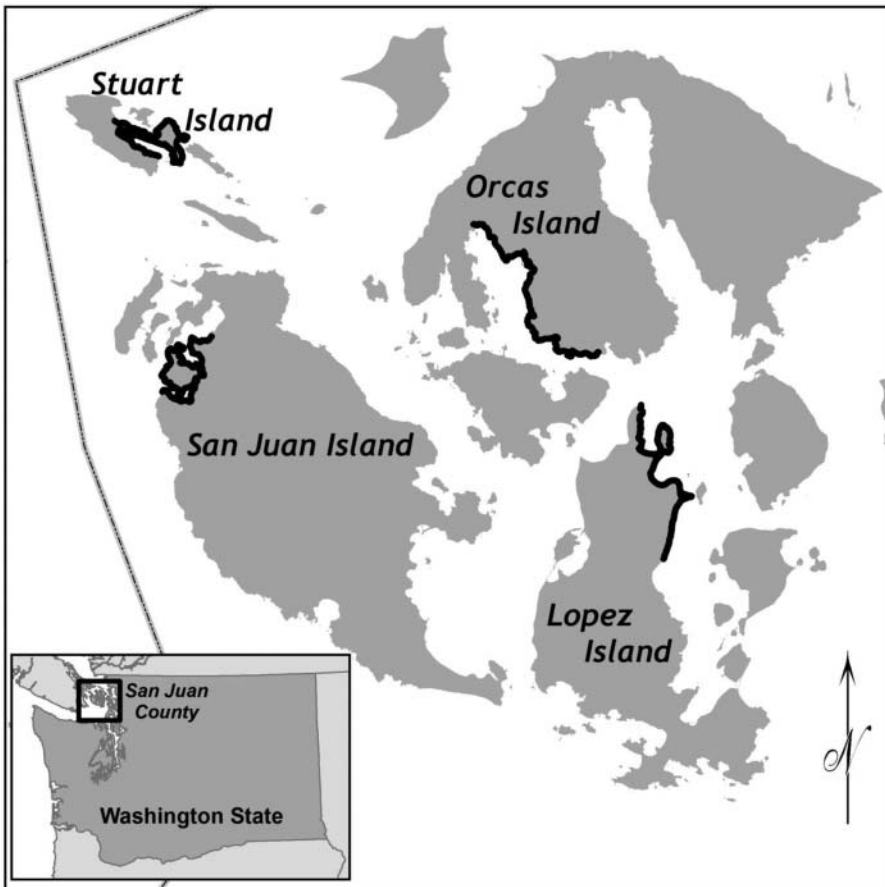


Figure 1. The San Juan Initiative Study Area, comprising four reaches shown in bold, was located in San Juan County, Washington, United States.

Methods

Study setting

San Juan County, Washington, is composed of 172 islands (Figure 1) with more marine shoreline than any other county in the continental United States. The community has transitioned from a resource-based economy with farming, logging, and fishing industries to tourism- and retirement-related services (Henley and Thomas 2016).

Study approach

We focused on the Marine Resource Area (MRA) defined as the area between 61 m landward of the ordinary high water mark (OHW; RCW 90.58.030(20(d)) and the outer extent of overwater structures, (i.e., piers and floats), that extend approximately -3.0 m below mean lower low water (MLLW). The OHW is approximately 0.5 m above mean higher high water (MHHW). We chose the individual ownership parcel as the unit of analysis because state and county governments issue permits at this scale.

This study was completed in two phases. Phase 1, conducted in 2006–2008, 1) characterized nearshore conditions and marine shoreline development pre and post 1977; 2) reviewed local and state permitting processes from 1993 to 2008; and 3) developed community-supported solutions for improving shoreline protection for San Juan County Council and state agency consideration. Phase 2, conducted in 2009–2012, characterized new shoreline development nearshore vegetation and permit inspections starting at the end of Phase 1.

Study areas selection

The Science Team identified a pool of 12 potential study reaches by first delineating discrete shoreline lengths of approximately 13 km with a variety of ownerships patterns (undeveloped, single family, corporate, nonprofit and public) and sensitive shoreline resources such as eelgrass, forage fish spawning beaches, and shoreline forest cover. Ideal reaches would also be visible and familiar to community members (e.g., areas near ferry landings, areas along major roads). The Policy Group selected four reaches for study, one on each of three ferry-served islands, San Juan, Orcas, Lopez, and one on Stuart Is, which is not served by ferry. In total, the four study reaches combined (hereafter study area) included 636 landowner parcels on 55 (8.4%) of the 657 km of county shoreline (Table 1, Figure 1).

Phase 1: 2006–2008

We characterized parcel scale changes in house setbacks, overwater structures (piers and floats), and shore armor over time. In particular, we were interested in exploring the relationships between these land-use practices relative to eelgrass beds, forage fish spawning, and forest cover. Shoreline conditions were assessed using a combination of existing county data sets, aerial photography, and field surveys conducted in March 2008.

All development features were attributed to one of the three time periods: Pre 1977 if the structure was present in 1977 and 2006 aerial photos, present during the 2008 survey, and if there was no change in dimensions between 1977 and 2006 photos; Post 1977 if the structure was not detected in 1977 photos but was present in the 2006 photos and during the 2008 field survey, and if no permits could be found for that structure; and finally, Permit 1993 if it met Post 1977 criteria and we found a county or state permit for its construction. Because we did not have photo documentation from 1993 to 2006,

Table 1. Parcel characteristics of the four shoreline study reaches that made up the study area in San Juan County, Washington, 2008. Parcels refer to discrete ownerships areas along marine shorelines. Mean are recorded by column. Standard errors are in parentheses.

Reaches	Reach Length (km)	No. Parcels	Mean Parcel Area (ha)	Mean Parcel Width (m)	Mean Parcel Length (m)
Lopez	13.64	202	1.1 (0.3)	67 (9)	43 (6)
Orcas	14.08	121	2.1 (0.4)	116 (9)	24 (2)
San Juan	14.54	202	1.8 (1.1)	72 (16)	26 (2)
Stuart	12.88	111	1.7 (0.4)	116 (28)	24 (2)
Means (SE)	13.79 (0.35)	159 (25)	1.6 (0.2)	93 (13)	29 (5)

we relied on the permit record to determine date of construction for the Permit 1993 time period.

These three time periods represent three different regulatory environments. Pre 1977 reflects shoreline management before SMA and baseline conditions against which future improvements were measured. Post 1977 reflects implementation of the SMA that prohibited armor on parcels with no home and required permits for shore armor on developed parcels and for overwater structures. Regulations for overwater structure and armor required review of impacts on littoral drift, feeder bluffs, water quality, and fish and wildlife habitat but did not provide numeric standards for addressing these impacts. Permit 1993 represents recent shoreline policy updates including GMA requirements to protect fish and wildlife habitat. The 1993 update of the SMP, along with GMA considerations, set numeric standards for home setback distances and overwater structures and qualitative guidelines for protection of shoreline vegetation, eelgrass bed, and forage fish spawning beaches.

Geomorphic shore type mapping

During boat surveys, we delineated shorelines into one of seven shore types: Feeder Bluff, Transport Zone, Accretion Shore, Pocket Beach, No Appreciable Drift, No Appreciable Drift—Bedrock (hereafter Bedrock) and Modified (Appendix 1). We determined the historical shore type on modified shores based on nearshore topography, adjacent shore types, and current and historic aerial photography. Where a single parcel contained multiple shore types, it was assigned the dominant type based on percent composition.

Upland parcel characteristics

We calculated the dimensions of each study area parcel using county maps (<http://parcel.sanjuanco.com/PropertyAccess/>). We digitized the footprint of houses based on high-resolution 2004–2006 aerial photographs in geographic information system (GIS) and measured the shortest setback distance between the house and HWM (Berry et al. 2008), hereafter referred to as the OWH, which HWM estimates. We recorded setback distance as a negative number for houses extending seaward of the OWH. Because we documented the presence/absence of houses on 1977 photos, we attributed the construction period of all houses present in 2004–2006 photographs to two time periods, Pre 1977 and Post 1977. Using high-resolution aerial photos (1:240, 2006 photos and 2006 oblique photos; DOE coastal atlas 2007), we ocularly estimated percent forest cover within the MRA, and the OWH (hereafter OWH forest cover) in each parcel using a line intercept approach. In cases of coastal erosion, vegetation cover immediately landward and overhanging the scarp of the bluff crest was used to estimate OWH forest cover.

Shore armor

We first characterized shore armor in 1977 using 1977 vertical (1:6,000 scale) and oblique aerial photos and in 2008 using 2006 high-resolution (1:240) and 2006 oblique photos (DOE coastal atlas 2007). We supplemented our initial GIS armoring map with field surveys. All shore armor located adjacent to or below the OWH, over 1.5 m in length and parallel to the water line, were measured, mapped using a global positioning system (GPS) unit, and

attributed to an ownership parcel. We recorded construction material (e.g., rock, timber, concrete), length alongshore, and the elevation of the seaward toe of the structure relative to MLLW. We determined the elevation of the structures by measuring it relative to the water level elevation at a given time and compared with observed water levels from the local NOAA tidal station. Positional data were recorded using Thales MobileMapper GPS unit in the WGS 84 (World Geodetic System or Latitude/Longitude) coordinate system with an accuracy of ± 2.75 m. We marked waypoints at the beginning and the end of each field-mapped structure.

Overwater structures

We mapped overwater structures (piers and floats) in 1977 and in 2008 using high-resolution (1:240) vertical and oblique (2006) photographs (DOE coastal atlas 2007). Because we could not distinguish ramps from piers in photos, we combined these structures and refer to them collectively as piers. We measured length, width, and area of piers and floats in GIS. We supplemented this information with data from March 2008 field surveys during which we determined pier and float width and length, construction materials including light-penetrating grating and the number of creosote pilings. In addition, we measured the height of piers above MLLW and the position of the pier and float relative to eelgrass beds.

Permit review

We limited permit review to the Post 1977 and Permit 93 time periods. We reviewed the county permit databases for all records of overwater and shore armor permits in the Post 1977 period construction. We also planned to review 24 permits in the Permit 1993 period for each of docks, armor, and home setback; and select randomly across the study area, to determine compliance with codes enacted in 1993. After 1977, construction for docks, shore armor, and home setback distance required different types of permits, i.e., substantial development, exemption, and residential pre-application permits for newly constructed homes, collectively referred to as county permits. County permit review for the Post 1993 period was designed to answer four questions: 1) Was there a permit for the activity? 2) Were sensitive resources identified (i.e., eelgrass beds, feeder bluffs, or forage fish beach spawning habitat) that could be negatively affected by the activities? 3) Did permits contain provisions to protect those sensitive resources? and 4) Were dimensions of field-measured armor and overwater structures compliant with permit conditions?

We also reviewed the five most recent shoreline permits issued anywhere in the county to determine if provisions of recent permit were more quantitative (i.e., contained all important structure dimensions) than older permits. However, we did not determine compliance on these permits.

To evaluate county permits, we reviewed county land-use codes associated with the SMP and GMA (San Juan County Unified Development Code 18.50.330, 2003) to determine what constituted ideal permits for each type. We then compared permits against ideal permits, which included a review of all construction provisions (e.g., overall size, length, width, tidal elevation, materials used, etc.); the identification and the protection of sensitive resources provisions, i.e., the presence of feeder bluffs, forage fish and eelgrass beds; and the protection of sensitive resources (construction timing windows, and avoidance of physical

disturbances). We also reviewed the County's enforcement process including regulatory authority, availability of resources for inspections, and other aspects of implementation.

We also attempted to review Hydraulic Permit Authority (HPA) permits issued by WDFW (RCW 90.58.030(20(d))). Since the 1970s, WDFW has issued permits to protect fish and fish habitat from the impacts of construction projects. However, we were unable to match county to state permits because of differences in how permits were cataloged and because of incomplete record keeping.

Permit process interviews and community engagement

To understand the county permit review process, we interviewed permit experts including county planners, realtors, contractors, landscapers, and environmentalists selected by the Policy Group and County Council. Interviews were conducted one on one or in small groups and occurred throughout the Initiative process. We asked questions about potential gaps in regulation, coordination issues, enforcement and compliance, and available capacity and expertise to review permits.

In four rounds of meetings, we obtained information related to shoreline management from three community groups: study area shoreline property owners, trades people (i.e., realtors, landscapers, and contractors), and the general public on each of the three ferry-served islands between 2007 and 2008, resulting in a total of 12 public meetings over 18 months. Our summarized comments from interviews and meetings along with our shoreline characterization results were used by the Policy Group to developed recommendations to the County Council.

Phase 1 analysis

We provide descriptive statistics for shoreline parcels by the four study reaches for illustrative purposes, but pooled data from reaches to the study area for analysis because we were more interested in differences in the study area through time than differences among study reaches. We used a log likelihood-ratio (G test) for 2×6 contingency tables (house presence/absence by six shore types) to determine if homes built in Pre 1977 and Post 1977 periods were constructed on shore types in proportion to shore type frequency across the study area. We were interested in determining if construction done Post 1977 would result in relatively fewer houses built on ecologically important shore types such as feeder bluffs and pocket beaches.

We used 2-way analysis of variance (ANOVA) (Pre 1977 and Post 1977 versus house setback distance) in three distance bands (0–15 m, 16–30 m, and 31–61 m) to examine the relationship between arcsine transformed forest cover (MRA and OHW shoreline forest), house construction time, and house setback distance. The distance bands were chosen because they correspond to San Juan County setback policy. Post 1977, houses could be placed ≥ 15 m from the top of the bank if there was vegetation sufficient to screen the house from waterside views. In the absence of screening vegetation, house setback distance was ≥ 31 m. The determination of *sufficient* screening was made by a county planner on a case-by-case basis during site visits. Houses with negative setback distances were lumped into the 0–15 m distance band for this analysis. We were interested in how house setback distance was related to time period and presence of MRA and OHW forest cover.

We used G tests for 2×2 contingency table (armor presence/absence by house presence/absence) to determine the extent to which shore armor on a parcel was associated with the presence of a house on that parcel. To determine if the presence of armoring was associated with the loss of MRA forest cover or overhanging shoreline forest cover, we compared the two measures of cover on parcels with armor and without armor using an ANOVA on arcsine transformed percent forest cover estimates. To evaluate if the presence of shore armor was associated with shore type (e.g., more armoring on eroding versus bedrock shore types), we used G tests on a 2×6 contingency table (armor presence/absence by three shore types) to determine if armoring was found on shore types in proportion to the amount of those shore types in the study area. We did not stratify this by time because of small sample sizes for each of Pre 1977 and Permit 1993 time periods. We compared pier width, length, area, and height among treatments, and float width, length, and area among treatments using the Kruskal-Wallis test. We also conducted 2×3 contingency table analyses (use versus nonuse by three time periods) to determine if the use of creosote pilings in piers and the use of grating on piers were consistent through time. Similarly, we used 2×3 contingency table analyses (use versus nonuse by three time periods) to determine if the use of creosote pilings on floats, use of grating on floats, and the counts of floats adjacent to eelgrass were consistent through time.

We used a general linear model (GLM) to determine how each of arcsine MRA forest cover and arcsine OHW forest cover were related to the presence of armor and houses (regardless of setback distance) by time period. Specifically, we modeled forest cover as a function of house construction time (no house, house constructed Pre 1977, and house constructed Post 1977) and armor construction time (no armor, armor constructed Pre 1977 and armor constructed Post 1977) as independent categorical variables.

Before statistical analysis, we examined univariate stem and leaf, box, and normality plots for each response variable to identify suspected outliers. When variables were not normally distributed, we used nonparametric tests or transformed them to improve normality as determined by Lilliefors test (Systat 12) before analysis. We used an alpha of 0.1 as a putative indication of statistical difference among treatments.

Phase 2, 2008–2012

In Phase 2, we explored how Phase 1-recommended regulatory changes resulted in improved shoreline protections. Specifically, we examined if: 1) The county experienced construction of new, unpermitted bulkheads between 2009 and 2012, 2) The county conducted construction inspections on at least 75% of county-issued shoreline permits, and 3) If forest cover on any parcels within the study area declined below 88% of the 2006 level.

Nearshore vegetation

We repeated the vegetation analysis done in Phase 1 to assess forest cover change occurring between 2006 and 2011 using National Agricultural Inventory Program imagery. We measured MRA forest cover and OHW forest cover across the study area in 2006 and 2011.

Overwater structures and shore armor

To determine the extent and type of shoreline change related to human activity between 2006 and fall of 2012, we surveyed the study area by boat on October 15, 2012. We compared 2012 shoreline conditions observed from a boat with conditions based on DOE's 2006 oblique aerial photography and the Initiative database. In addition to noting new modifications, we also characterized how shoreline modifications documented in 2006 had changed (e.g., replacing a wood armor with concrete or extending the length of shore armor). DOE's oblique photographs have high enough resolution that major shoreline features such as new bulkheads and overwater structures can often be identified by careful review, provided they are not obscured by shoreline vegetation.

Phase 2: Permit review

Upon completion of the shoreline survey, we provided a list of parcels with changes to San Juan County and the WDFW. County and State staff checked these changes against their permit databases to determine if a project permit existed and if an on-site inspection had occurred. For this phase, we were not interested in outcome of those inspections.

Phase 2 analysis

We determined percent change in MRA forest cover and OHW forest cover for each parcel between 2006 and 2011. We also determined the association between the loss of OHW and presence of eelgrass and forage fish because OHW forest cover can provide shade to the upper intertidal area and has been associated with lower embryo egg mortality in summer spawning surf smelt (Rice 2006).

Results

Phase 1: 2006–2008

Geomorphic shoretype mapping

In aggregate, the four study reaches represented approximately 56 of 657 km (8.4%) of San Juan County shoreline (Table 1). The number of parcels and parcels by shore type varied widely among study reaches (Table 2).

Table 2. The number of ownership parcels by dominant shore type and study area in San Juan County, Washington State, 2008. Numbers in parentheses represent the percentage of parcels with houses.

Study Reach	Accretion Shoreform	Feeder Bluff	No Appreciable Drift	Bedrock	Pocket Beach	Transport Zone	Total
Lopez Is	29 (62.1)	66 (67.7)	0 (0.0)	63 (49.2)	10 (60.0)	34 (61.8)	202 (60.0)
Orcas Is	5 (40.0)	18 (38.9)	7 (57.1)	80 (67.5)	6 (50.0)	5 (40.0)	121 (60.3)
San Juan Is	26 (65.4)	5 (80.0)	16 (56.3)	78 (55.1)	35 (68.6)	42 (54.8)	202 (59.5)
Stuart Is	22 (40.9)	4 (50.0)	0 (0.0)	70 (37.1)	4 (0.0)	11 (36.4)	111 (17.5)
Total	82 (56.1)	93 (61.3)	23 (56.5)	291 (60.0)	55 (54.3)	92 (55.5)	636(100.0)

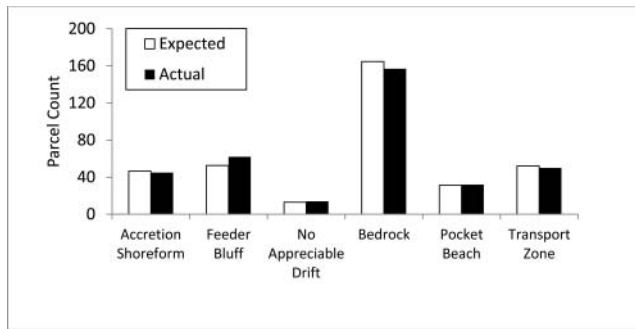


Figure 2. The actual and expected (based on contingency analysis) number of parcels with homes, constructed during the Pre 1977 and Post 1977 time periods combined, by shore type in the San Juan County, Washington State study area, 2008.

Parcel characteristics

Of the 636 parcels across the study area, 386 supported homes as of 2008 of which 352 were located within the MRA. Of these 352 homes, 214 and 138 were constructed in the Pre 1977 and Post 1977 time periods, respectively. Setback distances increased for 18 and decreased for 21 homes between Pre 1977 and Post 1977 periods and were not included in this analysis. Mean Pre 1977 house setback distance was less (*Mann-Whitney U* = 9228.5, *P* = 0.000) than mean Post 1977 house setback distance (Pre 1977, mean = 22.1 m, SE = 0.9, N = 175)

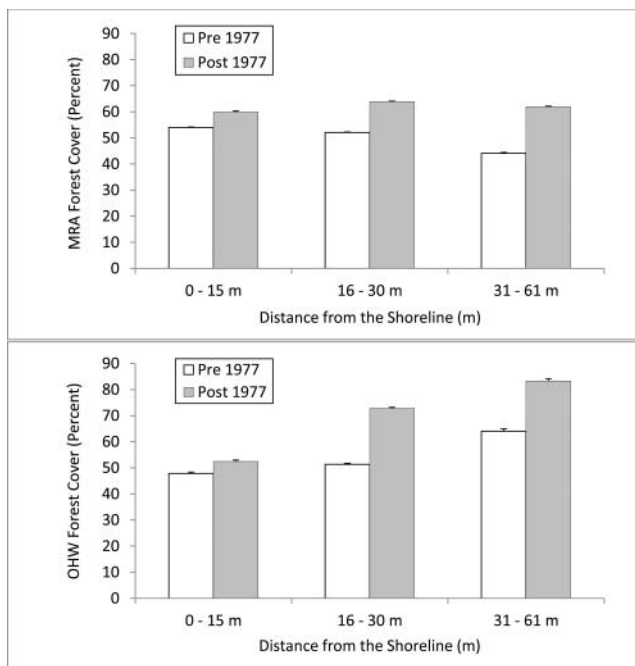


Figure 3. Mean Percent MRA forest cover (upper panel) and Percent OHW forest cover on parcels with shoreline homes, built in the Pre 1997 and Post 1977 periods, within 0–15 m, 16–30 m and 31–61 m of the shoreline in San Juan County, WA 2008. Error bars represent standard errors.

(Post1977, mean = 26.9 m, SE = 1.2, N = 138). Shoreline homes occurred in proportion to the availability of shore type in both Pre 1977 ($G_{(0.1),5} = 4.88, P = 0.430$) and Post 1977 ($G_{(0.1),5} = 5.35, P = 0.374$) periods and when data were combined across time periods ($G_{(0.1),5} = 4.63, P = 0.461$; [Figure 2](#)).

Parcels with homes built in the Post 1977 period had more MRA and more OHW forest cover than parcels in the Pre 1977 period (MRA forest cover by time period; $F_{(0.1)1,312} = 7.563, P = 0.006$; OHW forest cover by time period; $F_{(0.1)1,312} = 5.636, P = 0.006$; [Figure 3](#)). House setback distance was not related to MRA forest cover (two-way ANOVA, $F_{(0.1)2,312} = 0.495, P = 0.610$), but OHW forest cover decreased as house setback distance decreased (Two-way ANOVA, $F_{(0.1)2,312} = 3.876, P = 0.022$). We found no significant interaction with either measure of forest cover and setback distance ($F_{(0.1)2,312} = 0.548, P = 0.579$ for MRA forest cover and $F_{(0.1)2,312} = 0.670, P = 0.513$ for OHW forest cover; [Figure 3](#)).

In summary, shoreline homes built after 1977 were further from the shoreline than homes built prior to 1977, but homes from both time periods occurred in proportion to the availability of shore type. Parcels with homes built prior to 1977 had less MRA and OHW forest cover than parcels that were developed post 1977. Home setback distance was not related to MRA forest cover, but overhanging shoreline forest cover decreased as home setback distance decreased.

Shore armor

Of the 636 study area parcels, 199 (32%) had some type of hardened shoreline protection (i.e., bulkhead, riprap, or seawall) in 2008, representing approximately 12% of the study area shoreline length. We estimated that 22, 171, and 6 parcels were armored in the Pre 1977, Post 1977, and Permit 1993 periods, respectively ([Table 3](#)). While 215 homes were built before 1977, only 22 were armored prior to 1977, 16 associated with a home and 6 associated with no home. An additional 74 parcels with homes built before 1977 were armored after 1977.

Mean parcel armor lengths and elevations for Pre 1977, Post 1977, and Permit 1993 time periods were not significantly different (*Kruskal-Wallis* = 2.978, $P = 0.226$ and *Kruskal-Wallis* = 0.993, $P = 0.609$, respectively; [Table 3](#)). Of the 199 parcels with shore armor, 183 (92%) were below the OHW mark (+2.87 m), and 109 (55%) were below MHHL (+2.37 m; [Figure 4](#)). In addition, 68 parcels had armor that extended into documented or potential forage fish spawning habitat defined as the area between +1.22 to +2.44 MLLW (D. Pentilla, pers. comm.).

Because of relatively low counts of armored parcels in the Pre 1977 ($n = 16$) and Permit 1993 ($n = 7$) time periods, we combined these data with Post 1977 time period data before analyzing the association of armor with homes, armor with shore type, and armor with home setback distance. The presence of armor was significantly associated with the presence of a shoreline home ($G_{(0.1),1} = 8.629, P = 0.003$) with 136 instances of armor occurring on

Table 3. Comparisons using Mann-Whitney tests of field-measured armor length and armor elevation from three time periods in the San Juan, County, Washington study area, 2008.

Shoreline Armoring	Pre 1977			Post 1977			Permit 1993			Mann-Whitney	
	N ^a	Mean	SE	N ^a	Mean	SE	N ^a	Mean	SE	U	P
Armor length	22	71.9	17.8	169	58.8	5.1	6	69.5	21.3	0.99	0.609
Armor elevation	22	2.1	0.2	171	2.1	0.1	6	2.0	0.2	2.98	0.226

Note. N^a sample size out of a possible 22, 171 and 6 for Pre 1977, Post 1977, and Permit 1993, respectively.

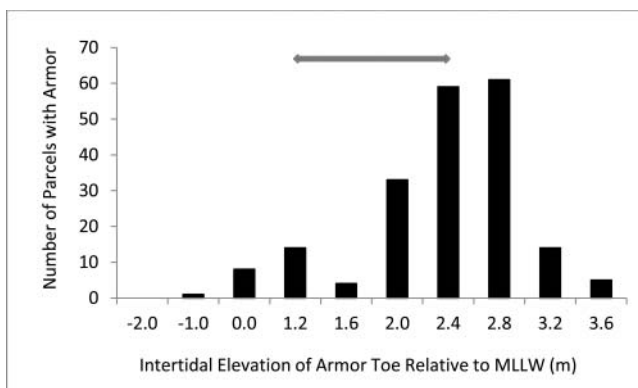


Figure 4. Distribution of shoreline armoring elevations for Pre 1977, Post 1997, and Permit 1993 periods combined in San Juan County, WA, 2008. The arrow shows the range of elevations where forage fish are known to spawn in San Juan County. OHW and MHHW occur at +2.87 and +2.37 m above MLLW, respectively. Note the scale change of the x-axis below 1.2 m.

parcels with homes and 61 occurring on parcels with no home. We found that the armored parcels were not distributed in proportion to shore type ($G_{(0.1),5} = 95.78$, $P < 0.000$; Figure 5). Similarly, we found that the incidence of armor increased as home setback distance from the shoreline decreased ($G_{(0.1),3} = 12.335$, $P = 0.006$; Figure 6).

The GLM showed that MRA forest cover was significantly different by home construction time period ($F_{(0.1),2,627} = 6.692$, $P = 0.001$), armor construction time period ($F_{(0.1),2,627} = 17.723$, $P = 0.000$), and the interaction of home and armor construction time periods ($F_{(0.1),4,627} = 7.037$, $P = 0.000$). Similarly, GLM showed that OHW forest cover was not significantly different by home construction time period ($F_{(0.1),2,626} = 1.184$, $P = 0.307$) but was significantly different by armor construction time period ($F_{(0.1),2,626} = 14.459$, $P = 0.000$). Further, the interaction of home and armor construction time periods was significant ($F_{(0.1),4,627} = 2.083$, $P = 0.082$; Figure 7).

In summary, we had no 1993 aerial photographs that allowed us to estimate armor reliably. Thus, we did not characterize shore armor that occurred between 1993 and 2006 except through the very incomplete permit record (i.e., we found only 7 county permits for armoring post 1993). Most shore armor was constructed in the Post 1977 period and was typically associated with the presence of a home. Armor lengths and armor elevations have not changed through

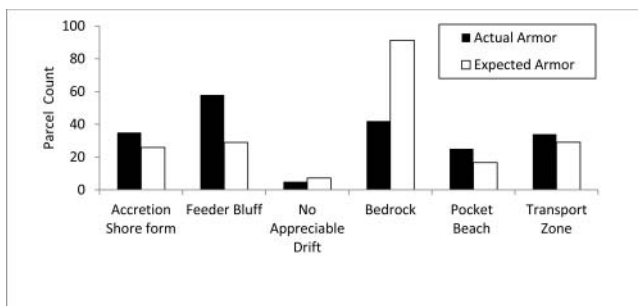


Figure 5. The actual and expected number of parcels with armor (based on contingency analysis) by shore type based on contingency analysis, in San Juan County, Washington, 2008. These data include armor constructed in the Pre 1977 and Post 1977 periods combined.

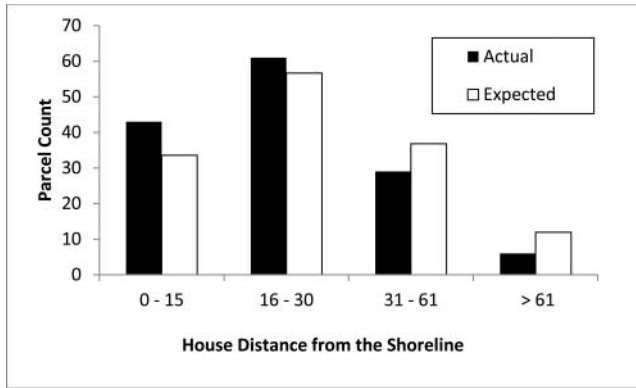


Figure 6. Actual versus expected counts of parcels with armor as a function of house setback distance band based on a contingency analysis in San Juan County, WA, 2008. These data include armor constructed in the Pre 1977 and Post 1977 periods combined.

time, and most armor is located at elevations below the OHW mark. More feeder bluffs and fewer bedrock shore types were armored than expected based on the number of parcels with those shore types. The relationship among forest cover, home presence and construction time, and armor presence and construction time is complex. MRA and overhanging shoreline forest

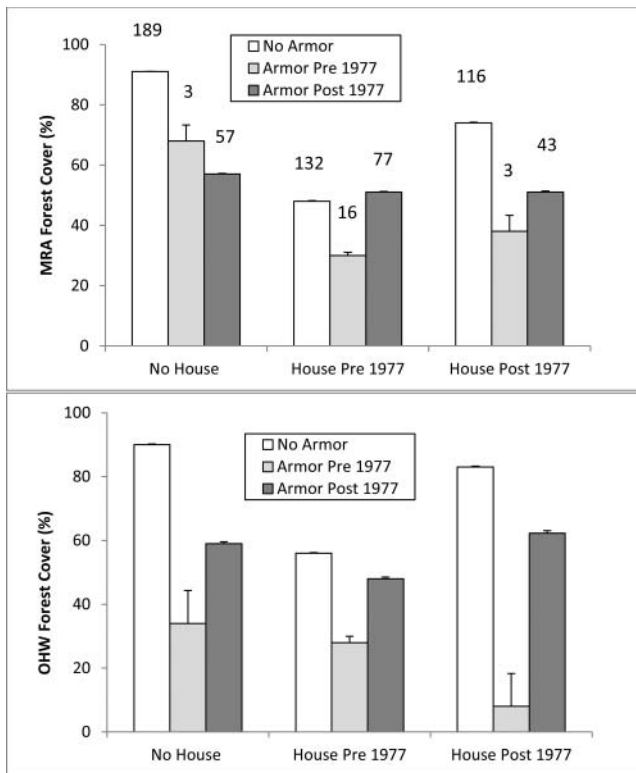


Figure 7. Mean percent (SE) of MRA (upper panel) and OHW forest cover by parcel across all possible combinations of home presence and home and armor construction time period in San Juan County, WA, 2008.

Table 4. Comparisons of field-measured overwater structural characteristics by three time periods in the San Juan County, Washington study area, 2008.

	Pre 1977			Post 1977			Permit 1993			Kruskal-Wallis	P
	N ^a	Mean	SE	N ^a	Mean	SE	N ^a	Mean	SE		
Overwater structure											
Pier length	42	30.04	2.80	34	22.87	3.09	17	34.43	4.37	7.59	0.022
Pier width	42	2.22	0.14	34	2.05	0.18	17	1.92	0.15	1.99	0.370
Pier area	42	67.65	6.51	34	48.61	7.92	17	69.25	10.69	5.31	0.070
Pier height	38	3.69	0.10	30	4.17	0.14	17	4.04	0.15	10.91	0.004
Float length	38	21.07	2.02	27	26.80	5.08	19	25.64	4.13	0.12	0.943
Float width	36	3.40	0.35	27	2.44	0.13	19	2.94	0.20	5.78	0.055
Float area	38	66.40	7.09	25	60.97	9.17	19	72.44	11.65	1.20	0.548

Note. ^aSample size out of a possible 42, 34 and 19 for Pre 1977, Post 1977, and Permit 1993, respectively.

cover was generally higher on parcels with no homes, parcels with homes built after 1977, and parcels with homes and armoring built after 1977, in that order.

Overwater structures

We measured 95 overwater structures in 2008 and attributed the construction of 42, 34, and 19 floats and or piers to Pre 1977, Post 1977, and Permit 1993 time periods, respectively (Table 4). We found significant differences in pier height (*Kruskal-Wallis* = 10.91, $P = 0.004$), pier length (*Kruskal-Wallis* = 7.59, $P = 0.022$), and pier area (*Kruskal-Wallis* = 5.31, $P = 0.070$) but no difference in pier width (*Kruskal-Wallis* = 1.99, $P = 0.370$) among time periods (Table 4). We also found significant differences in float width (*Kruskal-Wallis* = 5.78, $P = 0.055$) but not float length (*Kruskal-Wallis* = 0.12, $P = 0.943$), or float area (*Kruskal-Wallis* = 1.20, $P = 0.548$; Table 4). Two-way contingency analysis (use by time period) suggested that the use of creosote piles in piers ($G_{(0.1), 2} = 1.914$, $P = 0.384$) and floats ($G_{(0.1), 2} = 3.740$, $P = 0.154$) did not change across time periods (Table 5). Although small sample sizes prevented us from comparing the use of grating among time periods, grating use was low regardless of time period. In addition, there was no significant differences in the number of creosote piles per pier (*Kruskal-Wallis* = 0.216, $P = 0.898$) or the number of creosote piles per float (*Kruskal-Wallis* = 3.867, $P = 0.145$) by time periods. Across all time periods, 85 piers and 81 floats had a mean of 8.8

Table 5. The number of floats and piers that used specific building materials (creosote piles and grating), and floats located over eelgrass during three time periods in the San Juan County, Washington State study area.

	Pre 1977			Post 1977			Permit 1993			G	P
	Yes	No	Total ^a	Yes	No	Total ^a	Yes	No	Total ^a		
Piers with creosote piles	32	6	38	26	4	30	12	5	17	1.914	0.106
Piers with grating	2	40	42	0	34	34	1	18	19	NA	NA
Floats with creosote piles	25	12	37	20	5	25	9	10	19	3.740	0.156
Floats over eelgrass	8	30	38	1	25	28	7	12	19	7.823	0.020

Note. ^aSample size out of a possible 42, 34 and 19 for Pre 1977, Post 1977, and Permit 1993, respectively.

Table 6. Results of shoreline permit review from the Permit 1993 period comparing provisions in permits with field-measured characteristics of overwater structures and shoreline armoring. The Wilcoxon Signed Rank Test is the nonparametric analog of the paired *t*-test.

Characteristics	Permit			Field		Wilcoxon Signed Ranks Test	
	N ^a	Mean	(SE)	Mean	(SE)	(Z)	P
Overwater structures							
Pier material	4	NA		NA			
Pier width	8	1.7	(0.3)	2.1	(0.3)	-1.753	0.080
Pier height	4	4.3	(0.1)	4.1	(0.3)	-0.365	0.715
Float material	5	NA		NA			
Float width	13	2.5	(0.1)	2.7	(0.1)	-1.120	0.263
Float length	14	18.2	(6.1)	26.6	(6.7)	-1.648	0.099
Armoring							
Toe elevation	4	1.8	(0.4)	2.3	(0.2)	-1.095	0.273
Length	4	33.1	(15.4)	35.6	(13.7)	-0.365	0.715

Note. ^aN refers to the number of permits with a provision for that characteristics of a total of 19 and 7 permits for overwater structures and shoreline armor, respectively.

(SE = 0.90), and 3.25 (SE = 0.41) creosote piles per structure, respectively. In total, 16 of 71 floats (26%) crossed mapped eelgrass bed.

In summary, we found little change in overall area of overwater structures before and after 1977 and no decline in the use, or in the number, of creosote piles per overwater structure.

Permit review

We found 27 county permits for 34 overwater structures built in the Post 1977 period, representing a 79% permit rate, and 12 county permits for 178 instances of shore armor built in the Post 1977 period for a 7% permit rate. We also found 61 parcels with shore armor but no home in the Post 1977 period despite the fact that armor was prohibited on undeveloped shores Post 1977.

We found 19 county permits for overwater structures in the Permit 1993 period, 8 from inside and 11 (most recent permits) from outside the study area. Of these 19 permits, 14 had provisions for float length, and 4 permits had provisions for each of pier material, pier height, and pier grating. Mean pier width measured in the field was significantly larger ($Z = -1.75$, $P = 0.08$) than permitted pier width, and mean float length measured in the field was significantly longer ($Z = -1.65$, $P = 0.099$) than permitted float length. We found no other significant differences in dimensions between permitted and field-measured overwater structures dimensions (Table 6). County code for overwater structures in 1993 required that the area of overwater structures (pier, float, and ramp combined) be no greater than 65 m² or 130 m² for a single family use dock or joint use dock, respectively. However, all Permit 1993 period overwater structures exceeded these standards. Two multiple-use docks were on average 67 m² (52%) (range = 41–93 m) larger than 130 m², and single-use docks were on average 64.5 m² (98%) (range = 2–231 m) larger than 66 m² (Table 6). Of these same 19 permits, 8 were associated with parcels that had eelgrass and 4 had mapped forage fish spawning areas, but only 2 of the 8 permits identified eelgrass as a sensitive resource and listed eelgrass as a consideration in the permit. Similarly, only three of the four permits identified forage fish spawning as a permit consideration. All five most recent substantial

development permits for docks were conditioned to protect eelgrass and included conditions for pier width, float width, length and material, and four of five included conditions for pier height and grating.

We found seven county permits in the study area for shore armor in the Permit 1993 period. Of these seven permits, four had provisions for armor elevation and length (Table 6). Mean armor elevation and length measured in the field were not significantly different from permitted armor elevation and length, respectively (Table 6).

We found 19 county permits for new homes issued in the Permit 1993 period, 8 within, and 11 most recent permits outside the study area. The average setback distance for 19 homes was 11 m (range = 2 to 300 m) from the top of bank, 4 m less than the smallest distance allowed by county code. In addition, 5 of the 11 most recent permits required vegetation retention, but only 2 of 8 within the study area required it. All 19 permits received a site visit by county staff prior to approval.

Permit process interviews and community engagement

Approximately 120 people attended each of 4 rounds of meetings, and many attended multiple meetings. A large majority of community members and shoreline property owners agreed that the Initiative should seek to achieve five outcomes: 1) Increase technical assistance to property owners and government decision makers; 2) Improve the intent and clarity of regulations; 3) Reduce duplication in governmental processes; 4) Inspect construction projects and enforce current laws; and 5) Strengthen incentives for property owners.

We interviewed 20 experts involved in shoreline permitting including 5 county planners, 3 private permitting consultants, 3 realtors, 5 contractors, 2 landscapers, and 2 land-use environmentalists. Interviewees noted the importance of the following issues: 1) permit conditions were inconsistently applied, resulting in widely varying outcomes; 2) county staff lacked coastal ecology expertise; and 3) consistent criteria for permit review were lacking, e.g., house setback distance was determined by the presence of adequate vegetation to obscure the house from the water but the county had not defined “adequate vegetation.”

All interviewees noted that inspections for ongoing or completed work were rare, and when they did occur, focused more on education than enforcement. Others suggested that inspections were unnecessary since property owners generally “wanted to do the right thing,” and all noted that the county compliance system relied on private citizens to report suspected violations. The reliance on private citizens contributed to the strongly held view that the permitting system was arbitrary and unfair.

Many interviewees noted the county’s reliance on local environmental groups to provide location data for sensitive shoreline resources. This was appreciated by some, while others were suspicious of information offered by an advocacy nonprofit organization with a history of litigating land-use violations.

Phase 1 results synthesis

We provided the San Juan County Council synthesized information from the shoreline characterization, shoreline permit and policy review, permit process interviews, and public engagement. Based on this information, the Council directed county staff to: 1) better

protect feeder bluffs, pocket beaches, eelgrass beds, and forage fish spawning beaches; 2) develop a construction inspection program for county permits; and 3) create procedures to increase MRA and OHW forest cover.

To measure the County's implementation of the Initiative's recommendations, the Policy Group adopted three performance management metrics in 2009: 1) All new shore armor will have a permit, 2) Inspections will occur for 75% of new shore armor permits, and 3) Parcels within the study area will retain 88% of its forest cover within the MRA.

Phase 2, 2008–2012

Nearshore vegetation

Between 2006 and 2011, we measured a cumulative loss of 5490 m² of MRA forest cover (mean = 323 m², SE = 150 m²) across 17 of 636 parcels in the study area representing an average loss of 12%/parcel (SE = 3%)—the standard set by the Policy Group. Although the Policy Group did not establish a goal for retaining OHW forest cover, we measured a cumulative loss of 85 m of overhanging vegetation across 4 of 636 parcels for an average loss of 20%/parcel (SE = 7%, range = 35–50%). Three of the four parcels with a loss of OHW forest cover occurred on shorelines mapped as forage fish spawning beaches.

Permit review

Prior to 2009, post-construction inspections were not required for shoreline permits. As a result of the Initiative, inspection requirements were implemented in 2009. From 2008 to 2012, the county issued 325 shoreline permits consisting of 252 Shoreline Exemptions and 73 Shoreline Substantial Development permits. However, county staff found evidence of inspections for 4 (1%) of these 325 permits.

We identified 32 shoreline modifications between 2006 and 2012 in the study area judged to require a county and state permit, 20 related to overwater structures and 12 related to armoring. San Juan County and WDFW permit planning staff found both a State HPA and county permit for nine of the modifications and no permits of either type for another 16 (Table 7).

Discussion

Washington State implements the CZMA by tasking local governments with protecting shoreline resources under the auspices of the GMA, and local SMPs. Our work attempted to

Table 7. The number of ownership parcels with shoreline armor (Armor) or overwater structures (OWS) projects with a San Juan County (SJC) permit, a state Hydraulic Authority Permit (HPA) permit, both permits or no permits observed by 2012 boat survey in the San Juan County, Washington study area.

SJC + HPA Permits		SJC Permit		HPA Permit		No Permit			
Armor	OWS	Armor	OWS	Armor	OWS	Armor		OWS	
						New	Repair	New	Repair
3	7	0	3	0	3	3	6	0	7

evaluate how well local policies were protecting shorelines pre and post SMA and to suggest improvements to implementation.

Our analysis indicated mixed results in terms of changes in ecological conditions before and after the 1977 implementation of the SMA. The most positive change was associated with forest vegetation on shoreline parcels between Pre 1977 and Post 1977 period. Parcels with shoreline homes built in the Pre 1977 period had less MRA and OHW forest cover than parcels developed in the Post 1977 period. This finding is consistent with 1977 and 1993 SMA emphasis on shoreline forest protection and occurred despite the lack of numeric standards in county regulatory codes. It is also consistent with current science that suggests that similar to freshwater riparian vegetation, marine shoreline vegetation provides important ecological functions (Brennan and Culverwell 2004).

In contrast, we found that several other indicators had either changed little or become more negative post 1977. Our results suggest that although homes were located on shore types in proportion to the shore type occurrence, armoring was not, with feeder bluffs being armored at a higher rate relative to their abundance than other shore types. Perhaps this is not surprising given that feeder bluffs are actively eroding—by definition. Nonetheless, throughout the SMA time period (1977-current), armoring of feeder bluffs was only allowed when there was a clear danger to infrastructure, and then, only when erosional processes that delivered sediment to the beach could be maintained. We also found that much of the shore armor continues to be located at elevations below OHW, which means it is actually covering part of the wetted area of the beach and areas where forage fish spawn.

Armoring is arguably the most important shoreline management issue in Puget Sound because of its ability to alter sediment processes occurring on Puget Sound beaches. The erosion, transport, and deposition of sediments along beaches and bluffs in Puget Sound, along with other factors such as disturbance regimes, directly affect characteristics of beaches and the composition, abundance, and diversity of plant and animal communities associated with them. Disruption of sediment processes, which can result from structures placed either laterally along or horizontal to the shoreline, may affect the amount and grain size of sediment delivered to the beach, and how and where it is transported. Downing (1983) estimated that erosion of coastal bluffs supplies ~ 90% of the sediment to Puget Sound beaches. Changes in beach profiles and sediment composition can affect reproduction of beach spawning forage fish (Pentilla 2007) and food web processes. Armoring below OHW is significant because it can block longshore transportation of sediments and can also directly cover part of the beach, eliminating habitat for some organisms.

We found little change in overall area of overwater structures across time periods despite the fact that some elements of the structures differed slightly, such as pier height and float area. Perhaps more importantly, every overwater structure built since 1993 exceeded county code for the total surface area established in 1993. The amount of surface area of overwater structures is important because in certain areas, it can shade eelgrass (Fresh et al. 2006).

One final result of our analysis that was especially noteworthy was the amount of unpermitted shoreline armor that seemed to be occurring especially in comparison with overwater structures. Of the 178 parcels that were armored in the Post 77 period, we located only 7 county permits (and 12 corresponding WDFW HPA permits), while we located 27 permits for 34 overwater structures built in the Post 1977 period. The disparity between permits rates for overwater structure and shore armor may be related to the fact that armor is less visible than overwater structures or the perception that shore armor was a necessity, whereas

overwater structures were an amenity. Shore armor also requires a less rigorous review by the county than an overwater structures permit. In the case of armor and overwater structures, the presence of a permit did not seem to result in outcomes more protective of sensitive resources, i.e., there were no meaningful differences between permitted and unpermitted structure dimensions. Lack of compliance was also apparent in Phase 2. Of the 20 overwater structures that required a permit, we found 13 permits, while only 3 of 12 armor activities had a permit.

Our results suggest at a minimum that shoreline policies implemented in San Juan County were not protecting some shoreline functions. However, while we can measure indicators pre and post 1977, we cannot conclusively tie changes we observed to any single cause including the passage of SMA. Thus, maintaining forest cover may have occurred in response to the desire for privacy as shoreline house density increased post 1977.

We identified five of Englander, Feldmann and Hershman's (1977) nine problems that inhibit organizations from achieving goals and policies. Specifically, we found a lack of inter-agency coordination, insufficient planning and regulatory authority, inconsistent enforcement, a lack of expertise related to coastal ecosystems, and primitive analytical tools. The lack of coordination between public agencies was evident in a number of ways. County permit records did not reference state (or federal) permits that may have also been required as part of the permitting process. State and county permits were not easily cross-referenced since the state catalogues permits by property owner, tenant or contractor name, and county permits use ownership parcel number. In addition, county and state permit systems did not reference each other's permit conditions nor did county and state regulators share knowledge about important public resources during the permitting process.

County planners had little understanding of the State's permit authority, which limited their ability to identify improvements in coordination. In addition to the lack of coordination, there was also evidence of poor coordination within the county planning department. For example, the three county planners we interviewed had different approaches for retaining vegetation and for determining house setback distance. A lack of consistent criteria for determining setback was cited multiple times by community members as a source of concern because it supported the belief that arbitrary rules were applied inconsistently.

While inspections and enforcement actions were both generally rare, the lack of coordination coupled with the lack of standard performance criteria resulted in an inherently unfair enforcement program. Lack of inspections during the permit process was identified by property owners, community members, and county planners as being a key contributor to unpermitted activities and lack of compliance. The lack of county inspections created a system whereby community members took it upon themselves to report suspected violations committed by neighbors. Further, the lack of systematic enforcement (i.e., adequate authority, inspections, and financial penalties) meant that citizens had little incentive to comply with County rules provided their neighbors were not opposed to their construction activities. In 2010, NOAA (2010) suggested that state budget cuts for compliance were responsible for reducing the statewide effectiveness of the SMP and recommended that the State focus on key areas for improving compliance, enforcement, and monitoring. In 2009, San Juan County adopted an inspection program, funded by increased permit fees, and supported the development of enhanced enforcement code that included fines and penalties for both property owners and contractors breaking the law, although we did not find evidence of increased inspections during our study.

The County had very primitive analytical tools in addition to a lack of coastal ecology expertise at the time we conducted this work—factors that likely contributed to an ineffective permitting process. No county planners had coastal ecology backgrounds or special training in coastal dynamics. Because the county relied on experts hired by property owners, they had little recourse but to accept judgments offered by consultants working on behalf of the property owners. The county lacked basic maps showing the location of sensitive resources. In addition, county permits stretching back to the beginning of the SMA were stored in one of three databases, two of which were no longer supported technically and nearly impossible to search. In addition, the most recent permits were recorded on note cards filed in cardboard boxes. In addition to database problems, permits lacked essential information necessary to determine compliance. In 2008, only three of the seven permits for bulkheads had specific conditions for tidal elevation and armor length and height.

Despite our work in San Juan County, many shoreline managers continue to believe that the SMA is leading to better resource outcomes. NOAA's periodic reviews along with Bernd-Cohen and Gordon (1999) concluded that Washington State's coastal programs, which were based largely on the SMA, were effectively protecting marine shorelines based on specific policy measures. Indeed, all coastal programs reviewed nationally had significant regulatory controls, including house setbacks and armoring regulations (Bernd-Cohen and Gordon 1999). Although San Juan County had these same regulatory controls, we found a fairly dramatic disparity between policy goals/objectives and resource outcomes. In a similar study, Good (1994) also found that the goals to prevent shore protection structures along Oregon's Siletz shoreline were not being achieved and further recommended changes in the implementation of existing policies and more rigorous review of permits—recommendations similar to those of the Initiative.

In order to improve shoreline protection, we suggest several tactics. Clearly, establishing goals and objectives is a necessary first step to protection of the marine nearshore, but do not alone result in effective shoreline protection (Chasan 2000). Government regulatory agencies may not be meeting their statutory obligations because they have not developed clear and unambiguous decision criteria, useful analytical tools or effective tracking databases and inspection programs. Without monitoring, the public may be misled into believing that shorelines are better protected than they truly are. The San Juan community told us repeatedly that the county should just enforce the current policy instead of trying to make them more restrictive. However, the community may not understand the complexity of enforcing existing codes. For San Juan County, this would require the county to improve its implementation of almost every facet of its work from establishing unambiguous criteria for construction activities to initial site visits and code review to writing permits through monitoring compliance and effectiveness. Each of these steps would require a sizable investment that is unlikely to be supported when citizens believe that shoreline resources are currently protected adequately, and new efforts at enforcement will be as arbitrary as past efforts. Importantly, the community processes we used to identify problems may be the most effective avenue in trying to solve those problems.

Several shortcomings of our work are notable and relevant to interpreting our results. First, our study reaches were not randomly selected but instead were selected to be representative of conditions on the most developed islands. As a result, we could be underrepresenting or overrepresenting some conditions on non-sampled islands. Second, we have only studied one county's response to the SMA. Other counties may show different results

depending on different ecological settings, demographics, and sociopolitical drivers. Much of the geomorphology of the shorelines of San Juan Islands is bedrock, resulting in a relatively small percentage of beach shore types relative to the entire shoreline. Other parts of Puget Sound have more beaches relative to other shore types. The human population is not evenly spread around Puget Sound with most people clustered in King and Pierce counties (cities of Seattle and Tacoma), while regions such as the San Juan Islands and Strait of Juan de Fuca have much fewer people. These differences in human population could affect perception regarding the need for county planners and enforcement agents and the role of local versus state government in land-use planning and regulation. Finally, we had to rely on indirect indicators of ecological functions such as armoring and overwater structures as opposed to a direct measure of sediment processes, forage fish spawning distribution, or quantity of eelgrass. This was primarily due to the fact there was no historical set of baseline conditions for these indicators at the scale of the county.

Given the persistence of shoreline protection challenges and the paucity of community-based evaluations like the San Juan Initiative, counties around the United States with marine shorelines are likely to continue wrestling with implementing effective coastal management. To begin shifting outcomes on the ground, we recommend states monitor on the ground outcomes and hold counties accountable for specific metrics for additional future funding. In addition, compliance needs to be coordinated with state and local resources, and a joint approach that meets the needs of the overlapping jurisdiction would likely garner some local support as an efficient use of government resources.

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Appendix 1. Study area shorelines were delineated into one of seven different shore types.

Feeder Bluffs are characterized by the presence of landslide scarps, and obvious erosional features at the toe of bluffs.

Transport Zones represent areas that neither appeared to contribute appreciable amounts of sediment to the nearshore drift system nor showed signs of sediment accretion.

The No Appreciable Drift shore type characterizes areas where there was little or no net transport of sediment due to a lack of wave energy.

Bedrock shore type describes areas dominated by bedrock geology and the absence of nearshore sediments.

Accretion Shoreforms are defined as depositional areas based on the presence of one or more of the following features: broad backshore area (greater than 3 m wide), backshore vegetation community, and a spit and/or lagoon landward of a spit.

Pocket Beach types are characterized by a concave stretch of shoreline occurring between two bedrock headlands and had minimal exchange of sediment with adjacent shore types, i.e., were not located within drift cells.

Modified segments are severely altered areas such that natural geomorphic character of the shore is largely concealed. Modified shore segments are commonly armored and often contain fill, and thus, natural geomorphic processes including sediment supply and transport are severely altered.