NATURAL RESOURCES

Puget Sound Submerged Vegetation Monitoring Project

2009 Report

March 7, 2011

PSAMP
Puget Sound Assessment and Monitoring Program

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands

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Cover Photo: *Z. marina* bed north of E. Sunset Beach Lane, Lynch Cove, Mason County. Jeff Gaeckle, DNR.

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The following document fulfills DNR's Eelgrass Monitoring performance measure. It also fulfills tasks in the Puget Sound Partnership's Action Agenda by providing information on the status and trends of one of the indicators of environmental health.

The authors would like to give special recognition to Marine Resources Consultants who continue to play a significant role in the success of the project. Marine Resources Consultants showed great dedication and logged many hours of sea time collecting data for the project.

Hannah Julich and Dolores Sare were instrumental in the video data collection and post-processing for this report.

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http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_monitoring.aspx

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EXECUTIVE SUMMARY

The Washington State Department of Natural Resources (DNR) is steward of 2.6 million acres of state-owned aquatic lands. DNR manages these aquatic lands for the benefits of current and future citizens of Washington State. As part of its responsibilities, DNR monitors the status and trends of eelgrass (*Zostera marina* L.) abundance and depth distribution throughout greater Puget Sound.

Zostera marina, a marine flowering plant, is recognized globally as an indicator of ecosystem health and provides valuable nearshore habitat to ecologically and economically important species. In 2000, DNR established the Submerged Vegetation Monitoring Project (SVMP) to track this valuable resource. In 2010, the Puget Sound Partnership adopted eelgrass as a dashboard indicator of environmental health, using data from the SVMP. The SVMP uses a statistically robust sampling design and underwater videography to monitor *Z. marina* on an annual basis. This report presents the soundwide and *San Juan County-Cypress Island* focus area monitoring results from the 2009 field season.

Key Findings:

1. The results in 2009 continue to indicate a pattern of *Z. marina* decline throughout Puget Sound. This result is supported by three main findings:
    a. There have been twice as many sites with long-term declining trends in *Z. marina* area than increasing trends since 2004.
    b. More year-to-year significant declines than increases in *Z. marina* area were evident in eight out of nine sampling intervals since 2000.
    c. The multiple parameter assessment identified the *Hood Canal*, *San Juan-Straits*, and the *Central Puget Sound Regions* with evidence of *Z. marina* decline and the *Hood Canal Region* having the highest level of concern for *Z. marina* loss. The assessment found no current concern for *Z. marina* loss in the *Saratoga-Whidbey* and *North Puget Sound Region*.
2. The 2009 *Z. marina* area estimate in Puget Sound is 22,000 ± 3,600 hectares (± 95% CI). The decadal weighted mean over 2000-2009 is 21,500 ± 1,400 ha (± 95% CI). The patterns of *Z. marina* decline observed at the site level are not reflected in the soundwide areal estimate. A long-term, weighted linear regression analysis showed a marginally significant increasing trend in *Z. marina* area at the soundwide scale.
3. The first follow-up sampling of the *San Juan County-Cypress Islands* focus area, originally sampled in 2004, was completed in 2009. These data improve our understanding of the recent status and trends in *Z. marina* for this area:
    a. The *San Juan County-Cypress Island* focus area has 2,100 ± 770 ha (± 95% CI) of *Z. marina*. Overall area has not changed significantly since 2004.
    b. While the majority of sites remained stable between 2004 and 2009, losses outnumbered gains in area at individual sites. The majority of changes in depth

distribution reflect bed contraction (at 31% of sites the mean minimum depth deepened and at 28% of sites the mean maximum depth became shallower).

c. At previously identified sites of concern, declines noted since 2000 have ended at some sites (e.g., *flats55-Mitchell Bay*), while other sites continue to decline (e.g., *core002-Picnic Cove*).

Although there is a marginally significant increasing trend in *Z. marina* area, the pattern of site level decline throughout Puget Sound suggests losses are prevalent at individual sites. There is consistently greater prevalence of year-to-year and long-term declines in *Z. marina* area and depth distribution throughout the study area. There is also strong evidence of *Z. marina* decline in the *Hood Canal* region. The occurrence and soundwide distribution of sites with significant declines is of concern for habitat connectivity and ecological functions. The effect of *Z. marina* loss in areas that are considered critical nursery, forage, and migration habitat for ecologically and economically important species could affect ecosystem processes and the overall health of these areas and Puget Sound.

The SVMP met its 2009 program goals for sampling and reporting both soundwide and *San Juan County-Cypress Island* focus area results. The *San Juan-Cypress Island* focus area effort was the first subsequent sampling in the focus areas since 2004. These results provide detail assessments of *Z. marina* area and depth for each focus on a five year basis.

Priorities

The priorities for the SVMP to meet its monitoring mandate in the next year include:

1. Monitor the soundwide and focus area *Z. marina* status and trends. This includes thorough analyses of the 2005 and 2010 *Hood Canal* focus area data.
2. Disseminate reports of the *Z. marina* monitoring data. The *Z. marina* data are important to scientists and managers throughout the region and will assist the efforts of the Puget Sound Partnership in developing strategies to improve the health of Puget Sound by 2020. One such project that will make these data easily available is distribution of geospatial data and a web based data dissemination portal.
3. Analyze and synthesize the SVMP data to provide a more detailed understanding of sites with decline and changes in depth distribution throughout the study area. This effort will further develop the prevalence of sites with decline indicator and will improve efforts to track *Z. marina* in greater Puget Sound.
4. Evaluate and improve two aspects of monitoring methods:
    a. Assess the effect of sample polygon modifications on site and soundwide estimates to improve our understanding of the uncertainty caused by sample polygon delineation.
    b. Improve our understanding of the relationship between changes in overall area and areal distribution through quantitative comparison of the monitoring results over large areas and at individual sites.
5. Provide technical support and monitoring data to the Eelgrass Stressor-Response Project, Puget Sound Partnership dashboard indictor work, academics, concerned citizen groups, and others who investigate *Z. marina* in Puget Sound.

1 Introduction

The overall goal of the Submerged Vegetation Monitoring Program (SVMP) is to monitor the status and trends of *Z. marina* (eelgrass) in greater Puget Sound. *Zostera marina* is an important nearshore resource that is an indicator of estuarine health, it is distributed throughout the study area, and it provides a suite of ecological functions. In Puget Sound, *Z. marina* provides spawning grounds for Pacific herring (*Clupea harengus pallasi*), out-migrating corridors for juvenile salmon (*Oncorhynchus* spp.) (Phillips 1984, Simenstad 1994), and important feeding and foraging habitats for waterbirds such as the black brant (*Branta bernicla*) (Wilson & Atkinson 1995) and great blue heron (*Ardea herodias*) (Butler 1995).

Zostera marina has been extensively studied throughout its range. This research has generated an abundance of peer-reviewed literature and brought significant ecological and political attention to the species (e.g., Phillips 1984, Orth & Moore 1988, Krause-Jensen et al. 2003, Kemp et al. 1983, 2004, Moore & Short 2006). It responds quickly to anthropogenic stressors and has become an effective indicator of habitat condition (Dennison et al. 1993, Short & Burdick 1996, Lee et al. 2004, Kenworthy et al. 2006, Orth et al. 2006). In addition, *Z. marina* provides valued hunting grounds and ceremonial foods for Native Americans and First Nation People in the Pacific Northwest (Suttles 1951, Felger & Moser 1973, Kuhnlein & Turner 1991, Wyllie-Echeverria & Ackerman 2003).

The SVMP is implemented by the Washington State Department of Natural Resources (DNR). It supports the agency's mandate to ensure environmental protection (RCW 79.105.030) and to manage the state's resources sustainably. The DNR initiated *Z. marina* monitoring as a natural complement to its role as manager of state-owned aquatic lands and attached or embedded resources such as *Z. marina*, including all subtidal areas and a substantial amount of the state's intertidal lands.

Eelgrass monitoring also represents a key component of DNR's contribution to the Puget Sound Partnership's effort to protect and restore Puget Sound. The SVMP is one component of the Puget Sound Assessment and Monitoring Program (PSAMP), a multi-agency monitoring program coordinated by the Puget Sound Partnership (2002a). PSAMP is currently being combined into a broader monitoring program under the direction of the Puget Sound Partnership's Science Panel (Puget Sound Partnership 2009). The SVMP *Z. marina* status and trend data provide the basis for a key ecosystem indicator that has been used for integrated assessments of Puget Sound (Puget Sound Action Team 2007, 2005, 2002b). In 2009, the Puget Sound Partnership recognized *Z. marina* as an important ecosystem indicator in the Action Agenda (Puget Sound Partnership 2009). In 2010, the Puget Sound Partnership identified *Z. marina* as one of the 20 dashboard ecosystem

indicators to measure the health of Puget Sound (Puget Sound Partnership 2010). In February 2011, the Partnership adopted a target for eelgrass that reflects a 20% gain in area by 2020.

Other Washington State agencies also recognize the value of *Z. marina* as an aquatic resource. The Washington Department of Fish and Wildlife designated areas of *Z. marina* as habitats of special concern (WAC 220-110-250) under its statutory authority over hydraulic projects (RCW 77.55.021). Similarly, the Washington Department of Ecology designated *Z. marina* areas as critical habitat (WAC 173-26-221) under its statutory authority to implement the state Shoreline Management Act (RCW 90.58).
In order to satisfy a broad range of data needs, the SVMP produces results at a range of spatial scales (site, region, and soundwide scales; Figure 1-1) based on sampling at randomly selected sites. The SVMP was also designed to produce results at annual and long-term (5- and 10-year) temporal scales. The SVMP's primary programmatic performance measure is the ability to detect a 20% decline in *Z. marina* abundance with suitable statistical power over 10 years at the soundwide scale.

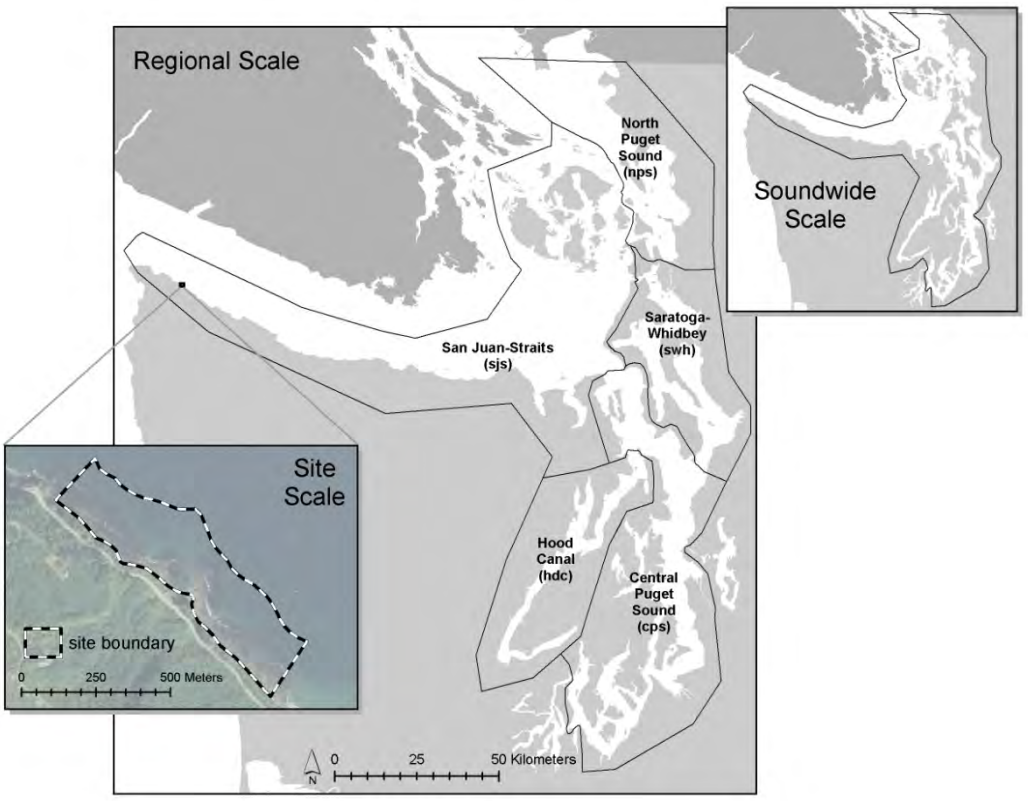

Figure 1-1. The SVMP monitors *Z. marina* condition at soundwide, regional, and site scales throughout greater Puget Sound, WA. Letters in parentheses indicate the regional prefix for site codes (see Table 2-2).

2 Methods

2.1 The SVMP Study Area and Sampling Design

The SVMP study area includes all of greater Puget Sound: the Strait of Juan de Fuca, southern Georgia Strait, the San Juan Islands, Saratoga Passage–Whidbey Basin, Hood Canal and Puget Sound proper. The extreme reaches of southern Puget Sound are excluded from the study because of the sparse distribution of *Z. marina* in this area (Figure 1-1; Berry et al. 2003).

The SVMP sampling design and statistical analyses have been thoroughly described in earlier reports (Berry et al. 2003, Dowty et al. 2005, Gaeckle et al. 2007, 2008, 2009, Skalski 2003) and technical assessments of the monitoring program (Dowty 2005, Dowty 2010, Reeves et al. 2006). The soundwide and focus area sampling designs, including specific changes for the 2009 sampling efforts, are outlined below.

2.2 Soundwide Sampling Design

2.2.1 Stratification and Sampling Frames

All potential *Z. marina* within the study area was delineated using the best available spatial data. Potential habitat was defined as the area between ordinary high water and the -6 m (MLLW) bathymetry contour. However, the actual extent of *Z. marina*, delineated with underwater video reconnaissance, is surveyed without regard to the depth boundaries of the digital data. The potential habitat was then sub-divided into either flats or fringe geomorphic categories (Berry et al. 2003). Fringe sites are 1000 m linear, alongshore, segments of the -6 m bathymetry line. Flats sites are shallow embayments and shoals.

Two additional stratifications were made to the fringe and flats strata to improve *Z. marina* area estimates. The changes included partitioning variance by dividing:

- the fringe sampling frame into narrow fringe and wide fringe based on a 305 m threshold width (Table 2-1; Berry et al. 2003).
- the flats sampling frame into persistent flats that are sampled each year and rotational flats that are subject to rotational sampling (Table 2-1; Dowty et al. 2005). Three sites were designated as persistent flats. These include: *flats11-Samish Bay North, flats 12-Samish Bay South,* and *flats20-Skagit Bay North.*

Six additional sites from the total number of sites (2,465) were non-randomly selected and designated as core sites for long-term sampling (Table 2-1; Berry et al. 2003). The six core sites include four flats sites (*core001-Padilla Bay, core002-Picnic Cove, core003-Jamestown* and *core004-Lynch Cove*), a wide fringe site (*core005-Dumas Bay*), and a narrow fringe site (*core006-Burley Spit*).

Table 2-1. Summary of SVMP sampling frames, strata and numbers of sites in 2009. Detailed explanations of SVMP sampling frame corrections and updates can be found in earlier reports (Dowty 2006a, Dowty 2006b, Gaeckle et al. 2007, 2008, 2009).

Geomorphic Category	Sampling Frame	No. Sites in Frame	Stratum	No. Sites in Stratum
fringe	fringe frame	2,392	core	2
			narrow fringe	2,027
			wide fringe	363
flats	flats frame	73	core	4
			persistent flats	3
			rotational flats	66

The site codes for all other fringe sites that are not in the core stratum have a prefix to identify the associated region (Table 2-2), and the remaining flats sites contain a prefix (flats) to identify their geomorphic type.

Table 2-2. Prefixes used in the site codes to identify the SVMP region for the fringe sites (see Figure 1-1).

Prefix	Region
cps	Central Puget Sound
hdc	Hood Canal
nps	North Puget Sound
sjs	San Juan Islands-Strait of Juan de Fuca*
swh	Saratoga Passage-Whidbey Basin*

* Note: the San Juan Islands-Strait of Juan de Fuca Region is referred to as the *San Juan-Straits Region* and the Saratoga Passage-Whidbey Basin Region is referred to as the *Saratoga-Whidbey Basin Region* throughout the report.

2.2.2 Rotational Design and Site Selection

Yearly site selection follows a rotational design in the narrow fringe, wide fringe and rotational flats strata (Berry et al. 2003, Dowty 2005, Dowty et al. 2005, Gaeckle et al. 2007, 2008, 2009). The core stratum (6 sites) and the persistent flats (3 sites) stratum are not subject to rotation and are completely surveyed each year (Table 2-3; Dowty et al. 2005).

2.2.3 Soundwide Sites

A total of 79 sites were selected in 2009 as part of the soundwide sample design. The sites were distributed in the core, persistent flats, and rotational flats and fringe strata throughout the five regions of greater Puget Sound (Figure 2-1). There were 63 matching sites from 2008 to 2009 that were used to calculate the soundwide change estimate (Table 2-3). Regional *Z. marina* condition is evaluated annually using a multiple parameter assessment and change within each region is evaluated at five year intervals as part of the focus area effort (Section 2.3).

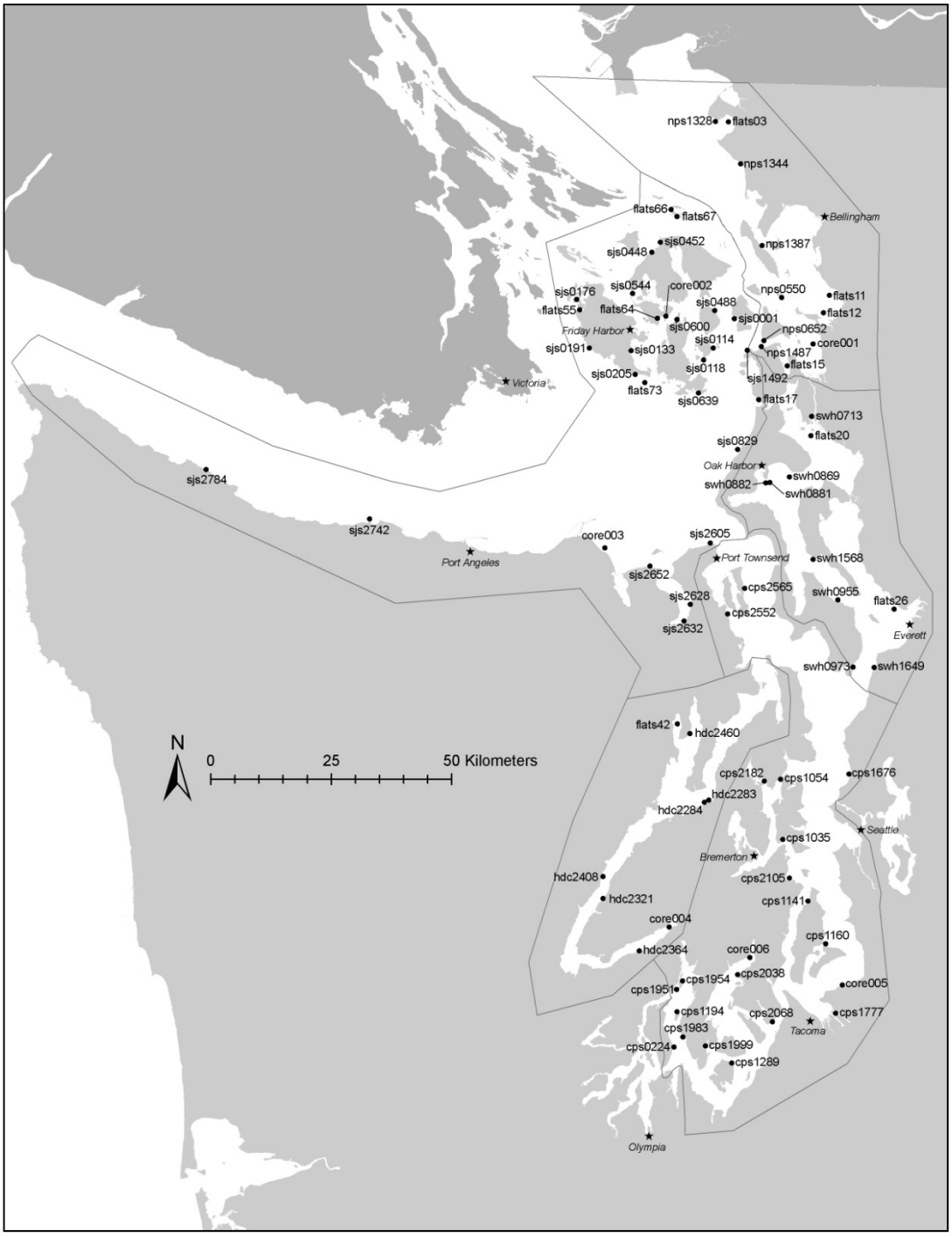

Figure 2-1. Sites sampled in 2009 for the SVMP soundwide study (n=79).

Table 2-3. Distribution of the 2009 sample sites by stratum and region. The distribution of the 2008-2009 matching sites used to calculate the annual change estimate is also listed.

2009	CPS	HDC	NPS	SJS	SWH	Total
SOUNDWIDE						
core	2	1	1	2	0	6
flats – persistent	0	0	2	0	1	3
flats – rotational	0	1	2	6	1	10
narrow fringe	16	4	2	19	4	45
wide fringe	3	2	4	2	4	15
						79
2008 – 2009 Matching Sites						
flats	0	2	3	7	2	14
fringe	18	4	5	14	8	49
						63

2.3 Focus Area Sampling Design and Site Selection: San Juan County-Cypress Island

In 2009, the SVMP performed its second assessment of the *San Juan County-Cypress Island* focus area (Figure 2-2). The sites sampled for the 2009 *San Juan County-Cypress Island* focus area were identical to the 2004 effort with the exception of *flats73-Salmon Bank* (Dowty et al. 2005, Dowty 2010). *Flats73-Salmon Bank* was not included in the 2004 focus area sampling but was added to the core stratum because of its large size and influence to the overall focus area *Z. marina* estimate. For this site, 2003 data collected by the Friends of the San Juans (Slocomb et al. 2004) was used as an approximation of 2004 conditions. Sampling the same sites in 2004 and 2009 provides data to perform a relative change assessment in the focus area between the two sample years – a statistically more powerful analysis compared to the absolute change assessment (Dowty 2010). Sites sampled in the soundwide sample pool, and subject to rotate out on a 5 year basis, also contribute to the focus area estimates. These sites varied between 2004 and 2009 (Table 2-4) resulting in a higher focus area sample effort in 2009 (Dowty et al. 2005, Figure 2-2, Table 2-5).

Table 2-4. 2004 and 2009 soundwide sites that contributed to the *San Juan County-Cypress Island* focus area *Z. marina* estimates for each sample year. Asterisk (*) identifies a site that is in both the focus area and soundwide sample pools for that particular year.

2004	2009
core002	core002
flats62	flats55*
sjs0081	flats64
sjs0311	flats66
sjs0351	flats67*
sjs0617	flats73*
sjs0635	sjs0001
sjs0649	sjs0114
sjs0683	sjs0118
sjs0695	sjs0133
	sjs0176
	sjs0191
	sjs0205
	sjs0448
	sjs0452
	sjs0488
	sjs0544

2004	2009
	sjs0600
	sjs0639

Table 2-5. The total number of sites used to calculate the *Z. marina* area in the *San Juan County-Cypress Island* focus area. The total was calculated as the combination of the sampling effort by stratum for the focus area sampling (Focus *n*) as well as sites sampled as part of the soundwide study (Soundwide *n,* Table 2-4). *Flats55-Mitchell Bay*, *flats67-Fossil Bay,* and *Flats73-Salmon Bank* were in both the focus area and soundwide sample pools but are only sampled and counted once (Focus *n*).

	2009 San Juan County-Cypress Island Focus Area			
	Stratum	Focus *n*	Soundwide *n*	Total *n*
flats strata	flats	8	4	12
fringe strata	narrow	20	13	33
	wide	0	0	0
total		28	17	45

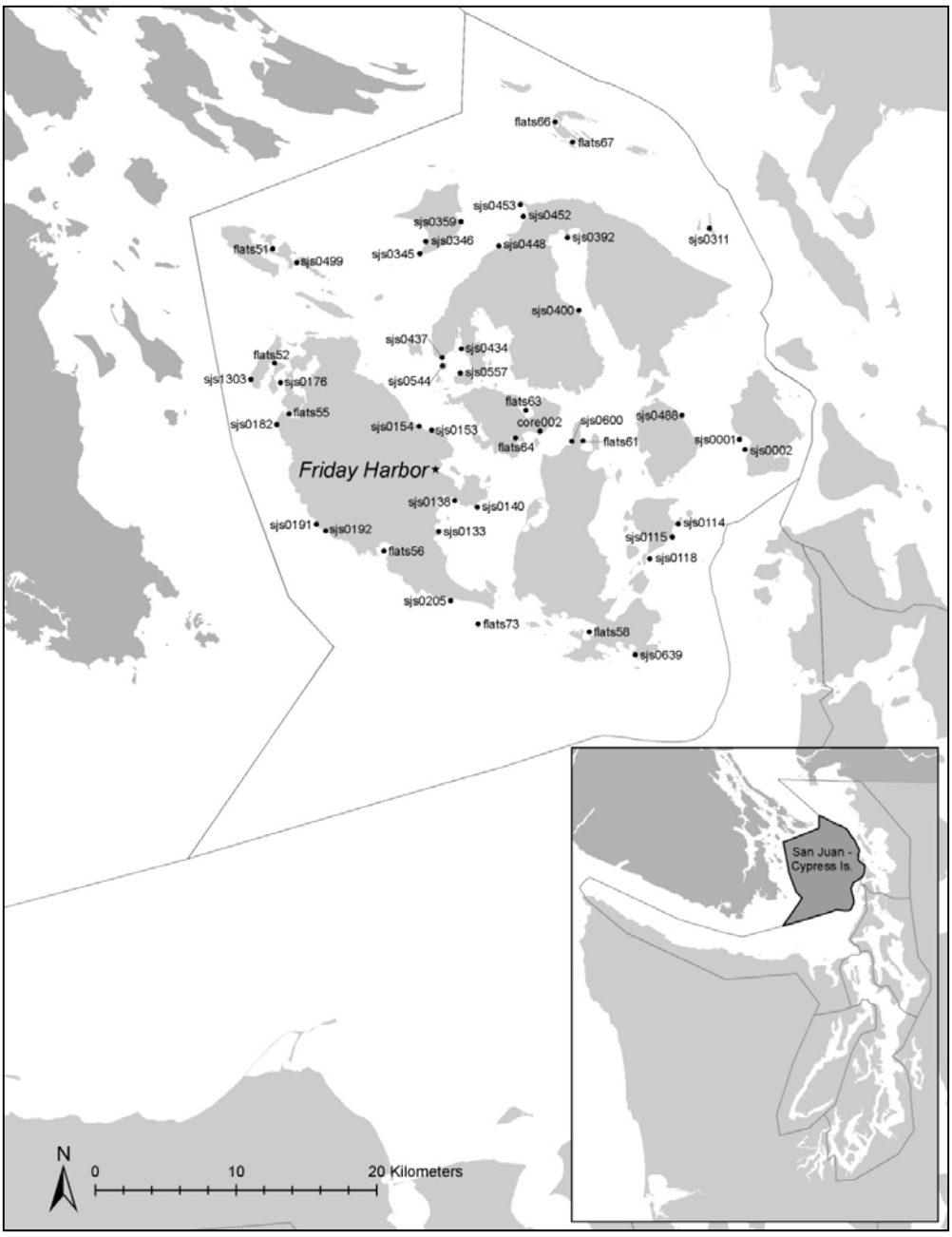

Figure 2-2. Sites sampled for the *Z. marina* estimate in the 2009 *San Juan County-Cypress Island* focus area (n = 45).

2.4 Site Sampling

At each site, underwater videography was used to sample the presence of *Z. marina* along random transects in a modified line-intercept technique (Norris et al. 1997). The random transects are restricted to an area, the eelgrass polygon, that represents a mosaic of *Z. marina* of varying density. This area is delineated from reconnaissance, available data from previous years, and other sources (e.g., PSEA 1987, ShoreZone Inventory 2001) prior to sampling. The random transects, oriented perpendicular to shore, extend beyond the

shallow and deep edges of the sample area. The target number of 11 random transects varies in practice and depends on the precision of previous site estimates.

The video sampling resolution is nominally one square meter and *Z. marina* is categorized as present or absent based on the observation of rooted shoots within the video field of view. The fractional cover of *Z. marina* along transects is used to calculate site *Z. marina* area. The depth at which *Z. marina* grows along each transect is used to estimate mean maximum and minimum depth of *Z. marina* relative to Mean Lower Low Water (MLLW) at each site and summarized within each region.

A 5 m aluminum skiff is used to sample sites where obstructions prevent the primary 11 m research vessel from safely accessing the full extent of the sample area. The data collection method at these sites varies from normal protocols; *Z. marina* presence and absence is determined from interpretation of a BioSonics echosounder echogram in concert with camera observations (Sabol et al. 2002).

Further details of site sampling methods are provided in earlier SVMP reports (Berry et al. 2003, Dowty et al. 2005, Gaeckle et al. 2007, 2008, 2009).

2.5 Video Data Processing and Analysis

Technicians review the video from the random transects at each site and classify *Z. marina* presence and absence. The fundamental video processing procedures are described in earlier publications (Berry et al. 2003, Dowty et al. 2005, Gaeckle et al. 2007, 2008, 2009; Reeves et al. 2006).

2.5.1 Data Analysis

Zostera marina Area Estimation

The probabilistic sampling design allows for statistical extrapolation methods to calculate the status of *Z. marina* area within each stratum, and on a site and soundwide basis (Skalski 2003). Status estimates in each region are produced every five years as part of the rotating focus area study. In focus areas, the *Z. marina* area estimate is calculated from the sites selected for the focus area sampling plus any sites selected for the soundwide sampling located in the focus area (Table 2-5, Dowty et al. 2005).

Zostera marina Change Analysis

The sampling design allows for change analyses at multiple temporal and spatial scales (Berry et al. 2003, Dowty 2005, Skalski 2003). The SVMP is designed to detect five and 10-year trends in *Z. marina* area at the site and soundwide scales using a test for a significant linear regression slope. For the soundwide analysis, a weighted regression is used to account for heterogeneous variances across the data record (i.e., 2003 to 2004). Furthermore, documentation of the shallow and deep edge of the seagrass bed provides a basis to detect change in *Z. marina* depth distribution at the site-level. At all scales, long-term trend calculations rely on linear regression analysis of status estimates. Methods to assess year-to-year change vary depending on the spatial scale of the analysis.

At the site-level and at the focus area, temporal change was assessed and tested for significance based on the calculation of relative change. Confidence intervals, measures of estimate precision, were calculated using analytical and Monte Carlo statistics.

At the soundwide level, year-to-year change was assessed using the paired sites sampled in consecutive years. Confidence intervals are derived through Monte Carlo simulations.

Multiple Parameter Assessment of Region-Level Change

Multiple parameters were assessed to determine *Z. marina* condition in each region relative to the other regions. The multiple parameter analysis assessed the number of significant changes (positive or negative, α=0.05) relative to the cumulative number of significant tests in each region from 2000 to 2009. The four parameters used to determine the status of *Z. marina* at the regional level include:

- Site-level *Z. marina* change: the number of sites with a significant change in *Z. marina* area from one year to the next.
- Deep edge depth change: the number of sites with a significant change in the deep edge depth of *Z. marina* from one year to the next.
- Shallow edge depth change: the number of sites with a significant change in the shallow edge depth of *Z. marina* from one year to the next.
- Five-year trends: the number of sites with significant five-year trends in area.

The primary goal of the multiple parameter assessment was to identify the status of *Z. marina* in each region based on the proportion of significant positive or negative indicators of *Z. marina* change. Another goal of the multiple parameter assessment was to identify regions with the greatest frequency of change (variability), identified as the regions with the greatest proportion of change, whether positive or negative. Each region was classified based on high, moderate, or low concern for *Z. marina* decline.

Multiple Parameter Assessment of Site-Level Change

All sites sampled between 2000 and 2009 were evaluated to determine the proportion of negative indicators of *Z. marina* change. The indicators included change in *Z. marina* area, change in *Z. marina* maximum depth, and change in *Z. marina* minimum depth from 2002-2009, and the results of five-year trend analyses were added to the assessment for 2005 through 2009. Sites with greater than 20% significantly negative tests results were classified as having strong evidence of *Z. marina* decline. Sites with significant negative tests results between 10-20% were classified as having evidence of *Z. marina* decline.

3 Results

3.1 Field Effort Summary

In 2009, the SVMP sampled 106 sites over 56 days from May through September (Table 3-1). The level of effort in 2009 remained consistent with the previous years; 79 sites were sampled as part of the soundwide effort while an additional 28 sites were sampled for the *San Juan County-Cypress Island* focus area effort (Table 3-1). The average number of random videography transects per sites was 13 (Table 3-1) and ranged from 7 (*hdc2364-Forest Beach*) to 30 (*flats63-Blind Bay).*

Table 3-1. Summary of the SVMP sampling effort from 2000-2009. The value in parentheses ( ) indicates the number of sites sampled in the focus area for that year.

Year	Field season months	Number of sites visited	Number sampled	Sites not sampled due to obstructions	Average transects per site	Sites without *Z. marina*	Number of sampling days
2000	July – October	66	61 (0)	5	12	13	46
2001	July – October	77	74 (0)	3	13	15	54
2002	June – September	76	73 (0)	3	12	14	54
2003	July – August	76	76 (0)	0	15	12	50
2004	June – September	110	110 (28)	0	14	12	72
2005	June – September	109	108(30)	1	14	6	67
2006	June – September	101	101(24)	0	14	9	67
2007	June – October	111	111(32)	0	14	21	71
2008	June – September	107	107(31)	3	13	19	61
2009	June – September	106	106(28)	0	14	20	56

Two sites in 2009 were sampled from a 5 m aluminum skiff with the Biosonics echosounder due to large rocks and shoaling (*flats56-False Bay*) and restricted navigation because of the Tommy Thompson Trail trestle that separates the northern and southern sections of Fidalgo Bay (*flats15-Fidalgo Bay*).

3.2 Status of Zostera marina

3.2.1 Soundwide *Z. marina* area

In 2009, the estimate of *Z. marina* in Puget Sound was 22,000 ± 3,600 ha (± 95% CI) and was not significantly different from the 2008 soundwide estimate (Figure 3-1, Appendix E). The 10 year weighted mean of *Z. marina* in Puget Sound was estimated at 21,500 ± 1,400 ha (± 95% CI).

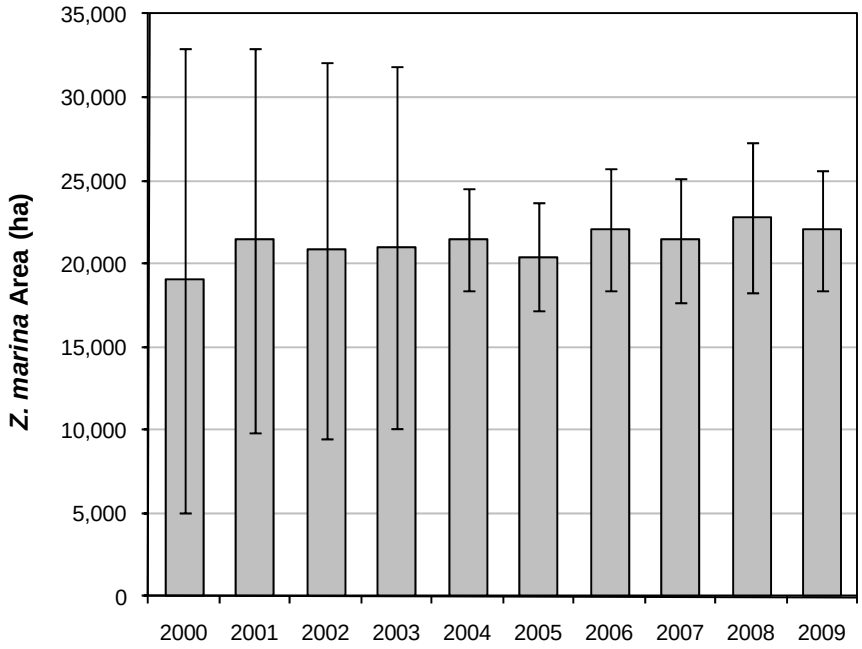

Figure 3-1. Estimates of total *Z. marina* area in the study area from 2000-2009. Error bars are 95% confidence intervals.

At the site level, the average *Z. marina* fraction ranged from 0.002 (*sjs2632-Between Sunset and City Lakes*) to 0.84 (*flats11-Samish Bay N.*) with an average of 0.43 (Appendix A and Appendix B). The *Z. marina* area estimates for individual sites ranged from 0.05 ha (*swh0869-Polnell Point Light W.*) to 3,155 ha (*core001-Padilla Bay*) (Appendix A and Appendix B).

3.2.2 Focus area *Z. marina* area

The 2009 *San Juan County-Cypress Island* focus area *Z. marina* estimate was 2,100 ± 770 ha (95% CI; Figure 3-10) calculated from 17 soundwide sites and 28 focus area sites (Appendix A and Appendix B). Eighty-two percent of the *Z. marina* area in the *San Juan County-Cypress Island* focus area was in the fringe strata and the remaining *Z. marina* was observed in the core (10%) and flats (8%) stratum (Table 3-2, Figure 3-2). The core stratum consisted of *core002-Picnic Cove* and *flats73-Salmon Bank*, 1.1 and 98.9% of the core stratum *Z. marina* area respectively.

Table 3-2. *Zostera marina* area and uncertainty by stratum for the *San Juan County-Cypress Island* focus area. The number of sites used in each estimate (*n*) and the total number of sites in the stratum (*N*) are shown.

Strata	*n*/*N*	*Z. marina* Area (ha)	Variance (ha^2)	s.e.	c.v.	95% CI	Proportion of *San Juan Co.-Cypress Is. Z. marina* area
Core	2/2	206	289	17	0.08	33	10%
Flats	10/19	168	637	25	0.15	49	8%
Fringe	33/500	1,732	152,094	390	0.23	764	82%
fringe-absent*	5/125	0					
fringe-other*	28/375	1,732	152,094	390	0.23	764	
Total	45/521	2,106	153,020	391	0.19	767	

* A description of fringe-absent and fringe-other can be found in Dowty et al. (2005).

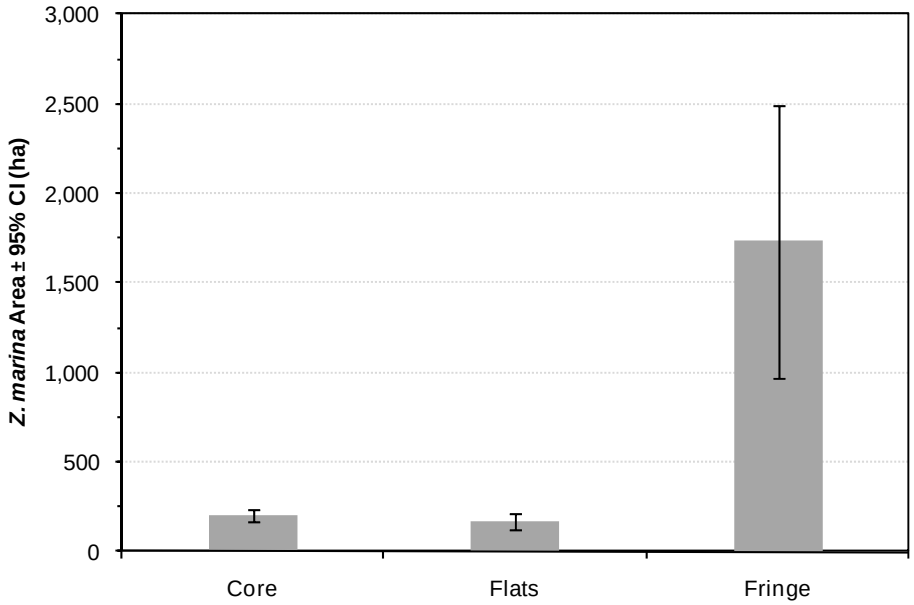

Figure 3-2. *Zostera marina* area by stratum for the *San Juan County-Cypress Island* focus area. The core strata consisted of *core002-Picnic Cove* (1.1% of the core strata area) and *flats73-Salmon Bank* (98.9% of the core strata area). Error bars are 95% confidence intervals.

3.3 Change in Z. marina

3.3.1 Soundwide Change in *Z. marina* Area

The *Z. marina* area change estimate based on 63 matching sites between 2008 and 2009 was -2.6% (± 10.4%, Monte Carlo 95% confidence intervals). The soundwide change in *Z. marina* was not statistically significant ($\alpha = 0.05$; Figure 3-3).

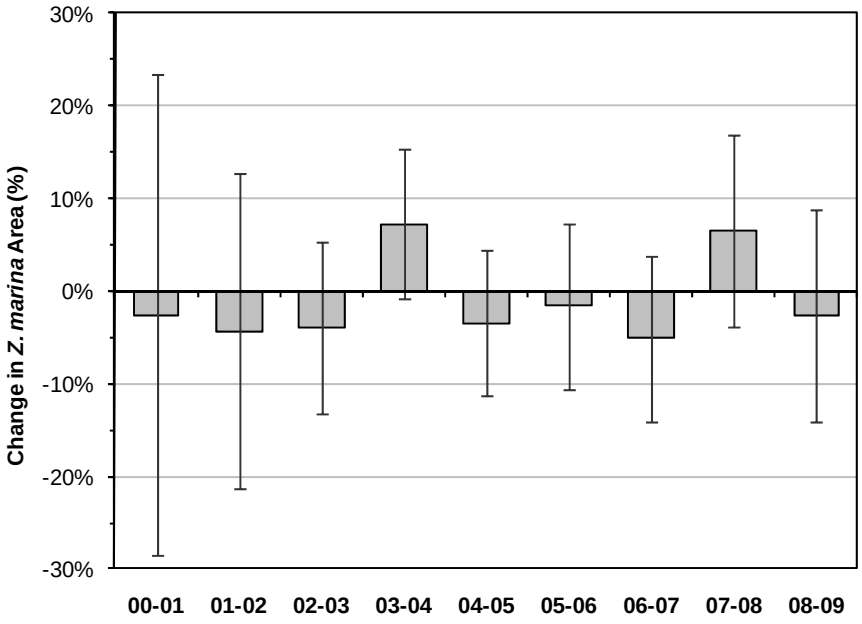

Figure 3-3. Overall soundwide annual change in *Z. marina* area from 2000-2009. Error bars are Monte Carlo 95% confidence intervals. Error bars that overlap the 0% line indicate that the change for the time period is not significant.

A weighted regression assessed the soundwide trend in *Z. marina* area from 2000 to 2009 (Figure 3-4). The weighted regression analysis detected a marginally significant increasing trend in area (two-tailed test, P=0.0576, α=0.05) over the last ten sampling efforts.

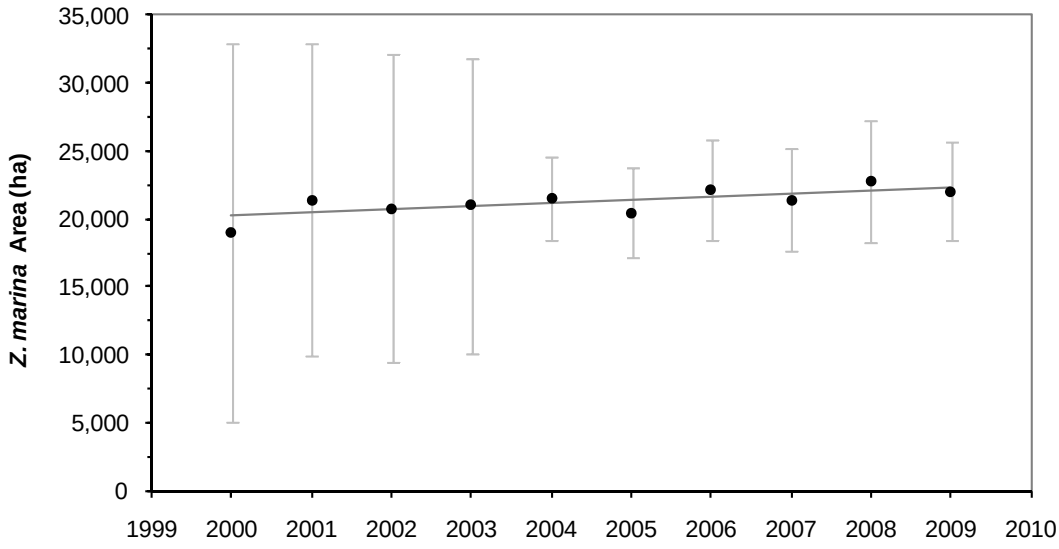

Figure 3-4. Soundwide trend analysis of *Z. marina* area from 2000 to 2009. The weighted regression analysis detected a marginally significant trend in soundwide *Z. marina* area since 2000 (P=0.0576). Error bars are 95% confidence intervals.

However, the pattern of soundwide decline continues to be observed in year-to-year, site level changes in *Z. marina* area. Between 2008 and 2009, a greater proportion of sites decreased (2 sites) in *Z. marina* area compared to sites that showed an increase in *Z. marina* area (1 site). A similar pattern where a greater proportion of sites throughout Puget Sound showed significant *Z. marina* loss compared to sites with significant *Z. marina* gains (α=0.05; Figure 3-5) was observed from 2000 – 2007. It was only from 2007 – 2008 that a greater number of sites (2) had an increase in *Z. marina* area compared to sites (1) with a decrease in *Z. marina* area (Figure 3-5).

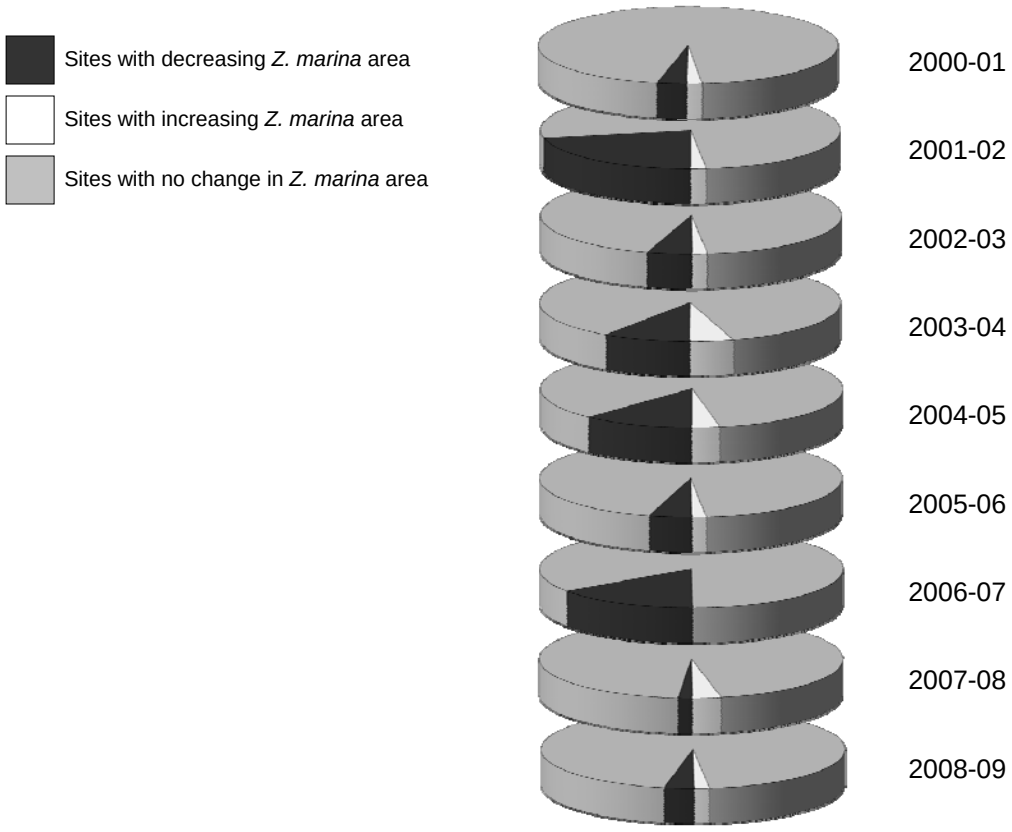

Figure 3-5. Proportion of sites with statistically significant year-to-year increases and decreases in *Z. marina* area (**α**=0.05). Sites with no significant change in *Z. marina* area are also shown. The number of sites compared each year ranged from 60-67. This figure has been adjusted slightly from a previously published figure (Gaeckle et al. 2008) as a result of a thorough data review (Gaeckle 2009).

The statistical significance of these results was tested by determining the probability of obtaining 8 years with more sites decreasing in *Z. marina* area than increasing under the null hypothesis that each site had an equal probability of experiencing decreasing or increasing *Z. marina* area (Dowty 2009). The rejected null hypothesis (P = 0.0045) provides strong statistical evidence that there is a prevalence of declining sites.

3.3.2 Site-Level Change in *Z. marina* Area

Year-to-Year Change in Z. marina Area

There were 63 sites sampled in 2008 and 2009 that were tested for year-to-year change in *Z. marina* area at the site-level (Table 2-3, Figure 3-6, Appendix C). From 2008-2009, two sites showed a decrease and one site showed an increase in *Z. marina* area (α=0.05; Figure 3-6, Figure 3-7). When tested with α=0.2, six additional sites had significant changes (2 increased, 4 decreased) from 2008 to 2009 (Figure 3-6, Figure 3-7, Appendix C).

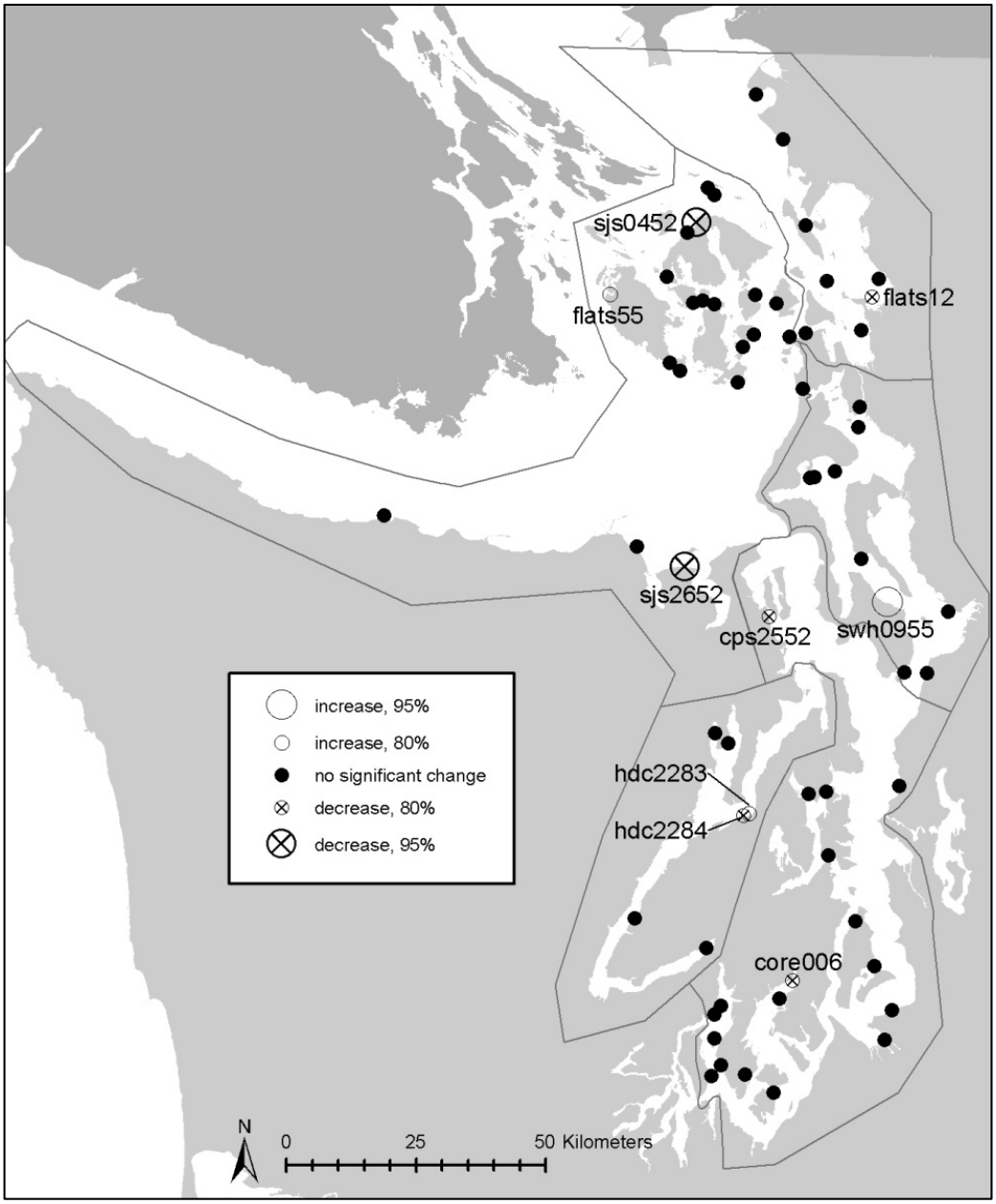

Figure 3-6. Sites with significant relative change in *Z. marina* area from 2008 to 2009 (**α**=0.2 and **α**=0.05, n = 63). Sites that were tested but exhibited no significant change are also shown.

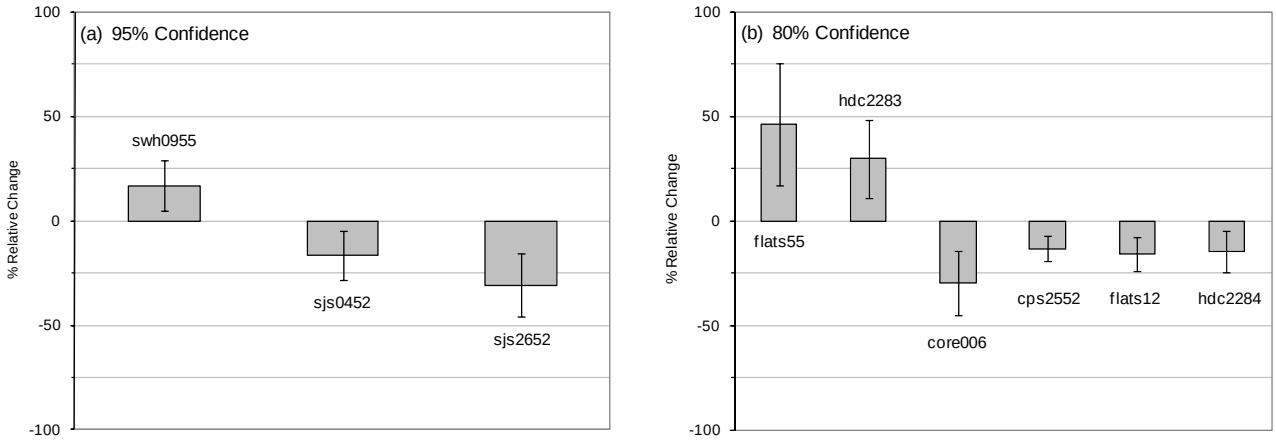

Figure 3-7. Estimated relative change in *Z. marina* area from 2008 to 2009 for sites with significant change (**α**=0.2 and **α**=0.05). Error bars are associated (a) 95% and (b) 80% confidence intervals.

Trends in Site-Level Z. marina Area

Through 2009, 38 sites were sampled for four years or more and tested for trends in *Z. marina* area. Nine sites had significant trends when tested at α=0.05 (Table 3-3, Figure 3-8, Appendix H). Sites with a significant increasing trend in *Z. marina* area included *flats11-Samish Bay N.*, *flats67-Fossil Bay*, *cps1035-NE of White Point*, and *swh0955-West of Langley* (α=0.05, Table 3-3, Figure 3-8, Appendix H). Sites with a significant declining trend included *core002-Picnic Cove*, *core005-Dumas Bay*, *core006-Burley Spit*, *flats26-Snohomish Delta N.*, and *sjs0205-E. of Eagle Point* (α=0.05, Figure 3-8, Appendix H). There were nine additional sites with an increasing (2 sites) or decreasing (7 sites) trend when data were analyzed at a lower level of significance (α=0.2, Table 3-3, Figure 3-8, Appendix I).

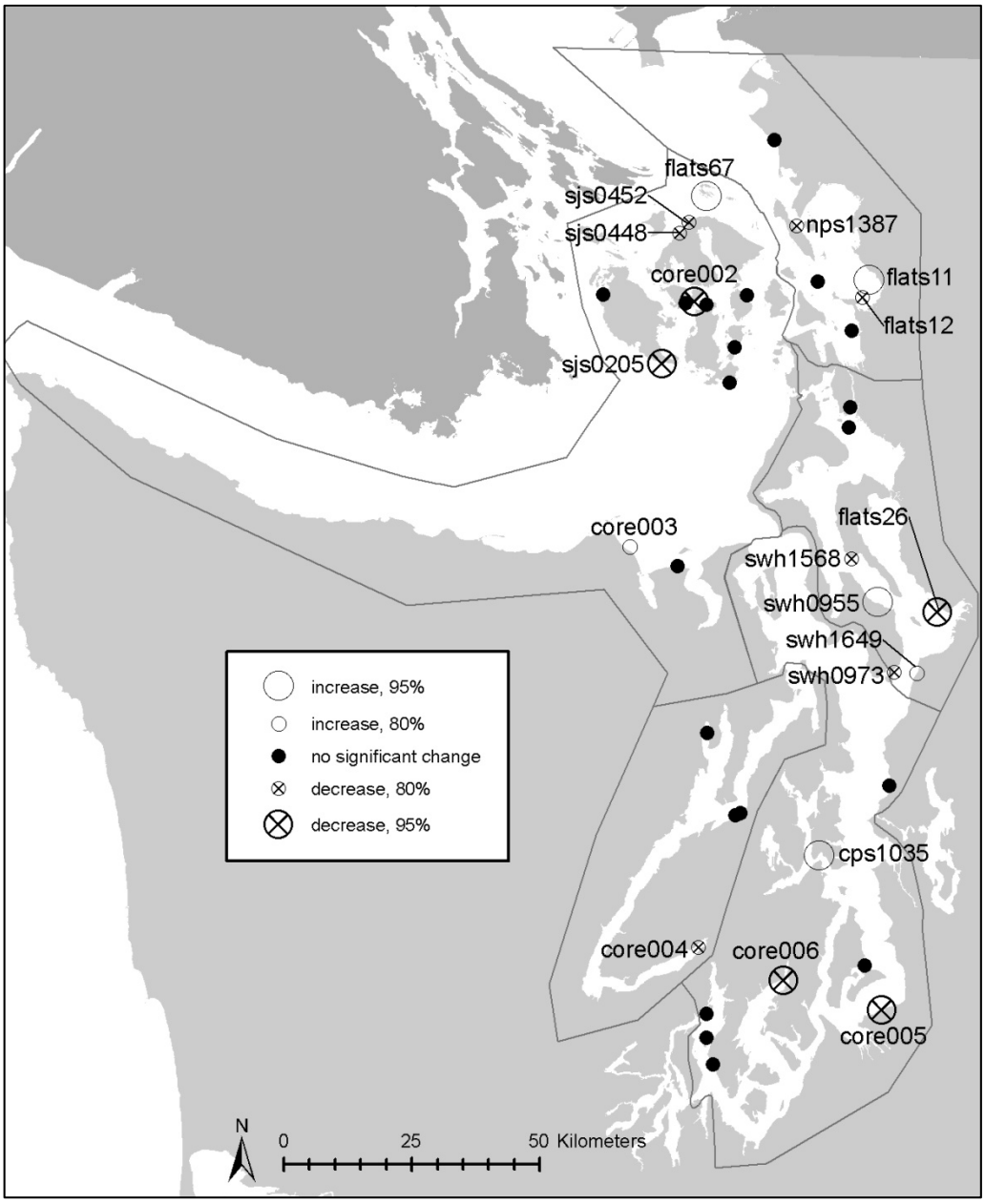

Figure 3-8. Sites sampled in 2009 with significant trends in *Z. marina* for four years or more (**α**=0.2 and **α**=0.05). Sites that were tested but exhibited no significant trend are also shown.

Table 3-3. *Zostera marina* area trends observed for four years or more through 2009 at two levels of significance. The estimated trends are based on the regression slope and the percent change values are relative to the *Z. marina* area calculated the first year the site was sampled. Site codes followed by an asterisk (*) indicate sites with no *Z. marina* present (Appendix J).

Direction of Trend	Site code	Site name	Site area (ha)	Years of trend	p - value	α	Estimated trend (ha yr^{-1})	Equivalent annual relative change (% yr^{-1})
	flats11	Samish Bay N.	1,253.3	9	0.004	0.05	+19.8	+11
	flats67	Fossil Bay	6.7	6	0.018	0.05	+0.4	+7
increasing	cps1035	NE of Point White	0.1	5	0.011	0.05	+0.02	+74
area	swh0955	West of Langley	9.6	5	0.002	0.05	+0.8	+12
	core003	Jamestown	507.5	10	0.048	0.2	+8.7	+3
	swh1649	Nelson's Corner	5.4	5	0.162	0.2	+0.1	+1
	core002	Picnic Cove	2.3	10	0.001	0.05	-0.2	-7
	core005	Dumas Bay	1.0	10	0.031	0.05	-0.2	-10
	core006	Burley Spit	1.4	10	0.001	0.05	-0.6	-13
	flats26	Snohomish Delta N.	99.1	5	0.023	0.05	-12.1	-10
	sjs0205	E. of Eagle Point	10.6	5	0.049	0.05	-0.7	-5
decreasing	core004	Lynch Cove	119.7	10	0.069	0.2	-4.3	-2
area	flats12	Samish Bay S.	606.8	6	0.087	0.2	-29.3	-4
	nps1387	Sunrise Cove	3.7	4	0.198	0.2	-0.1	-2
	sjs0448	S. of West Beach	4.9	4	0.085	0.2	-0.1	-3
	sjs0452	S. of Pt. Doughty	11.9	4	0.199	0.2	-0.6	-5
	swh0973	North Possession	12.6	4	0.197	0.2	-0.4	-4
	swh1568	Lowell Point	0.2	5	0.168	0.2	-0.01	-3
	core001	Padilla Bay	3,155.2	9				
	flats20	Skagit Bay N.	200.8	10				
	flats42	Quilcene Bay	108.6	5				
	flats55	Mitchell Bay	4.9	4				
	flats64	Squaw Bay	1.5	4				
	cps1160	Tramp Harbor	2.4	4				
	cps1194*	N. Herron Island		4				
	cps1676	Broadview	5.2	5				
	cps1951*	S. of Stretch Island		5				
	cps1983*	N. Joemma Beach		4				
no trend	hdc2283	E. of Warrenville	12.3	4		no trend	no trend	no trend
	hdc2284	Warrenville	8.2	5				
	nps0550*	Vendovi East Light		4				
	nps1344	E. of Ferndale	0.4	5				
	sjs0118	SE Decatur Island	24.0	4				
	sjs0488*	E. of Blakely Peak		4				
	sjs0600	Odlin County Park	2.9	4				
	sjs0639*	Blind Island		5				
	sjs2742*	Between Agate & Crescent Beach		5				
	swh0713	Entrance Shelter Bay	0.7	4				

Sites sampled can be assessed for long-term trends in *Z. marina* area after 5 consecutive years of sampling data (2004). The assessment of sites with multiple year trends (≥ 5 years) in *Z. marina* between 2004 to 2009 has identified more sites with significant decreasing long-term trends in *Z. marina* area relative to sites with increasing long-term trends (α = 0.05, Figure 3-9, Table 3-4).

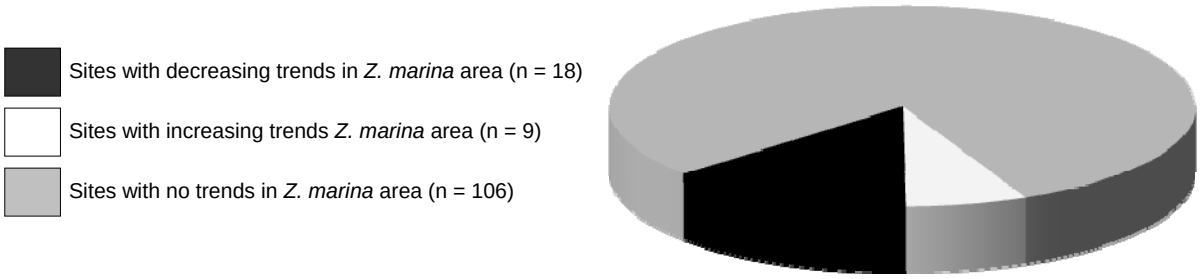

Figure 3-9. Proportion of sites with statistically significant long-term (≥ 5 years) increasing and decreasing trends in *Z. marina* area (**α**=0.05) from 2004-2009. Sites with a significant trend that spanned > 5 years were included in the analyses only for the last year of the trend. Sites with no significant trend in *Z. marina* area are also shown. Total number of sites tested for significant long-term trends in *Z. marina* area = 135.

Table 3-4. Sites with significant (**α**=0.05) long-term (≥ 5 years) increasing and decreasing trends in *Z. marina* area from 2004 to 2009. Sites with no significant trend in *Z. marina* over the sample interval are not listed (n=106).

Year	Increasing trend	Years of trend	Decreasing trend	Years of trend
2004			nps1363	5
			swh1625	5
2005	core003	6	hdc2338	6
	flats35	6	hdc2359	6
2006	sjs0617	5	flats18	7
			hdc2239	5
2007	flats20	8	cps1175	5
			hdc2344	5
			sjs0635	5
			sjs0683	5
2008	cps1820	5	flats41	5
			cps1967	5
			nps0670	5
2009	flats11	9	core002	9
	flats67	6	core005	9
	cps1035	5	core006	9
	swh0955	5	flats26	5
			sjs0205	5

3.3.3 Focus area change in *Z. marina* area

The 2004 *Z. marina* estimate in the *San Juan County-Cypress Island* focus area was 1,600 ± 870 ha (± 95% CI; Figure 3-10).

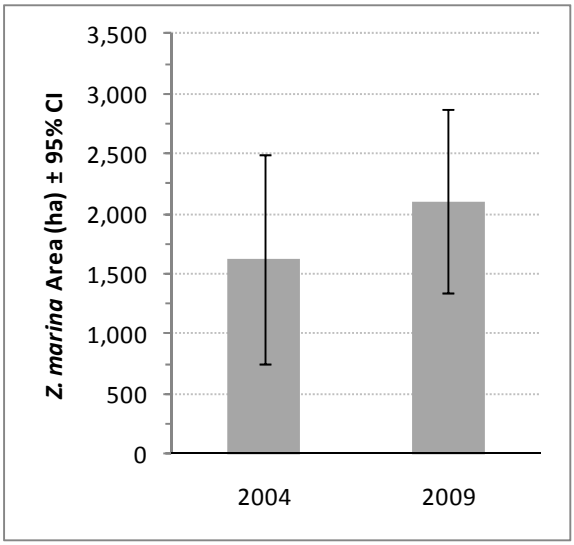

Figure 3-10. 2004 and 2009 *San Juan County-Cypress Island Z. marina* area estimate (ha, ± 95% CI). The 2004 *Z. marina* estimate is different than previously published values (Dowty et al. 2005) due to changes in data analyses (Dowty 2010).

The difference between the 2004 and 2009 *San Juan County-Cypress Island* focus area *Z. marina* estimates was 484 ± 1,160 ha (± 95%; Figure 3-11). The *Z. marina* relative change estimate, based on 31 matching sites over the 5 year period, was -5.0% ± 14.7% (± 95% Monte Carlo CI). However, the 2004 to 2009 relative change estimate was not statistically significant (Figure 3-11).

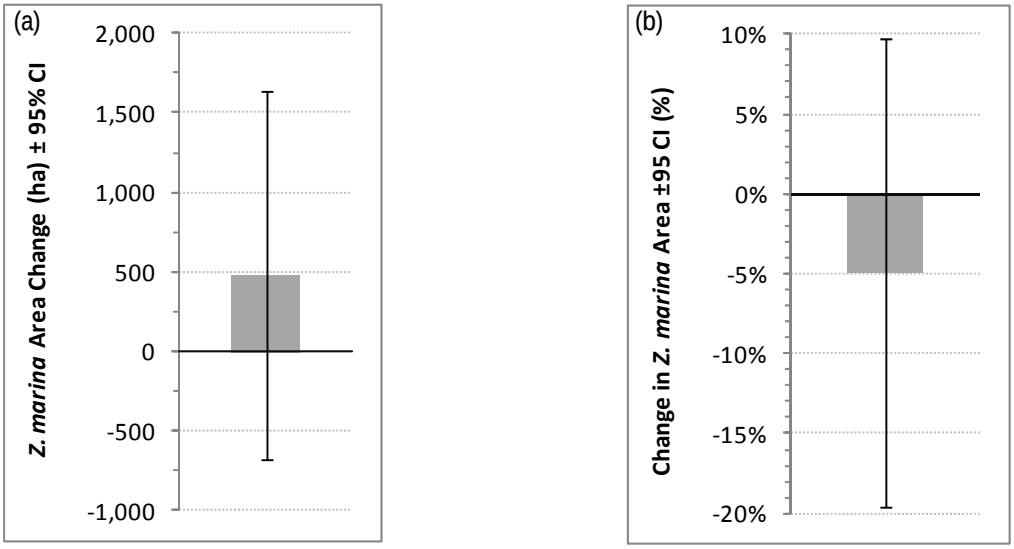

Figure 3-11. *San Juan County-Cypress Island* focus area *Z. marina* change between 2004 and 2009. The figure on the left (a) shows the difference between 2004 and 2009 *Z. marina* area estimates (ha ± 95% CI, n=46). The figure on the right (b) shows the relative change (% ± 95% Monte Carlo CI, n=31) using a more powerful approach that relies on paired sites in the two years. Neither estimate of change was statistically significant.

Of the 31 sites sampled in 2004 and 2009 that were tested for change in *Z. marina* area in the *San Juan County-Cypress Island* focus area (Figure 3-12, Figure 3-13, Appendix D), six sites showed a decrease (three with α=0.05 and three additional sites with α=0.2) and four sites showed an increase in *Z. marina* area (α=0.2; Figure 3-12, Figure 3-13, Appendix D).

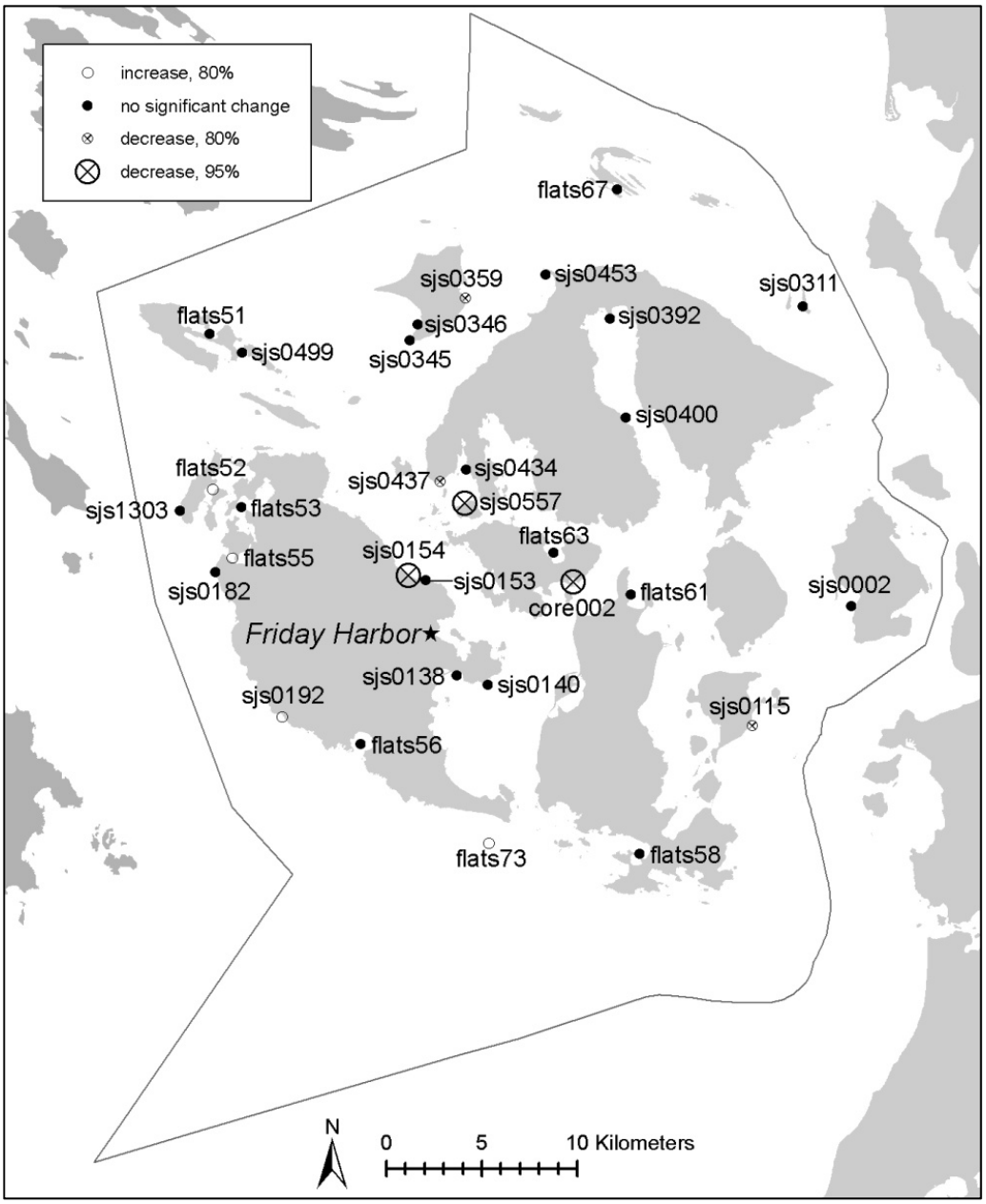

Figure 3-12. *San Juan County-Cypress Island* focus area sites with relative change in *Z. marina* between 2004 and 2009 (**α**=0.2 and **α**=0.05, n=31). Sites that were tested but exhibited no significant change are also shown. The 2004 site estimate for *flats73-Salmon Bank* was based on the 2003 Friends of the San Juans data (Slocomb et al. 2004, Dowty 2006b).

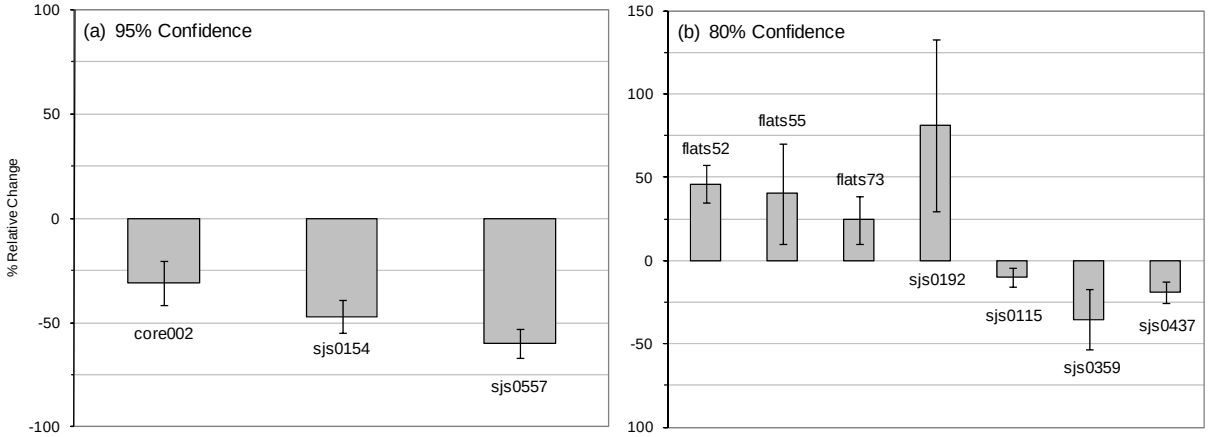

Figure 3-13. Estimated relative change in *Z. marina* area between 2004 and 2009 for focus area sites with significant change (α=0.2 and α=0.05). Error bars are associated (a) 95% and (b) 80% confidence intervals. The 2004 site estimate for *flats73-Salmon Bank* was based on the 2003 Friends of the San Juans data (Slocomb et al. 2004, Dowty 2006b).

3.4 Zostera marina Depth Distribution

3.4.1 Soundwide *Z. marina* depth distribution

Regions

The minimum and maximum depths (m, MLLW) of *Z. marina* were recorded on all transects at all sites sampled in 2009 throughout the study area (Table 3-5, Appendix F, Appendix G). The shallowest *Z. marina* depth was 0.7 m (MLLW) at *flats12-Samish Bay S.* and the deepest observed depth was -11.2 m (MLLW) at *sjs0205-E. of Eagle Point* (Appendix F). The site mean minimum and site mean maximum *Z. marina* depth ranges within the five regions did not differ from 2008 to 2009 (Table 3-5).

Table 3-5. The absolute depth and range of mean maximum and minimum *Z. marina* depths (MLLW) for all strata by region from 2002-2009. Data from the first two years of monitoring, 2000-2001, are not included because the depth sounder used during those years was less accurate.

Region	Minimum Depth (m, MLLW)		Maximum Depth (m, MLLW)	
	Absolute	Range in Site Means	Absolute	Range in Site Means
Central Puget Sound	+1.5	+0.9 to -3.5	-11.9	-0.7 to -6.9
Hood Canal	+2.3	+0.6 to -2.6	-7.6	-1.4 to -5.2
North Puget Sound	+1.6	+0.6 to -3.3	-8.6	-0.7 to -6.1
San Juan/Straits	+0.6	+0.1 to -5.9	-12.4	-2.1 to -11.0
Saratoga/Whidbey	+1.0	+0.4 to -1.8	-7.3	-0.4 to -4.9

Site-level

The 63 matching sites sampled in 2008 and 2009 were tested for significant changes in the mean minimum and maximum depth distribution. Sixteen (16) sites had a significant change from 2008 to 2009 in the mean shallow depth distribution of *Z. marina* (Table 3-6). Four sites (*cps2552-Oak Bay Ramp, flats20-Skagit Bay N., hdc2283-E. of Warrenville*, and *swh0955-W. of Langley*) had shallower mean minimum depths in 2009 compared to 2008

when tested at α=0.05. Three other sites (*cps1676-Broadview*, *cps2038-Allen Point*, and *swh1568-Lowell Point*) also had shallower mean minimum depths in 2009 compared to 2008 but only when tested at α=0.2 (Table 3-6).

The remaining nine sites had significantly deeper mean shallow depths of *Z. marina* in 2009 compared to depths measured in 2008. Four sites (*core006-Burley Spit*, *flats67-Fossil Bay*, *hdc2460-Lindsay's Beach*, and *sjs1492-Shannon Point W.*) had significantly deeper mean shallow *Z. marina* depths (α=0.05). Five additional sites (*flats55-Mitchell Bay*, *cps1160-Tramp Harbor*, *nps1487-Loverick's*, *sjs0114-Decatur Head S.*, *swh0869-Polnell Point Light W.*) had significantly deeper mean shallow depths of *Z. marina* at α=0.2 (Table 3-6).

Table 3-6. Sites with significant changes in mean minimum *Z. marina* depth (MLLW) from 2008 to 2009.

Shallow edge direction of change	Site	α	Mean minimum depth (m, MLLW)		
			2008	2009	Difference
shallower (expanding)	cps2552	0.05	-0.1	0.2	0.3
	flats20	0.05	-0.5	-0.1	0.5
	hdc2283	0.05	-0.4	0.0	0.4
	swh0955	0.05	-0.4	-0.1	0.3
	cps1676	0.2	-0.7	-0.4	0.3
	cps2038	0.2	-0.9	-0.7	0.2
	swh1568	0.2	-1.8	-1.4	0.4
deeper (receding)	core006	0.05	-1.0	-1.3	-0.3
	flats67	0.05	-2.9	-3.4	-0.5
	hdc2460	0.05	-0.9	-1.7	-0.8
	sjs1492	0.05	-2.0	-4.1	-2.1
	flats55	0.2	-2.8	-3.5	-0.7
	cps1160	0.2	-0.1	-0.2	-0.1
	nps1487	0.2	-0.1	-0.3	-0.2
	sjs0114	0.2	-1.6	-2.0	-0.4
	swh0869	0.2	-0.8	-1.0	-0.2

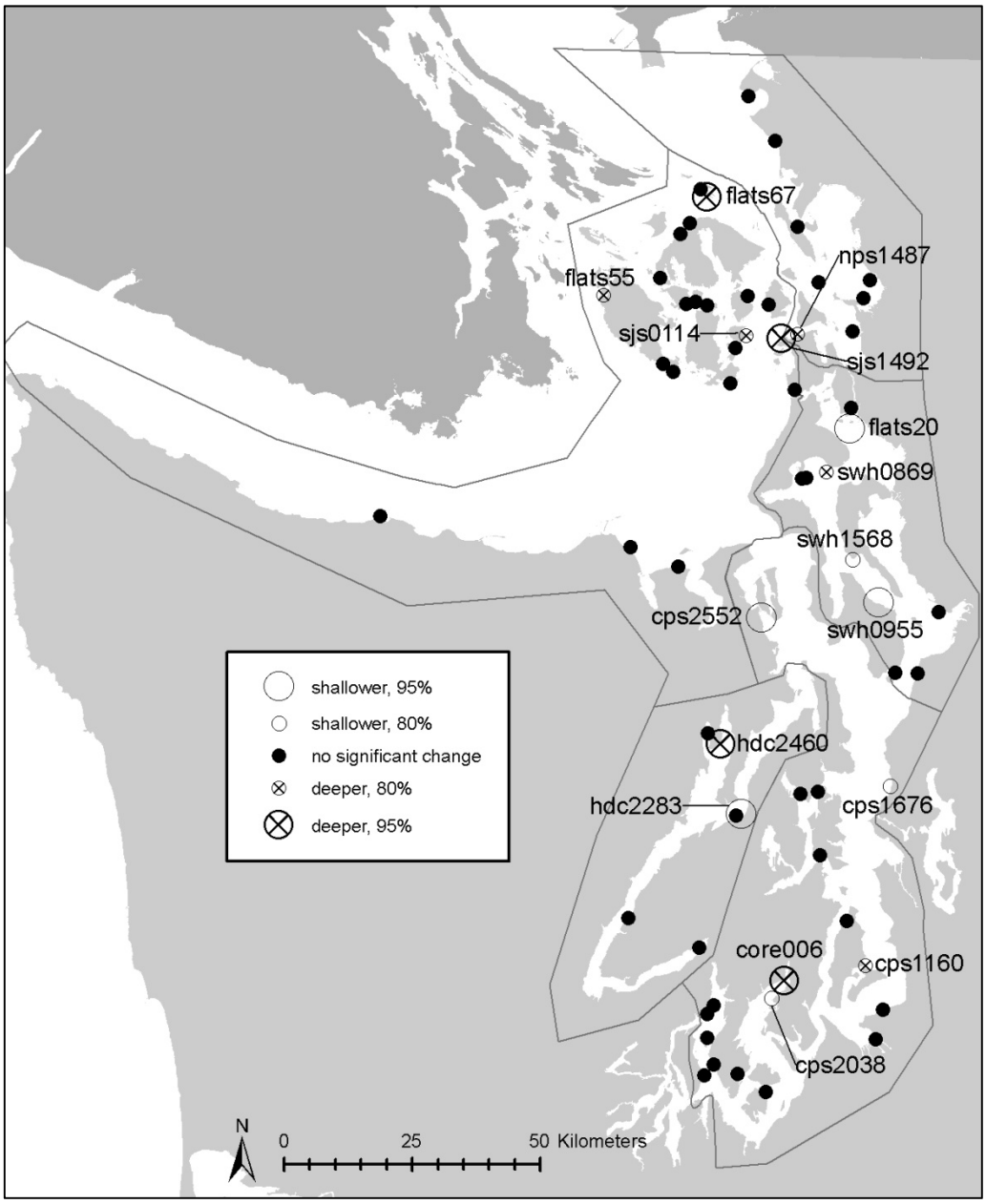

Figure 3-14. Sites with significant change in mean minimum *Z. marina* depth from 2008 to 2009 (**α**=0.2 and **α**=0.05). Sites that were tested but exhibited no significant change in the minimum depth are also shown.

There was only one site, *sjs1492-Shannon Point W.*, with a significant change in the maximum depth between 2008 and 2009 when tested at α=0.05. The mean deep edge of the *Z. marina* bed at *sjs1492-Shannon Point W.* was significantly deeper in 2009 by 2.2 m compared to the 2008 mean deep edge depth (α=0.05). Nine (9) other sites showed significant changes in the mean maximum depth between 2008 and 2009 when tested at α=0.2 (Table 3-7). Four sites (*core001-Padilla Bay, core005-Dumas Bay, core006-Burley Spit,* and *flats55-Mitchell Bay*) had significantly deeper mean maximum depths in 2009

compared to 2008 (α=0.2). The remaining five sites (*cps1676-Broadview*, *sjs0118-SE Decatur Island*, *sjs0452-S. of Pt. Doughty*, *swh0955-West of Langley*, and *swh1568-Lowell Point*) had significantly shallower mean maximum depths in 2009 compared to 2008 (α=0.2).

Table 3-7. Sites with significant changes in mean maximum *Z. marina* depth (MLLW) between 2008 and 2009.

Deep edge direction of change	Site	α	Mean maximum depth (m, MLLW)		
			2008	2009	Difference
shallower (receding)	cps1676	0.2	-4.5	-3.9	0.6
	sjs0118	0.2	-7.8	-7.6	0.2
	sjs0452	0.2	-6.9	-6.1	0.8
	swh0955	0.2	-4.0	-3.7	0.3
	swh1568	0.2	-3.2	-3.0	0.3
deeper (expanding)	sjs1492	0.05	-4.7	-6.9	-2.2
	core001	0.2	-3.2	-3.5	-0.4
	core005	0.2	-1.6	-1.7	-0.1
	core006	0.2	-2.0	-2.3	-0.3
	flats55	0.2	-4.2	-5.1	-0.9

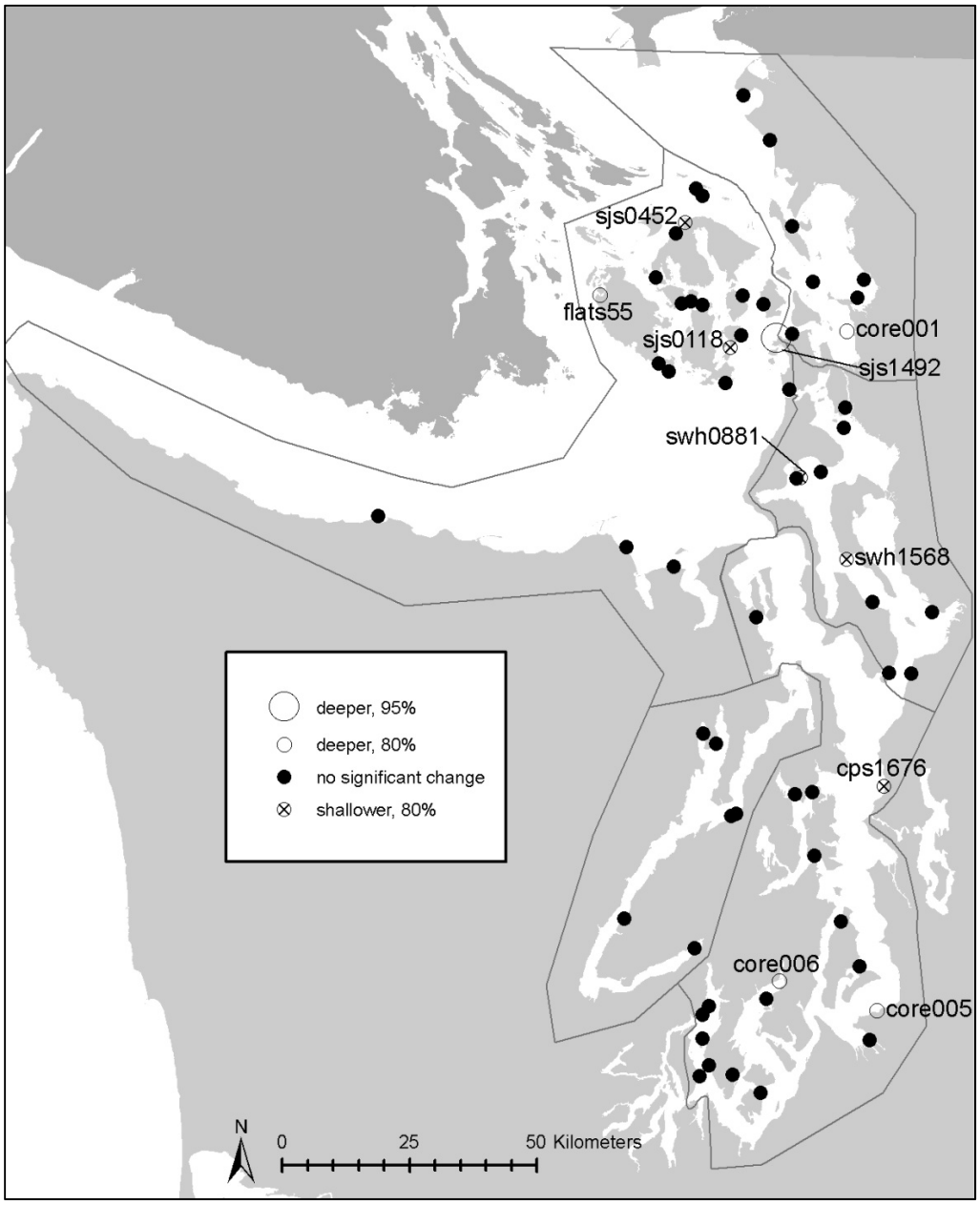

Figure 3-15. Sites with significant change in mean maximum *Z. marina* depth from 2008 to 2009 (**α**=0.2 and **α**=0.05). Sites that were tested but exhibited no significant change in the mean maximum depth are also shown.

3.4.2 Focus area *Z. marina* depth distribution

The 31 matching sites sampled in 2004 and 2009 were tested for significant changes in the mean minimum and mean maximum depth distribution. The mean minimum depth distribution of *Z. marina* at eight sites was significantly deeper in 2009 compared to the *Z. marina* depth in 2004. Five of these sites (*flats56-False Bay*, *flats67-Fossil Bay*, *sjs0434-Deer Harbor*, *sjs0437-Steep Point*, and *sjs0453-Point Doughty*) had a deeper mean minimum depth when tested at α=0.05, and three additional sites (*flats61-Shoal Bay*, *sjs0115-White Cliff*, and *sjs0359-S. of Mail Bay*) were significant at α=0.2 (Table 3-8, Figure 3-16). None of the 31 *San Juan County-Cypress Island* focus area sites sampled in 2004 and 2009 had a significantly shallower mean minimum depth in 2009 compared 2004.

Table 3-8. Focus area sites with significant changes in mean minimum *Z. marina* depth (MLLW) between 2004 and 2009.

Shallow edge direction of change	Site	α	Mean minimum depth (m, MLLW)		
			2004	2009	Difference
deeper (receding)	flats56	0.05	-0.6	-1.1	-0.5
	flats67	0.05	-2.0	-3.4	-1.4
	sjs0434	0.05	-0.6	-0.9	-0.3
	sjs0437	0.05	-1.0	-1.4	-0.4
	sjs0453	0.05	-1.0	-1.7	-0.7
	flats61	0.2	-0.1	-0.3	-0.2
	sjs0115	0.2	-1.1	-1.4	-0.3
	sjs0359	0.2	-2.5	-3.4	-0.9

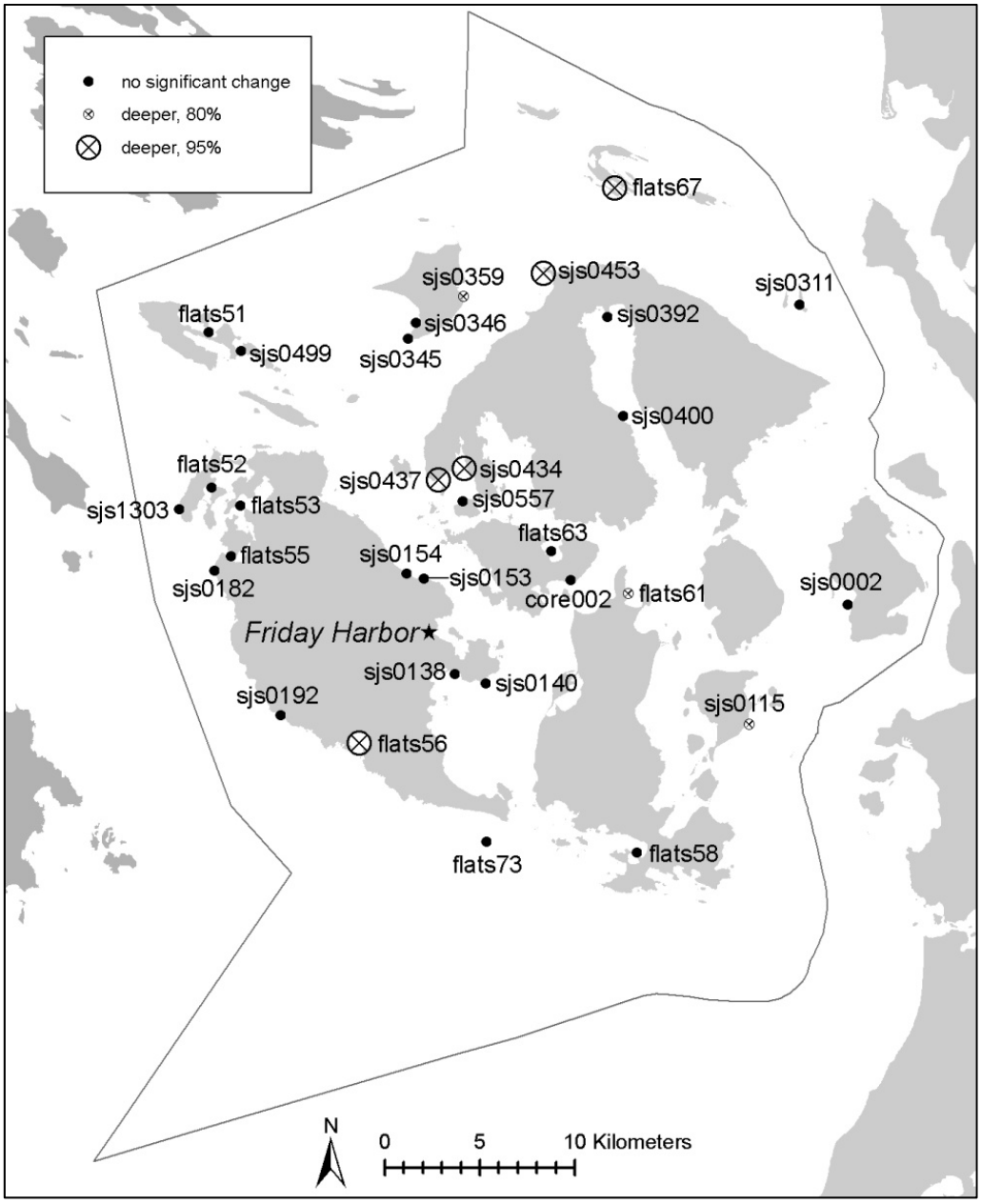

Figure 3-16. *San Juan County-Cypress Island* focus area sites with significant change in mean minimum *Z. marina* depth between 2004 and 2009 (**α**=0.2 and **α**=0.05, n=31). Sites that were tested but exhibited no significant change are also shown. The 2004 site estimate for *flats73-Salmon Bank* was based on the 2003 Friends of the San Juans data (Slocomb et al. 2004, Dowty 2006b).

The mean maximum depth distribution of *Z. marina* at eight *San Juan County-Cypress Island* focus area sites was significantly different in 2009 compared to the mean maximum depth measured in 2004 (Table 3-9, Figure 3-17). The mean maximum depth at only one site in the focus area, *sjs0392-Shannon Point*, was significantly deeper in 2009 compared to 2004 (α=0.05; Table 3-9, Figure 3-17). The mean maximum depth at seven sites was significantly shallower in 2009 compared to the depth measured in 2004. The mean

maximum depth at two sites (*core002-Picnic Cove* and *sjs0138-North side of North Bay*) was shallower when tested at α=0.05. The mean maximum depth at the remaining sites (*sjs0140-Pear Point, sjs0453-Point Doughty*, *sjs0499-NW John's Island*, and *sjs0557-North of Crane Island*) was shallower when tested at α=0.2 (Table 3-9, Figure 3-17).

Table 3-9. Focus area sites with significant changes in mean maximum *Z. marina* depth (MLLW) between 2004 and 2009.

Deep edge direction of change	Site	α	Mean maximum depth (m, MLLW)		
			2004	2009	Difference
shallower (receding)	core002	0.05	-5.2	-4.7	0.5
	sjs0138	0.05	-6.0	-4.7	1.3
	flats51	0.2	-5.1	-4.5	0.6
	sjs0140	0.2	-6.9	-5.9	1.0
	sjs0453	0.2	-5.4	-4.8	0.6
	sjs0499	0.2	-7.1	-5.9	1.2
	sjs0557	0.2	-7.0	-6.1	0.9
deeper (expanding)	sjs0392	0.05	-2.9	-3.6	-0.7

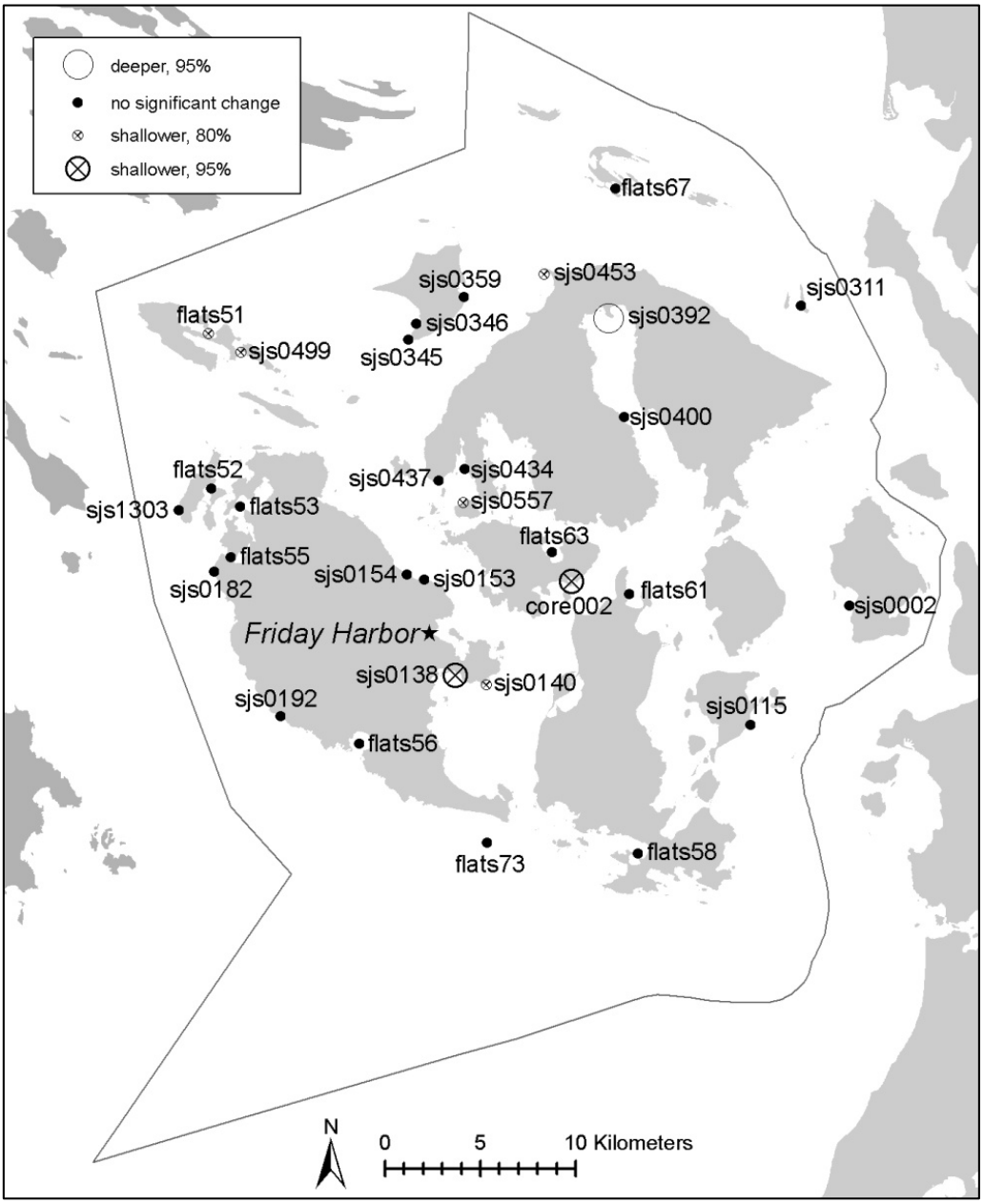

Figure 3-17. *San Juan County-Cypress Island* focus area sites with significant change in mean maximum *Z. marina* depth between 2004 and 2009 (**α**=0.2 and **α**=0.05, n=31). Sites that were tested but exhibited no significant change are also shown. The 2004 site estimate for *flats73-Salmon Bank* was based on the 2003 Friends of the San Juans data (Slocomb et al. 2004, Dowty 2006b).

3.5 Multiple Parameter Assessment

3.5.1 Assessment of *Z. marina* in the Regions

The multiple parameter assessment evaluated regional patterns by quantifying the proportion of significant changes among all *Z. marina* parameter tests within each region from 2000 to 2009 (Table 3-10). The proportion of significant *Z. marina* parameter assessments provides an indicator of variability within a region and the proportion of negative or positive changes indicates the status of the resource in the region (Table 3-10, Figure 3-18). Every region exhibited both positive and negative changes for the four parameters from 2000-2009 (Table 3-10).

The *Hood Canal Region* had the largest proportion of significant changes and negative changes in the tested *Z. marina* parameters compared to the other four regions in the study area (Table 3-10, Figure 3-18). These results place the *Hood Canal Region* in a category of high concern for *Z. marina* decline. The *San Juan-Straits* and *Central Puget Sound Regions* had fewer overall significant results but a greater number of these were negative changes than positive. These results suggest that *Z. marina* in the *San Juan-Straits* and *Central Puget Sound Regions* is in decline but not at a level of decline similar to the *Hood Canal Region*. Instead, there is concern for *Z. marina* decline in the *San Juan-Straits Region* and a moderate level of concern in *Central Puget Sound Region* based on the proportion of significant declines. In contrast, the *Saratoga-Whidbey* and *North Puget Sound Regions* had smaller proportions of decreases in *Z. marina* parameters. The multiple parameter assessment has identified *Z. marina* in the *Saratoga-Whidbey* and *North Puget Sound Regions* as stable, the proportion of significant negative results is approximately 0.50 (Table 3-10, Figure 3-18, Figure 3-18).

Table 3-10. Results of multiple parameter assessment of regional *Z. marina* condition based on data collected from 2000-2009. The number of measurable changes within a region was quantified and compared to the number of significant positive or negative changes (**α**=0.05).

	CPS				HDC				NPS				SJS				SWH			
	No. Change Tests	Significant change	Positive change	Negative change	No. Change Tests	Significant change	Positive change	Negative change	No. Change Tests	Significant change	Positive change	Negative change	No. Change Tests	Significant change	Positive change	Negative change	No. Change Tests	Significant change	Positive change	Negative change
Site-level area	165	10	1	9	78	14	2	12	78	9	3	6	154	15	1	14	99	11	6	5
Deep edge depth	118	14	7	7	59	2	0	2	67	8	6	2	103	8	3	5	75	7	3	4
Shallow edge depth	118	15	8	7	58	11	3	8	67	7	3	4	103	9	5	4	75	12	6	6
5-year area trends	23	6	2	4	13	6	0	6	13	2	1	1	19	7	2	5	16	3	1	2
Proportion of significant results	0.11				0.16				0.12				0.10				0.12			
Proportion of significant positive results	0.40				0.15				0.50				0.28				0.48			
Proportion of significant negative results	0.60				0.85				0.50				0.72				0.52			

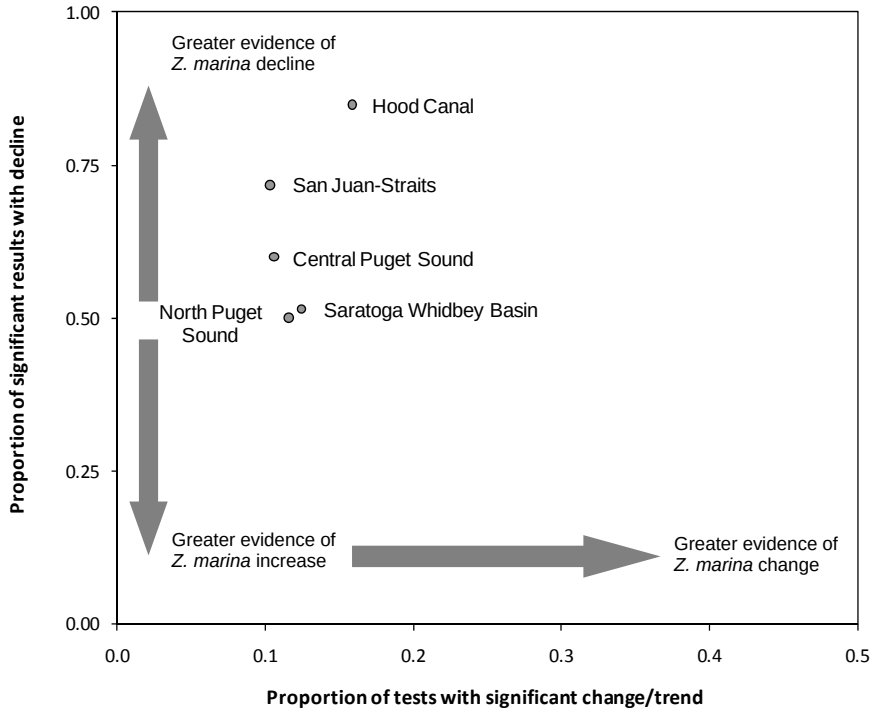

Figure 3-18. Proportion of significant declining results in the multiple parameter *Z. marina* assessment relative to the proportion of significant *Z. marina* parameter changes in each region from 2000–2009.

3.5.2 Assessment of Site-Level *Z. marina* Change

A total of 19 sites evaluated in 2009 were identified through a site-level multiple parameter assessment with strong evidence of *Z. marina* decline. The strong evidence of decline category included sites with significant decline in greater than 20% of the *Z. marina* area and depth change tests and the long-term trend assessments. An additional 22 sites were identified with evidence of decline (Table 3-11). The evidence of decline category included sites with a significant decline result in 10-20% of the change tests.

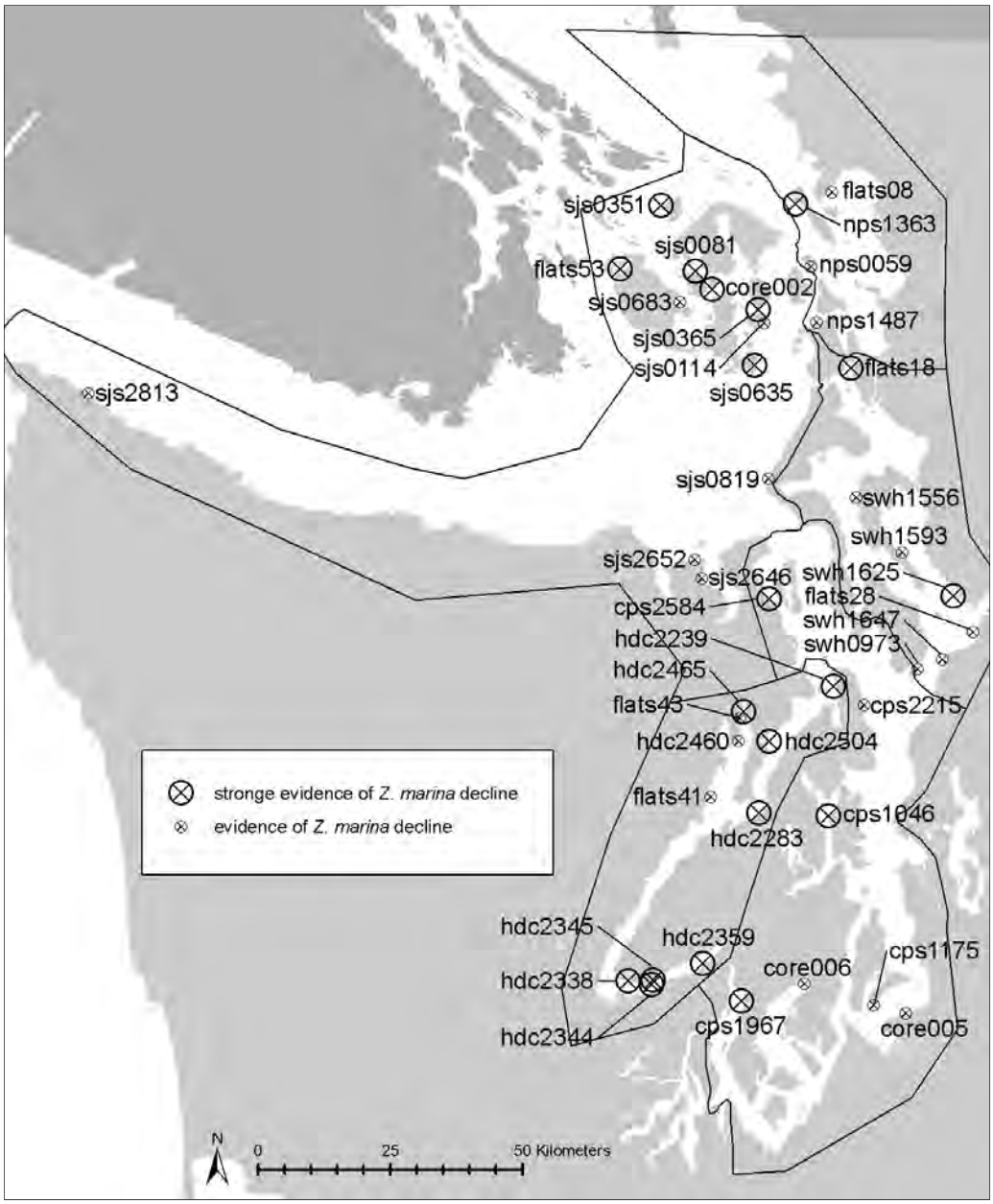

Figure 3-19. Sites with evidence of *Z. marina* decline in 2009 based on a site-level multiple parameter assessment. The last column in Table 3-11 (below) indicates whether the site will be sampled in 2010 or when the site rotated out of the SVMP sampling.

Table 3-11. Sites with evidence of *Z. marina* decline in 2009 based on a site-level multiple parameter assessment. The last column indicates whether the site will be sampled in 2010 or when the site rotated out of the SVMP sampling after the year listed in parentheses ( ).

Category	Site code	Site name	Region	Remains in 2010 sample pool?
strong evidence of decline	core002	Picnic Cove	sjs	yes
	flats18‡	Similk Bay	swh	no (2006)
	flats43‡	Dabob Bay	hdc	no (2005)
	flats53*	Westcott Bay	Sjs	no (2001)
	cps1046	Battle Point	cps	no (2002)
	cps1967‡	Vaughn Bay	cps	no (2008)
	cps2584	Lower Hadlock	cps	no (2002)
	hdc2239	Hood Canal NE	hdc	no (2006)
	hdc2283	E. of Warrenville	hdc	yes
	hdc2338	Across from Union	hdc	no (2005)
	hdc2344	Great Peninsula	hdc	no (2007)
	hdc2345	Sisters Point	hdc	no (2002)
	hdc2359	Lynch Cove Fringe	hdc	no (2005)
	hdc2504	Thorndyke Bay	hdc	no (2001)
	nps1363‡	Lummi Island	nps	no (2004)
	sjs0081	Broken Point	sjs	no (2005)
	sjs0351	NW Waldron Island	sjs	no (2004)
	sjs0365	Thatcher Pass	sjs	no (2003)
	sjs0635‡	Watmough Bay	sjs	no (2007)
	swh1625‡	S. of Tulalip Bay	swh	no (2005)
evidence of decline	core005	Dumas Bay	cps	yes
	core006	Burley Spit	cps	yes
	flats08	Portage Bay	nps	no (2007)
	flats28	Snohomish Delta	swh	no (2002)
	flats41†	Dosewallips	hdc	no (2008)
	cps1175†	Piner Point	cps	no (2007)
	cps2215	Eglon, Kitsap	cps	no (2002)
	hdc2460	Lindsay's Beach	hdc	yes
	hdc2465†	SE of Dabob Bay	hdc	no (2008)
	nps0059	Sinclair Island S.	nps	no (2005)
	nps1487	Loverick's Marina	nps	yes
	sjs0114	Decatur Head South	sjs	yes
	sjs0683	Brown Island N.	sjs	no (2007)
	sjs0819	N. of Partridge Point	sjs	no (2005)
	sjs2646	Discovery Bay	sjs	no (2004)
	sjs2652	Thompson Spit	sjs	yes
	sjs2813	Rasmusson Creek	sjs	no (2003)
	swh0973	North Possession	swh	yes
	swh1556†	NW Camano Island	swh	no (2004)
	swh1593	Cornell	swh	no (2005)
	swh1647	Mukilteo	swh	no (2003)

* *flats53-Westcott Bay* was sampled by the SVMP in 2000-2001, and then it rotated out of the annual monitoring pool. From 2000-2001, the site experienced a significant decline in *Z. marina* (α=0.2). In 2003 a large die-off of *Z. marina* at *flats53-Westcott Bay* was observed. Since then, detailed research by DNR's Eelgrass Stressor-Response Project has confirmed and evaluated the observed losses (Ferrier et al 2010).

† indicates sites that were added to the evidence of decline table in 2009 but should have been included in 2008.

‡ indicates sites that were classified as evidence of decline in 2008 but should have been classified as strong evidence of decline.

3.6 Observations of *Zostera japonica* and *Phyllospadix* spp.

In 2009, *Z. japonica* was observed at 18 sites throughout Puget Sound (Figure 3-20). Three of these sites (*flats03-Birch Bay, hdc2408-Jorsted Creek South, and sjs2628-Between Adelma and Madrona Beach Drive*) were not previously sampled. Since 2000, *Z. japonica* has been observed at 68 sites in Puget Sound (Figure 3-21). *Phyllospadix* spp. was observed at four sites during the 2009 sample effort (Figure 3-20); an addition of only one new site, *sjs2652-Chinese Gardens Lagoon*, since 2008 (Figure 3-21).

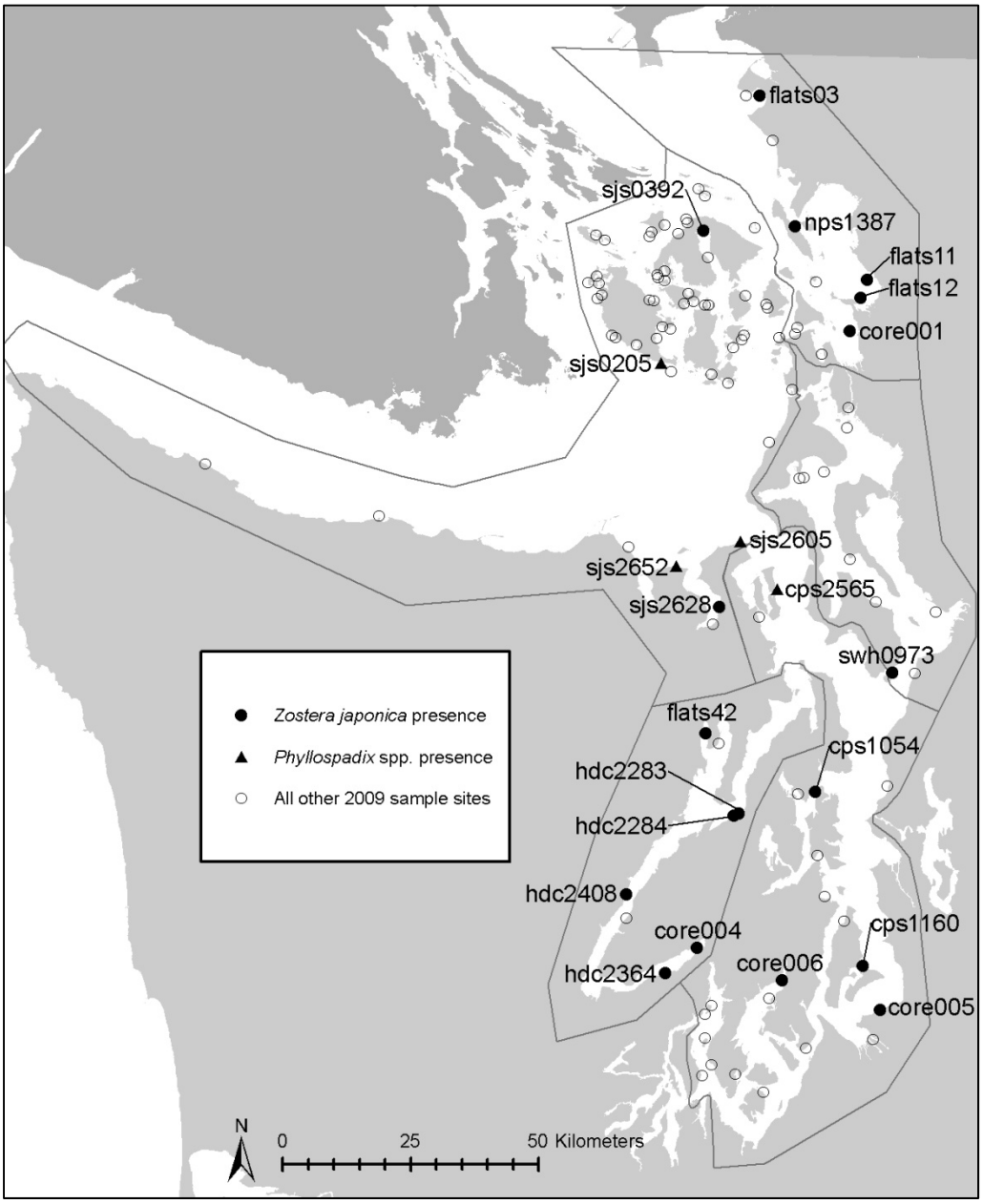

Figure 3-20. Sites where *Z. japonica* and *Phyllospadix* spp. was observed in the 2009 Puget Sound study area.

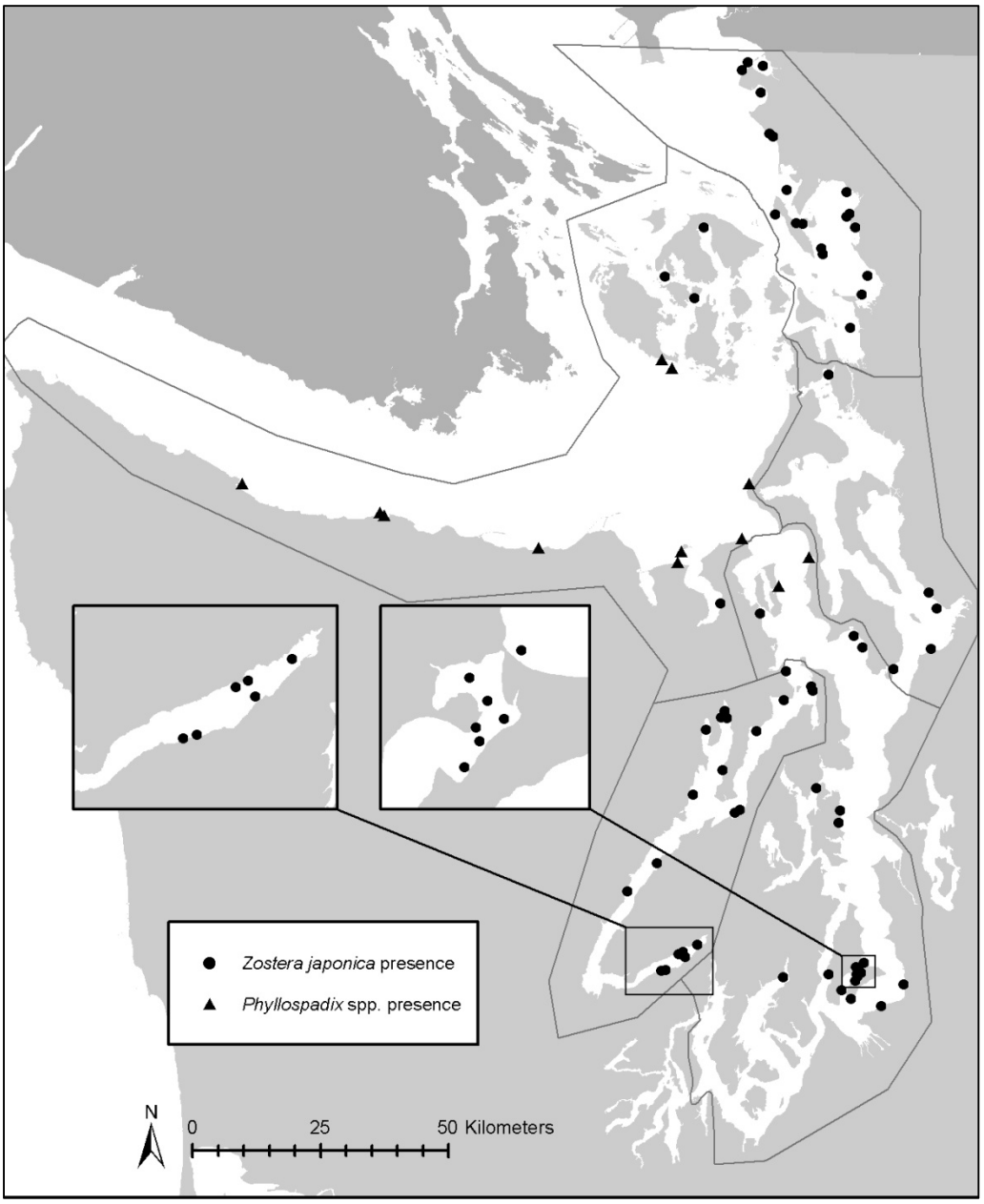

Figure 3-21. Sites where *Z. japonica* (n=68) and *Phyllospadix* spp. (n=12) was observed in the Puget Sound study area from 2000 to 2009.

4 Discussion and Recommendations

4.1 Importance of *Zostera marina*

Zostera marina beds provide many ecological functions that are important to the nearshore ecosystem in Puget Sound. *Zostera marina* creates complex habitat that supports a diverse food web including fish, invertebrates, and waterfowl and produces oxygen, dampens wave energy, absorbs nutrients and promotes conditions that facilitate organic matter mineralization and sedimentation. *Zostera marina* has been recognized as an ecological indicator throughout its range (Dennison et al 1993, Krause-Jensen et al. 2005, Lee et al. 2004, Orth et al. 2006, Short et al. 1993), responding to natural and anthropogenic activities that modify its habitat and the water quality in Puget Sound. The presence and distribution of *Z. marina* in Puget Sound is a valuable indicator of environmental condition and ecosystem health for the region.

4.2 Status and Trends in Puget Sound

The data collected by the SVMP provides a mechanism to assess status and trends in *Z. marina* abundance and depth distribution at multiple scales. The latest SVMP results vary depending on the spatial scale of the analyses. The soundwide *Z. marina* area data suggest stability or even a slight increase. At the soundwide scale there was no difference in *Z. marina* area from 2008 to 2009 or any of the earlier year-to-year analyses (Figure 3-3). A slightly significant increasing trend was observed when the soundwide *Z. marina* area data were analyzed from 2000 to 2009 (Figure 3-4).

However, results at the site level data over yearly or multi-year intervals suggest declines in *Z. marina* throughout the sound. For eight out of the last nine years, there have been more sites with significant declines in *Z. marina* area compared to increases (Figure 3-5). The significantly low probability of this result occurring by chance and the soundwide distribution of these sites support a pattern of a *Z. marina* decline throughout Puget Sound. A similar pattern was evident in the assessment of long-term trends (Figure 3-9). The cumulative assessment of 5-year trends since 2004 found twice as many sites with long-term declining *Z. marina* area trends than increases (Figure 3-9, Table 3-4).

The pattern of decline is also evident in the multiple parameter assessment. The proportion of significant negative tests in year-to-year *Z. marina* area, minimum and maximum depth, and long-term trends was greater in four of the five regions. Both the *North Puget Sound* and *Saratoga-Whidbey Regions* have nearly equal proportions of positive and negative significance tests (50:50) (Table 3-10), and therefore are not currently a concern for *Z.*

marina decline.. The *Hood Canal* Region has the highest proportion of significant negative results for the four *Z. marina* parameters tested (Table 3-10, Figure 3-18). Roughly 85% of the cumulative significant tests in this region indicate *Z. marina* area is declining or the seagrass bed is receding at the shallow or deep edge (i.e., a significant shallow or deep depth change that causes bed size reduction). The observed declines in the *San Juan-Straits* and *Central Puget Sound Regions* continue to be a concern but are less extreme than those observed in the *Hood Canal* Region.

Finally, the core sites, selected to represent *Z. marina* habitat types in Puget Sound (Berry et al. 2003), provide a longer data series compared to other soundwide sites that are subject to the rotational sample design. Although these sites were non-randomly selected, the analysis of the longer data series from the core sites has greater power to detect trends. Only one of six cores sites showed an annual decline from 2008-2009, a period when the *Z. marina* area at the five other core sites remained stable, while four of core sites had significant 5-year declining trends in *Z. marina* area (Table 3-3, Figure 3-8, Appendix H, Appendix I). Furthermore, three of the core sites have been identified in the site-level multiple parameter assessment as sites with strong evidence of decline (*core002-Picnic Cove*) or as sites with evidence of decline (*core005-Dumas Bay* and *core006-Burley Spit*).

The indicators (year-to-year site level assessments, long-term trends, regional multiple parameter analyses, and an evaluation of the core sites) suggest a pattern of *Z. marina* decline throughout Puget Sound. However, the magnitude of observed changes is not sufficient to cause a decrease in the total soundwide *Z. marina* area estimate (Figure 3-1). In 2009, 76% (60 sites) of the sites sampled (79 sites) for the soundwide area estimate had less than 10 ha of *Z. marina* area. Significant changes in these small sites have little influence on the soundwide *Z. marina* area estimate. Sites with the greatest influence on the soundwide estimate are the larger, stable flats sites (e.g., *core001-Padilla Bay*, *core003-Jamestown*, *core004-Lynch Cove, flats11-Samish Bay N.*, *flats12-Samish Bay S.*, *flats19-Pull and Be Damned*, *flats20-Skagit Bay N.*, *flats26-Snohomish Delta N.*, and *flats70-South Fork Skagit River*) in the study area. In 2009, these sites were only 11% of the sample pool but represented approximately 30% of the total *Z. marina* area in Puget Sound. There is a need to explore the effect a few larger sites have on the soundwide estimate compared to many smaller sites. It would also be important to understand whether larger sites are more or less likely to change annually due to mutual protection provided by the abundance of other shoots in the *Z. marina* patch, bed or meadow (Olesen and Sand-Jensen 1994).

While the overall abundance of *Z. marina* has not decreased, the pattern of site-level decreases could reflect important changes in environmental conditions in sub-areas within Puget Sound. A reduction in *Z. marina* distribution could have critical habitat implications in areas of Puget Sound. Losses in distribution may cause decreases in important habitat functions of *Z. marina*, including nursery habitat, habitat connectivity and migration corridors.

Annual relative change and long-term trends in area provide an assessment of *Z. marina* area over time and insight as to whether observed changes are a result of yearly variability

or an indication of persistent losses in *Z. marina*. Sites with significant annual declines or long-term declining trends in *Z. marina* area are strong candidates for additional, more intensive analyses that investigate causes of decline. The SVMP refers such sites to DNR's Eelgrass Stressor-Response Project for further research into causal factors of *Z. marina* decline.

4.3 Areas of Concern

Individual Sites

Sites with stable and changing *Z. marina* area and depth distribution are dispersed throughout the greater Puget Sound study area. Although sites with stable, increasing, or decreasing *Z. marina* or changes in depth distribution are not aggregated (Figure 3-6, Figure 3-8, Figure 3-14, Figure 3-15), there continue to be more sites with declines in the year-to-year and 5-year trend area assessments.

A number of sites have been identified as areas of concern due to the cumulative significant yearly declines observed at these sites (Table 3-11). There is evidence of *Z. marina* decline at these sites based on significant negative change in the year-to-year, 5-year trends, and depth distribution assessments (Section 3.3.2 and Section 3.4.1). If the *Z. marina* decline is evident in only one measured parameter as opposed to the site-level multiple parameter assessments, it is important to consider these sites as areas of concern.

Three core sites have been identified as sites having strong evidence of decline (*core002-Picnic Cove*) or evidence of decline (*core005-Dumas Bay*, and *core006-Burley Spit*). These sites were selected the first year of monitoring to represent different *Z. marina* habitat types throughout the study area and have been monitored each year. There is year-to-year variability in the 10 year data record from these sites, but the cumulative area and depth change results strongly indicate significant *Z. marina* losses. Other sites identified with evidence of *Z. marina* decline have rotated out of the sample pool due to the sampling with partial replacement design of the SVMP (Berry et al. 2003). Continued monitoring by the SVMP, academics, and other groups at sites throughout the study area will provide valuable data on causal or correlative factors for *Z. marina* loss.

Regions

The number of significant tests from sites within the regions, a measure of *Z. marina* variability or change, was less than 12% for all the regions except the *Hood Canal Region* (Table 3-10). The higher proportion of significant tests in the *Hood Canal Region* (16%), suggests the region is more variable compared to the other regions in terms of eelgrass condition. It is unclear whether the accumulation of significant tests (i.e., variability) in any of the regions is due to the naturally dynamic environment or a result of anthropogenic stressors that cause greater change in the regions.

The multiple parameter assessment also identified three regions (*Hood Canal*, *San Juan-Straits*, and *Central Puget Sound*) where the significance tests indicated a much greater frequency of measured losses in *Z. marina* than increases (Table 3-10, Figure 3-18). Only the *North Puget Sound* and the *Saratoga Whidbey Region*s had approximately equal

numbers of positive and negative significant tests, suggesting the *Z. marina* in these regions is stable.

The combined results of high variability and evidence of loss in the four regions is a concern. More detailed investigations beyond the scope of the SVMP are required to further understand the drivers behind the stressors which cause change in *Z. marina*. The Eelgrass Stressor-Response Project has tested some hypotheses specific to the *Hood Canal* region and at *flats53-Westcott Bay*, an embayment in the *San Juan-Straits* region (Dowty et al. 2007, Dowty and Ferrier 2009, Schanz et al. 2010). Although certain environmental parameters in specific locations (e.g., photosynthetic available radiation in Westcott Bay, Dowty and Ferrier 2009) have been discounted as potential stressors, the cause for *Z. marina* decline at sites throughout Puget Sound is still not entirely clear. It has been proposed that a suite of site specific and regional stressors are causing *Z. marina* decline in Puget Sound.

4.4 Focus Area Regional Assessment

In 2009, the *San Juan County-Cypress Island* focus area was re-sampled for the first time since its initial sampling in 2004. While the differences in total *Z. marina* area and the relative change result in *Z. marina* area were not significant at the regional scale, there were more sites throughout the focus area that had significant declines in *Z. marina* area and depth distribution than increases from 2004-2009. In addition to the recent observed changes, a cumulative assessment of significant area and depth distribution tests from 2000-2009 further suggests a number of sites are experiencing declines in *Z. marina* area, a contraction of *Z. marina* depth distribution, or both in the *San Juan County-Cypress Island* focus area (Figure 4-1). The assessment accounted for significant year-to-year and long-term changes in *Z. marina* area and depth at all sites sampled in the *San Juan County-Cypress Island* focus area between 2000 and 2009. *Z. marina* was evaluated at each site based on the quantity and direction of significant results.

Since 2000, 67 sites have been sampled in the *San Juan County-Cypress Island* focus area. Eight of these sites did not have *Z. marina* present and four additional sites were only sampled for one year and therefore did not have sufficient data to assess change. The evaluation of the *Z. marina* area and depth data at the remaining 55 sites showed *Z. marina* losses measured as a decline in area or a contraction of the bed at the shallow or deep edge in 27 sites, gains in nine sites, and stability in 19 sites (Figure 4-1, Table 4-1).

The largest documented *Z. marina* declines in this focus area occurred at *flats53-Westcott Bay* and *flats54-Garrison Bay* with nearly a total loss of *Z. marina* in these two embayments between 2001 and 2003 (Dethier and Ferguson 1998, Dowty et al. 2007, Ferrier and Berry 2010, Wyllie-Echeverria et al. 2003). The latest assessment shows small patches of *Z. marina* in both bays with increasing abundance at sites between these flats and Mosquito Pass (Ferrier and Berry 2010, Schanz et al. 2010). There have been additional sites with *Z. marina* losses in the focus area that have raised concern.

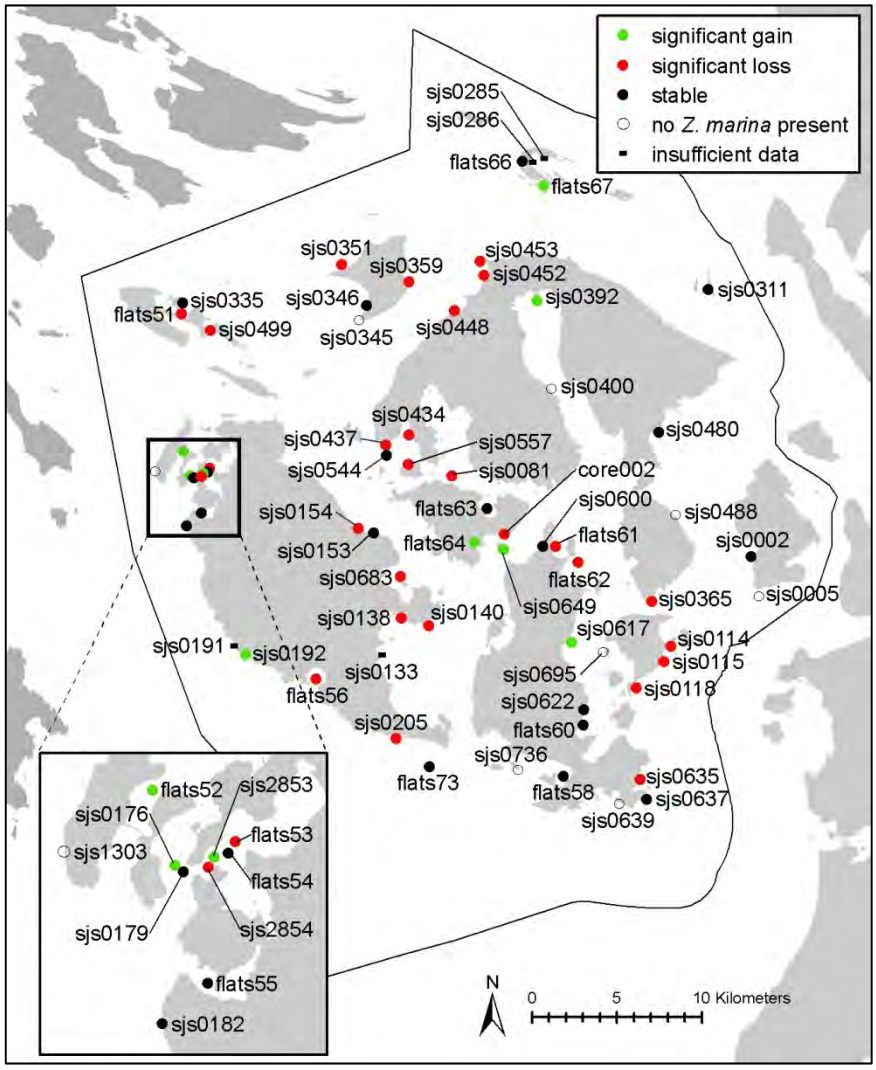

Figure 4-1. Assessment of *Z. marina*, based on the quantity and direction of significant area and depth results at sites, in the *San Juan County-Cypress Island* focus area from 2000-2009 data (n=67). Three sites, *flats54-Garrison Bay*, *flats55-Mitchell Bay*, and *flats63-Blind Bay*, have been identified as stable based on the SVMP data record, but have previously observed significant declines when evaluated to data collected prior to 2000 (Wyllie-Echeverria 2003, PSEA 1987). *Flats67-Fossil Bay* was also identified as a site with previous declines in *Z. marina* (Wyllie-Echeverria 2005a, 2005b), but the latest assessment shows a significant, multi-year increasing trend in area (Appendix H).

Significant changes in *Z. marina* area and the minimum and maximum depth distribution occurred at *core002-Picnic Cove*, *flats62-Swifts Bay*, *sjs0081-Broken Point*, *sjs0351-NW Waldron Island*, *sjs0452-S. of Point Doughty*, *sjs0635-Watmough Bay*, and *sjs0683-Brown Island N*. Considering the *Z. marina* losses were observed in both the area and depth parameters suggests stronger evidence of decline in *Z. marina* at these sites. At other sites with *Z. marina* loss, it was only observed in the yearly or multi-year area analyses or the depth analysis (Table 4-1).

Five sites, *flats54-Garrison Bay*, *flats55-Mitchell Bay*, *flats63-Blind Bay*, *flats66-Shallow Bay* and *flats67-Fossil Bay* were previously identified as having significant losses in *Z.*

marina based on changes in year-to-year or multi-year area assessments and depth distributions (Dowty et al. 2005, Gaeckle et al. 2008, Ferrier and Berry 2010) or analyses of aerial photographs and herring spawn surveys (Wyllie-Echeverria et al. 2003), but the latest SVMP assessment shows *Z. marina* at these to be stable or in the case of one site increasing (Figure 4-1). At *flats54-Garrison Bay* and *flats55-Mitchell Bay*, the *Z. marina* distribution data from the Puget Sound Environmental Atlas (PSEA) showed a large portion of both shallow embayments vegetated but current records show no *Z. marina* in these shallow areas (PSEA 1987, Ferrier and Berry 2010). Based on the PSEA data there was a significant decline in *Z. marina* at both sites (PSEA 1987), but more recently there was no observed change in the *Z. marina* area estimate and depth distribution at f*lats54-Garrison Bay* between 2008 and 2009 (Ferrier and Berry 2010). Similarly at *flats55-Mitchell Bay*, the PSEA data showed *Z. marina* in the shallow portion of the embayment (1987) but no *Z. marina* was observed in more recent surveys (Ferrier and Berry 2010). From 2008-2009, there was a slight recovery of *Z. marina* area at *flats55-Mitchell Bay* (Figure 3-13), but there continues to be no evidence of *Z. marina* recolonization in the shallow part of the embayments at either site. The previously documented losses observed at *flats63-Blind Bay* were based on yearly herring spawn surveys from 1970 to 2003 (Wyllie-Echeverria et al. 2003), but the latest SVMP data show no changes in *Z. marina* area or depth distribution at this site between 2004 and 2009.

Table 4-1. Sites with significant gains or losses in *Z. marina* in the *San Juan County-Cypress Island* focus area between 2000-2009 based on significant results in year-to-year and long-term area trends and the minimum and maximum depth distribution. Between 2000-2009, 67 sites were sampled in the focus area; 9 sites observed significant gains in *Z. marina*, 27 sites observed significant losses in *Z. marina*, 19 sites were stable, 8 sites had no *Z. marina*, and four sites were only sampled one year.

Assessment	*Z. marina* Area and Depth	*Z. marina* Area	*Z. marina* Depth
(Gain/Loss)	(yr-to-yr, long-term trends, and minimum and/or maximum depth)	(yr-to-yr and/or long-term trends)	(minimum and/or maximum depth)
Significant Gain	sjs0617	flats52	flats64
	sjs0649	flats67	sjs0176
		sjs0192	sjs0392
			sjs2853
Significant Loss	core002	flats53	flats51
	flats62	sjs0154	flats56
	sjs0081	sjs0205	flats61
	sjs0351	sjs0365	sjs0114
	sjs0452		sjs0118
	sjs0635		sjs0138
	sjs0683		sjs0140
	sjs0115		sjs0448
	sjs0359		sjs0434
	sjs0437		sjs0453
	sjs0557		sjs0499
			sjs2854

At *flats66-Shallow Bay*, there have been changes in the *Z. marina* depth distribution but the area has remained stable over the past three years of sampling. *Flats67-Fossil Bay* was

identified as a site with strong declines in *Z. marina* (Wyllie-Echeverria et al. 2005a, 2005b), and some of these losses may have been mitigated by an increasing trend in *Z. marina* area over the last five years (Appendix H). The significant, multi-year increasing trend in area observed at *flats67-Fossil Bay* suggests conditions have improved at this site for *Z. marina*. However, a number of significant changes in the minimum depth distribution of *Z. marina* between 2004 and 2009 indicate bed contraction along the shallow edge. The status of *Z. marina* at *Flats67-Fossil Bay* will be further assessed during the next *San Juan County-Cypress Island* focus area effort in 2014.

Overall, the prevalence of sites with significant declines in *Z. marina* area and depth distribution is apparent in the *San Juan County-Cypress Island* focus area (Figure 4-1, Table 4-1). Similar to results at the soundwide scale, cumulative results from 2000-2009 and results from the matching sites between 2004 and 2009, show more sites with significant declines than increases in *Z. marina* area throughout the focus area. The cause of *Z. marina* decline is uncertain, but the greater prevalence of sites with decline is a concern. In the 2004-2009 time period, most of the sites with significant declines occurred in the central part of the focus area closer to higher population centers and recreational boat traffic (Figure 3-12), but this is not always the case as apparent in the results that encompass the full temporal data record (Figure 4-1). Four sites with significant increases in area between 2004-2009 were distributed along the southwestern side of San Juan Island, an area subject to greater oceanic influences (i.e., higher water quality and higher flushing rates) (Figure 3-12).

Approximately 25% of the matching sites (8 of 31 sites) showed a deeper minimum *Z. marina* depth in 2009 compared to 2004. A receding *Z. marina* shallow edge could result in a reduction in area and, although three focus area sites showed a significantly deeper shallow edge and a reduction in area, the exact cause for these changes is unclear (Figure 3-12). At another site in the focus area, *sjs0453-Point Doughty*, there were significant changes in the minimum and maximum depth while the *Z. marina* area remained stable. Whereas at *core002-Picnic Cove*, the shallow *Z. marina* depth was not significantly different between 2004 to 2009, but there was a significant long-term trend that showed the shallow depth has been receding since 2000 (Ferrier and Berry 2010). Furthermore, the *Z. marina* area at *core002-Picnic Cove* remained unchanged from 2008-2009, but there was a significant long-term declining trend in *Z. marina* area since 2000. Changes in the shallow edge of *Z. marina* within the focus area could be a result of natural variability, but the changes from 2004 to 2009 only occurred in one direction (receding shallow edge) and suggest other factors are causing declines in the shallow edge of *Z. marina*. Stressors causing these changes in the shallow edge need to be explored further by the Eelgrass Stressor-Response Project.

The pattern of *Z. marina* loss was also evident in the results of the deep edge depth analyses from 2004 to 2009. There was significant evidence of a receding deep edge at seven sites (23%) tested over this period, whereas only one site showed a significant increase in the deep edge of the bed. The soundwide results also showed more sites with significant negative changes in the deep edge of the bed compared to positive changes (Figure 3-15). Changes in the deep edge of a seagrass bed are likely due to changes in

water quality (Dennison et al. 1993, Short et al. 1995), and more sites showing a retreating deep edge suggests there may be negative changes in water quality in this focus area.

It is unclear what factors have caused the declines in *Z. marina* at *core002-Picnic Cove* and others throughout the focus area. However, considering the significant changes that have occurred in the shallow and deep edges of the bed, it is likely there are multiple, confounding stressors. Additional research beyond the scope of the SVMP needs to focus on drivers and stressors that cause *Z. marina* decline in greater Puget Sound and specifically the *San Juan County-Cypress Island* focus area.

The SVMP successfully completed the *San Juan County-Cypress Island* focus area and the soundwide sampling goals for the 2009 field season. The *San Juan County-Cypress Island* focus area effort provided detailed changes between 2004 and 2009 in *Z. marina* area and depth distribution and an assessment of *Z. marina* at all the sites in the focus area from 2000-2009.

4.5 Priorities

The SVMP will continue to monitor *Z. marina* abundance and distribution to fulfill its mandate of aquatic resource assessment and to satisfy monitoring guidelines outlined by the Puget Sound Partnership.

Project priorities include:

1. Monitor the soundwide and focus area *Z. marina* status and trends throughout greater Puget Sound. The *Hood Canal* focus area was sampled in 2005 and the subsequent sampling in 2010 will provide detailed insight on *Z. marina* changes in this focus area. The status and trend monitoring of *Z. marina* in Puget Sound allows DNR to properly manage resources on state-owned aquatic lands.
2. Disseminate reports of the *Z. marina* monitoring data. The *Z. marina* data are important to scientists and managers throughout the region and will assist the efforts of the Puget Sound Partnership in developing strategies to improve the health of Puget Sound by 2020. One such project that will make these data easily available is the development of a geospatial database and a web based data dissemination portal.
3. Analyze and synthesize the SVMP data to provide a thorough understanding of sites with decline and depth distribution throughout the study area. This effort will further develop sample polygon delineation and the prevalence of sites with decline indicator and will improve efforts to track *Z. marina* in greater Puget Sound.
4. Assess the effect of sample polygon modifications on site and soundwide estimates to improve our understanding of the uncertainty caused by sample polygon delineation.
5. Increase our understanding of the relationship between changes in overall area and areal distribution through quantitative comparison of the monitoring results over large areas and at individual sites.
6. Provide technical support and monitoring data to the Eelgrass Stressor-Response Project, Puget Sound Partnership dashboard indictor work, academics, concerned citizen groups, and others who investigate *Z. marina* in Puget Sound.

As an indicator of Puget Sound health, it is critical to know the historical abundance and distribution of *Z. marina* and the stressors that impede its growth and persistence. Knowledge of historic *Z. marina* abundance and distribution will allow scientists and managers to understand the changes that have occurred over the last 5-10 decades, while knowledge of the stressors will provide direction for ecosystem improvements and restoration. Early *Z. marina* abundance and distribution records for greater Puget Sound are limited in spatial extent and lack quantitative rigor (Dowty et al. 2010). The most numerically valid and statistically robust *Z. marina* abundance record for this area was generated by the SVMP in 2000. To fully understand changes in *Z. marina* abundance, an effort is needed to generate a valid historical estimate prior to 2000.

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6 Appendices

Appendix A *Z. marina* Area Estimates at 2009 SVMP Sample Sites

Site	Location	Approximate Latitude (dec. deg.)	Approximate Longitude (dec. deg.)	Date Sampled	Number of Transects	*Z. marina* Fraction Along Transects	*Z. marina* Area at Site (hectares)	Variance	Coefficient of Variance	Estimated *Z. marina* Area Confidence Interval 95% Lower Limit (hectares)	95% Upper Limit (hectares)
Core											
core001	Padilla Bay	48.521	-122.507	03-Jul-09	11	0.70	3155.16	50469.10	0.07	2714.84	3595.48
core002	Picnic Cove	48.565	-122.923	23-Jun-09	14	0.49	2.28	0.03	0.08	1.92	2.64
core003	Jamestown	48.131	-123.073	17-Sep-09	11	0.58	507.49	1928.78	0.09	421.41	593.57
core004	Lynch Cove	47.430	-122.863	20-Aug-09	14	0.52	119.67	180.47	0.11	93.34	146.00
core005	Dumas Bay	47.331	-122.383	17-Aug-09	15	0.24	1.04	0.03	0.17	0.69	1.39
core006	Burley Spit	47.378	-122.638	13-Aug-09	15	0.10	1.36	0.06	0.18	0.87	1.84
Persistent Flats											
flats11	Samish Bay N.	48.612	-122.465	05-Jul-09	9	0.84	1253.30	2256.61	0.04	1160.20	1346.41
flats12	Samish Bay S.	48.579	-122.480	18-Jul-09	11	0.61	606.83	1796.92	0.07	523.74	689.91
flats20	Skagit Bay N.	48.350	-122.507	30-Jun-09	18	0.29	200.84	622.09	0.12	151.95	249.72
Rotational Flats											
flats03	Birch Bay	48.929	-122.763	21-Jul-09	12	0.44	104.91	42.92	0.06	92.07	117.75
flats15	Fidalgo Bay	48.479	-122.578	18-Jun-09	26	0.30	177.20	235.73	0.09	147.11	207.29
flats17	Bowman Bay	48.415	-122.655	17-Jun-09	22	0.20	2.14	0.13	0.17	1.42	2.85
flats26	Snohomish Delta N	48.032	-122.263	04-Aug-09	11	0.20	99.06	751.04	0.28	45.35	152.77
flats42	Quilcene Bay	47.808	-122.857	26-Aug-09	13	0.71	108.61	38.55	0.06	96.44	120.78
flats55	Mitchell Bay	48.571	-123.165	22-Jul-09	19	0.43	4.89	0.20	0.09	4.02	5.76
flats64	Squaw Bay	48.560	-122.946	15-Jul-09	17	0.33	1.45	0.05	0.15	1.03	1.87
flats66	Shallow Bay, Sucia	48.763	-122.917	25-Jun-09	20	0.37	5.33	0.62	0.15	3.79	6.87
flats67	Fossil Bay	48.750	-122.900	24-Jun-09	21	0.48	6.69	1.66	0.19	4.16	9.21
flats73	Salmon Bank	48.440	-122.977	14-Jul-09	12	0.59	203.78	288.91	0.08	170.47	237.10
Narrow Fringe											
cps0224	Wilson Point	47.207	-122.839	12-Aug-09							
cps1035	NE of Point White	47.599	-122.557	11-Aug-09	14	0.05	0.09	0.00	0.55	-0.01	0.19
cps1054	Agate Pass Bridge SE	47.711	-122.567	10-Aug-09	13	0.33	0.80	0.02	0.18	0.52	1.08
cps1141	Fern Cove North, Vashon Island	47.485	-122.482	11-Aug-09	16	0.38	4.54	0.51	0.16	3.14	5.94
cps1194	N. Herron Island	47.273	-122.834	12-Aug-09							
cps1289	Villa Beach N	47.181	-122.680	14-Aug-09							
cps1676	Broadview	47.724	-122.378	07-Aug-09	14	0.42	5.18	0.14	0.07	4.44	5.92
cps1777	E. 11th St, Hylebos Waterway	47.278	-122.399	17-Aug-09							

Site	Location	Approximate Latitude (dec. deg.)	Approximate Longitude (dec. deg.)	Date Sampled	Number of Transects	*Z. marina* Fraction Along Transects	*Z. marina* Area at Site (hectares)	Variance	Coefficient of Variance	Estimated *Z. marina* Area Confidence Interval 95% Lower Limit (hectares)	95% Upper Limit (hectares)
cps1951	S. of Stretch Island	47.314	-122.837	12-Aug-09							
cps1954	Stretch Point State Park	47.331	-122.821	12-Aug-09							
cps1983	N. Joemma Beach	47.226	-122.816	12-Aug-09							
cps1999	Filucy Bay, Longbranch	47.211	-122.753	14-Aug-09							
cps2038	Allen Point, Carr Inlet	47.345	-122.671	13-Aug-09	15	0.24	1.89	0.12	0.18	1.21	2.58
cps2068	Point Fosdick NE	47.260	-122.572	14-Aug-09	10	0.14	0.09	0.00	0.27	0.04	0.14
cps2182	Lemolo Shore Drive NE, Lemolo	47.706	-122.612	10-Aug-09							
cps2552	Oak Bay Ramp	48.015	-122.726	27-Aug-09	13	0.54	9.34	0.33	0.06	8.22	10.46
hdc2321	Across from Eagle Pt	47.479	-123.047	24-Aug-09							
hdc2364	Forest Beach	47.384	-122.943	24-Aug-09	7	0.39	0.49	0.01	0.19	0.31	0.67
hdc2408	Jorsted Creek South	47.520	-123.049	24-Aug-09	11	0.58	5.05	0.18	0.08	4.22	5.89
hdc2460	Lindsay's Beach	47.791	-122.821	25-Aug-09	12	0.51	4.79	0.10	0.07	4.17	5.41
nps0550	Vendovi East, Light	48.605	-122.599	06-Jul-09							
nps1344	E. of Ferndale	48.852	-122.725	21-Jul-09	15	0.06	0.41	0.02	0.33	0.14	0.68
sjs0001	Strawberry Bay North	48.564	-122.730	02-Jul-09	14	0.64	10.77	0.18	0.04	9.95	11.59
sjs0114	Decatur Head South	48.508	-122.787	22-Jun-09	18	0.66	10.34	0.54	0.07	8.91	11.78
sjs0118	SE Decatur Island	48.485	-122.813	18-Jun-09	13	0.46	23.98	1.71	0.05	21.42	26.54
sjs0133	Mulno Cove	48.499	-123.017	29-Jul-09	16	0.21	1.64	0.07	0.16	1.14	2.14
sjs0176	White Point	48.591	-123.175	16-Jul-09	11	0.60	4.51	0.14	0.08	3.78	5.24
sjs0191	Edward's Reef, San Juan Island	48.501	-123.135	11-Sep-09	11	0.53	0.45	0.00	0.11	0.36	0.55
sjs0205	E. of Eagle Point	48.455	-123.004	14-Jul-09	11	0.33	10.56	0.51	0.07	9.16	11.96
sjs0448	S. of West Beach	48.683	-122.968	26-Jun-09	15	0.53	4.87	0.04	0.04	4.48	5.27
sjs0452	S. of Pt. Doughty	48.702	-122.945	25-Jun-09	13	0.60	11.87	0.63	0.07	10.31	13.43
sjs0488	E. of Blakely Peak	48.578	-122.786	07-Jul-09							
sjs0544	Reef Island	48.605	-123.019	01-Jul-09	16	0.46	2.22	0.03	0.08	1.86	2.58
sjs0600	Odlin County Park	48.559	-122.892	24-Jun-09	15	0.51	2.85	0.13	0.13	2.15	3.55
sjs0639	Blind Island	48.424	-122.825	17-Jun-09							
sjs1492	Shannon Point W	48.506	-122.692	02-Jul-09	14	0.51	11.73	1.31	0.10	9.49	13.96
sjs2605	Chinese Gardens Lagoon	48.146	-122.779	28-May-09	11	0.36	5.42	0.24	0.09	4.45	6.39
sjs2628	Between Adelma & Madrona Beach Dr	48.031	-122.830	31-Aug-09	11	0.47	3.38	0.04	0.06	3.00	3.76
sjs2632	Between Sunset & City Lakes	47.999	-122.847	31-Aug-09	11	0.00	0.00	0.00	1.01	0.00	0.01
sjs2652	Thompson Spit, Discovery Bay	48.100	-122.946	01-Sep-09	15	0.34	4.17	0.60	0.19	2.65	5.69
sjs2784	5 sites SE of Slip Point	48.247	-124.193	28-May-09	15	0.16	0.70	0.03	0.24	0.37	1.04
swh0713	Entrance Shelter Bay	48.386	-122.506	30-Jun-09	14	0.25	0.70	0.06	0.34	0.23	1.17
swh0973	North Possession	47.923	-122.373	06-Aug-09	11	0.57	12.60	1.49	0.10	10.21	15.00

Site	Location	Approximate Latitude (dec. deg.)	Approximate Longitude (dec. deg.)	Date Sampled	Number of Transects	*Z. marina* Fraction Along Transects	*Z. marina* Area at Site (hectares)	Variance	Coefficient of Variance	Estimated *Z. marina* Area Confidence Interval 95% Lower Limit (hectares)	95% Upper Limit (hectares)
swh1568	Lowell Point	48.121	-122.492	03-Aug-09	16	0.33	0.15	0.00	0.13	0.11	0.19
swh1649	Nelson's Corner	47.923	-122.315	06-Aug-09	11	0.72	5.43	0.15	0.07	4.67	6.19
Wide Fringe											
cps1160	Tramp Harbor	47.407	-122.431	17-Aug-09	20	0.35	2.38	0.06	0.11	1.88	2.87
cps2105	Yukon Harbor Center	47.527	-122.535	18-Aug-09	12	0.03	0.80	0.15	0.49	0.04	1.57
cps2565	N of E County Park	48.064	-122.681	28-Aug-09	15	0.17	2.86	0.58	0.26	1.38	4.35
hdc2283	E. of Warrenville	47.668	-122.764	19-Aug-09	14	0.75	12.29	0.24	0.04	11.34	13.25
hdc2284	Warrenville	47.664	-122.775	25-Aug-09	14	0.53	8.18	0.49	0.09	6.81	9.54
nps0652	Kellys Point South	48.524	-122.645	04-Jul-09	11	0.18	0.43	0.02	0.31	0.17	0.70
nps1328	W of Birch Bay	48.929	-122.799	20-Jul-09	15	0.18	1.83	0.21	0.25	0.93	2.72
nps1387	Sunrise Cove	48.701	-122.658	06-Jul-09	14	0.56	3.74	0.09	0.08	3.15	4.34
nps1487	Loverick's	48.513	-122.652	04-Jul-09	11	0.53	4.32	0.32	0.13	3.21	5.44
sjs0829	Joseph Whidbey State Park	48.321	-122.711	13-Jul-09	12	0.04	0.49	0.02	0.27	0.23	0.74
sjs2742	Between Agate & Crescent Bay	48.168	-123.732	29-May-09							
swh0869	Polnell Point Light W	48.273	-122.564	31-Jul-09	11	0.14	0.05	0.00	0.31	0.02	0.09
swh0881	Maylor Point, Whidbey Island	48.262	-122.618	31-Jul-09							
swh0882	West Maylor Point, Whidbey Is.	48.260	-122.630	31-Jul-09							
swh0955	West of Langley	48.046	-122.420	03-Aug-09	11	0.76	9.61	0.14	0.04	8.87	10.35

Appendix B *Z. marina* Area Estimates at 2009 Focus Area Sample Sites

Site	Location	Approximate Latitude (dec. deg.)	Approximate Longitude (dec. deg.)	Date Sampled	Number of Transects	*Z. marina* Fraction Along Transects	*Z. marina* Area at Site (hectares)	Variance	Coefficient of Variation	Estimated *Z. marina* Area Confidence Interval 95% Lower Limit (hectares)	95% Upper Limit (hectares)
Flats											
flats51	Provost Harbor (Stuart Island)	48.676	-123.186	08-Jul-09	18	0.71	12.01	0.51	0.06	10.61	13.41
flats52	Nelson Bay	48.603	-123.181	15-Jul-09	21	0.54	21.71	12.90	0.17	14.67	28.75
flats55	Mitchell Bay	48.571	-123.165	22-Jul-09	19	0.43	4.89	0.20	0.09	4.02	5.76
flats56	False Bay (San Juan Island)	48.485	-123.069	10-Sep-09	15	0.25	6.12	0.11	0.05	5.46	6.78
flats58	Barlow Bay	48.438	-122.869	29-Jul-09	15	0.66	7.29	0.64	0.11	5.71	8.86
flats61	Shoal Bay	48.560	-122.881	23-Jun-09	21	0.57	6.52	0.47	0.10	5.18	7.86
flats63	Blind Bay	48.578	-122.937	07-Jul-09	30	0.25	4.41	0.91	0.22	2.53	6.28
flats67	Fossil Bay	48.750	-122.900	24-Jun-09	21	0.48	6.69	1.66	0.19	4.16	9.21
Fringe											
sjs0002	S. Strawberry Bay (Cypress Island)	48.557	-122.725	02-Jul-09	10	0.59	4.96	0.12	0.07	4.27	5.65
sjs0115	White Cliff (Decatur Island)	48.500	-122.792	22-Jun-09	12	0.63	14.10	0.37	0.04	12.91	15.30
sjs0138	North side of North Bay	48.519	-123.003	28-Jul-09	15	0.45	1.33	0.05	0.16	0.92	1.75
sjs0140	Pear Point (San Juan Island)	48.515	-122.981	28-Jul-09	11	0.66	2.36	0.04	0.09	1.95	2.76
sjs0153	San Juan Channel, Terrace	0.000	0.000	08-Jul-09							
sjs0154	San Juan Channel, N. of Terrace Dr.	48.566	-123.040	08-Jul-09	20	0.28	0.10	0.00	0.17	0.07	0.14
sjs0182	Smugglers Cove (San Juan Island)	48.564	-123.177	22-Jul-09	14	0.66	0.29	0.00	0.09	0.24	0.34
sjs0192	S of Edwards Reef (San Juan Is.)	48.497	-123.126	11-Sep-09	12	0.62	0.91	0.01	0.09	0.76	1.07
sjs0311	Clark Island	48.698	-122.765	10-Jul-09	15	0.40	1.65	0.05	0.13	1.23	2.07
sjs0345	Point Disney (Waldron Island)	48.676	-123.044	25-Jun-09							
sjs0346	Waldron Dock (Waldron Island)	48.684	-123.039	25-Jun-09	11	0.55	3.00	0.07	0.09	2.49	3.50
sjs0359	S of Mail Bay (Waldron Island)	48.697	-123.005	09-Jul-09	14	0.23	0.15	0.00	0.24	0.08	0.22
sjs0392	E. Sound County Park (Orcas Island)	48.689	-122.902	27-Jul-09	15	0.59	0.31	0.00	0.12	0.24	0.38
sjs0400	Across from Rosaria (Orcas Island)	48.643	-122.889	27-Jul-09							
sjs0434	Deer Harbor (Orcas Island)	48.616	-123.001	01-Jul-09	15	0.61	4.08	0.16	0.10	3.30	4.86
sjs0437	Steep Point (Orcas Island)	48.610	-123.019	28-Jul-09	15	0.52	0.58	0.00	0.11	0.45	0.71
sjs0453	Point Doughty (Orcas Island)	48.709	-122.949	26-Jun-09	11	0.70	3.61	0.06	0.07	3.12	4.09
sjs0499	NW John's Island	48.668	-123.163	09-Jul-09	11	0.73	2.13	0.02	0.07	1.85	2.42
sjs0557	North of Crane Island	48.600	-123.001	01-Jul-09	14	0.26	1.73	0.08	0.16	1.19	2.27
sjs1303	NW of Kellett Bluff (Henry Island)	48.592	-123.203	16-Jul-09							

Appendix C Change in *Z. marina* Area for Sites Sampled in 2008 and 2009

Site	2008 *Z. marina* area (ha)	2008 variance	2009 *Z. marina* area (ha)	2009 variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
core001	3,439.7	26,768.0	3,155.2	50,469.1	-8.3	61.7	7.9	10.1	15.4	ns
core002	2.3	0.0	2.3	0.0	-2.6	115.7	10.8	13.8	21.1	ns
core003	517.3	1,037.8	507.5	1,928.8	-1.9	109.4	10.5	13.4	20.5	ns
core004	128.7	140.3	119.7	180.5	-7.0	182.1	13.5	17.3	26.4	ns
core005	1.3	0.0	1.0	0.0	-17.3	411.7	20.3	26.0	39.8	ns
core006	1.9	0.1	1.4	0.1	-30.0	308.2	17.6	22.5	34.4	80% dec
cps0224	0.0	0.0	0.0	0.0						ns
cps1035	0.0	0.0	0.1	0.0	107.6	33,188.3	182.2	233.6	357.1	ns
cps1054	0.6	0.0	0.8	0.0	24.0	882.1	29.7	38.1	58.2	ns
cps1141	4.1	0.6	4.5	0.5	11.8	778.0	27.9	35.8	54.7	ns
cps1160	2.0	0.1	2.4	0.1	19.5	450.4	21.2	27.2	41.6	ns
cps1194	0.0	0.0	0.0	0.0						ns
cps1289	0.0	0.0	0.0	0.0						ns
cps1676	5.7	0.3	5.2	0.1	-9.9	123.3	11.1	14.2	21.8	ns
cps1777	0.0	0.0	0.0	0.0						ns
cps1951	0.0	0.0	0.0	0.0						ns
cps1954	0.0	0.0	0.0	0.0						ns
cps1983	0.0	0.0	0.0	0.0						ns
cps1999	0.0	0.0	0.0	0.0						ns
cps2038	1.7	0.2	1.9	0.1	10.5	1,302.4	36.1	46.3	70.7	ns
cps2182	0.0	0.0	0.0	0.0						ns
cps2552	10.8	0.3	9.3	0.3	-13.3	49.6	7.0	9.0	13.8	80% dec
flats11	1,328.1	3,593.4	1,253.3	2,256.6	-5.6	30.9	5.6	7.1	10.9	ns
flats12	720.0	2,888.7	606.8	1,796.9	-15.7	74.2	8.6	11.0	16.9	80% dec
flats17	1.3	0.2	2.1	0.1	59.9	3,060.7	55.3	70.9	108.4	ns
flats20	197.8	577.6	200.8	622.1	1.5	311.3	17.6	22.6	34.6	ns
flats26	102.4	885.0	99.1	751.0	-3.2	1,507.8	38.8	49.8	76.1	ns
flats42	103.0	29.5	108.6	38.5	5.5	67.2	8.2	10.5	16.1	ns
flats55	3.3	0.3	4.9	0.2	46.1	691.1	26.3	33.7	51.5	80% inc
flats64	1.5	0.1	1.4	0.0	-4.5	399.8	20.0	25.6	39.2	ns
flats66	5.1	0.8	5.3	0.6	5.2	593.9	24.4	31.2	47.8	ns
flats67	6.4	2.2	6.7	1.7	4.8	1,006.6	31.7	40.7	62.2	ns
flats73	183.9	368.7	203.8	288.9	10.8	219.4	14.8	19.0	29.0	ns
hdc2283	9.5	1.1	12.3	0.2	29.7	239.8	15.5	19.9	30.4	80% inc
hdc2284	9.6	0.8	8.2	0.5	-14.6	114.3	10.7	13.7	21.0	80% dec
hdc2321	0.0	0.0	0.0	0.0						ns
hdc2460	5.2	0.1	4.8	0.1	-7.8	70.7	8.4	10.8	16.5	ns
nps0550	0.0	0.0	0.0	0.0						ns

Site	2008 *Z. marina* area (ha)	2008 variance	2009 *Z. marina* area (ha)	2009 variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
nps1328	2.5	0.3	1.8	0.2	-26.4	641.4	25.3	32.5	49.6	ns
nps1344	0.2	0.0	0.4	0.0	74.1	9,469.7	97.3	124.8	190.7	ns
nps1387	3.6	0.1	3.7	0.1	2.9	186.6	13.7	17.5	26.8	ns
nps1487	4.7	0.2	4.3	0.3	-8.5	223.8	15.0	19.2	29.3	ns
sjs0001	9.8	0.5	10.8	0.2	10.2	86.6	9.3	11.9	18.2	ns
sjs0114	10.8	0.4	10.3	0.5	-4.1	78.5	8.9	11.4	17.4	ns
sjs0118	26.2	2.4	24.0	1.7	-8.5	54.2	7.4	9.4	14.4	ns
sjs0205	9.9	0.4	10.6	0.5	7.1	102.9	10.1	13.0	19.9	ns
sjs0448	5.2	0.0	4.9	0.0	-5.5	24.5	5.0	6.3	9.7	ns
sjs0452	14.2	1.1	11.9	0.6	-16.5	67.8	8.2	10.6	16.1	95% dec
sjs0488	0.0	0.0	0.0	0.0						ns
sjs0544	1.9	0.1	2.2	0.0	16.9	442.3	21.0	27.0	41.2	ns
sjs0600	2.6	0.1	2.9	0.1	11.6	418.1	20.4	26.2	40.1	ns
sjs0639	0.0	0.0	0.0	0.0						ns
sjs1492	13.1	1.8	11.7	1.3	-10.6	158.3	12.6	16.1	24.7	ns
sjs2652	6.0	0.5	4.2	0.6	-30.8	224.9	15.0	19.2	29.4	95% dec
sjs2742	0.0	0.0	0.0	0.0						ns
swh0713	0.4	0.0	0.7	0.1	81.9	7,532.3	86.8	111.3	170.1	ns
swh0869	0.1	0.0	0.1	0.0	-28.5	953.8	30.9	39.6	60.5	ns
swh0881	0.0	0.0	0.0	0.0						ns
swh0882	0.0	0.0	0.0	0.0						ns
swh0955	8.2	0.2	9.6	0.1	16.8	59.1	7.7	9.9	15.1	95% inc
swh0973	13.4	2.4	12.6	1.5	-6.1	200.1	14.1	18.1	27.7	ns
swh1568	0.1	0.0	0.1	0.0	9.0	483.3	22.0	28.2	43.1	ns
swh1649	5.4	0.1	5.4	0.1	0.4	96.6	9.8	12.6	19.3	ns

ns = no significant change detected
80% inc / 80% dec = increasing or decreasing change detected when α = 0.2
95% inc / 95% dec = increasing or decreasing changed detected when α = 0.05

Appendix D Change in *Z. marina* Area for Focus Area Sites Sampled in 2004 and 2009

Site	2004 *Z. marina* area (ha)	2004 variance	2009 *Z. marina* area (ha)	2009 variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
core002	3.3	0.1	2.3	0.0	-31.1	59.9	7.7	9.9	15.2	95% dec
flats51	11.3	0.7	12.0	0.5	6.6	104.5	10.2	13.1	20.0	ns
flats52	14.9	0.8	21.7	12.9	45.9	659.0	25.7	32.9	50.3	80% inc
flats53*	0.0	0.0	0.0	0.0						ns
flats55	3.5	0.3	4.9	0.2	40.2	708.7	26.6	34.1	52.2	80% inc
flats56	6.9	1.1	6.1	0.1	-11.1	201.8	14.2	18.2	27.8	ns
flats58	7.4	0.2	7.3	0.6	-1.3	151.4	12.3	15.8	24.1	ns
flats61	7.0	0.2	6.5	0.5	-6.6	131.7	11.5	14.7	22.5	ns
flats63	5.5	1.3	4.4	0.9	-19.6	580.9	24.1	30.9	47.2	ns
flats67	4.7	0.9	6.7	1.7	41.4	1,554.4	39.4	50.5	77.3	ns
flats73**	163.9	226.2	203.8	288.9	24.3	237.5	15.4	19.8	30.2	80% inc
sjs0345	0.0	0.0	0.0	0.0						ns
sjs0400	0.0	0.0	0.0	0.0						ns
sjs1303	0.0	0.0	0.0	0.0						ns
sjs0002	5.4	0.1	5.0	0.1	-7.8	74.6	8.6	11.1	16.9	ns
sjs0115	15.7	0.6	14.1	0.4	-10.0	33.4	5.8	7.4	11.3	80% dec
sjs0138	1.5	0.2	1.3	0.0	-9.1	864.3	29.4	37.7	57.6	ns
sjs0140	2.3	0.0	2.4	0.0	4.4	120.0	11.0	14.0	21.5	ns
sjs0153	0.0	0.0	0.0	0.0						ns
sjs0154	0.2	0.0	0.1	0.0	-47.1	101.3	10.1	12.9	19.7	95% dec
sjs0182	0.3	0.0	0.3	0.0	9.5	167.5	12.9	16.6	25.4	ns
sjs0192	0.5	0.0	0.9	0.0	81.1	1,858.6	43.1	55.3	84.5	80% inc
sjs0311	1.8	0.0	1.7	0.0	-10.7	233.6	15.3	19.6	30.0	ns
sjs0346	3.4	0.1	3.0	0.1	-12.4	104.2	10.2	13.1	20.0	ns
sjs0359	0.2	0.0	0.2	0.0	-35.3	440.6	21.0	26.9	41.1	80% dec
sjs0392	0.3	0.0	0.3	0.0	1.7	225.6	15.0	19.3	29.4	ns
sjs0434	4.0	0.1	4.1	0.2	2.1	174.0	13.2	16.9	25.9	ns
sjs0437	0.7	0.0	0.6	0.0	-18.9	111.3	10.6	13.5	20.7	80% dec
sjs0453	3.8	0.1	3.6	0.1	-5.8	99.6	10.0	12.8	19.6	ns
sjs0499	2.1	0.0	2.1	0.0	3.4	155.1	12.5	16.0	24.4	ns
sjs0557	4.3	0.1	1.7	0.1	-59.8	53.1	7.3	9.3	14.3	95% dec

ns =no significant change detected
80% inc / 80% dec = increasing or decreasing change detected when α = 0.2
95% inc / 95% dec = increasing or decreasing changed detected when α = 0.05
* - flats53 data was acquired from Sandy Wyllie-Echeverria (pers. comm. 2004) and from the Eelgrass Stressor-Response Field data (Ferrier and Berry 2010).
** - 2004 data for flats73 is from 2003 underwater video transects performed by the Friends of the San Juans (Slocomb et al. 2004, Dowty 2010).

Appendix E Total *Z. marina* area estimates from 2000 – 2009

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Estimate (ha)	19,000	21,400	20,800	21,000	21,500	20,400	22,000	21,400	22,800	22,000
Standard Error (ha)	7,100	5,900	5,800	5,600	1,600	1,700	1,900	1,900	2,300	1,900
CV	0.17	0.27	0.27	0.26	0.07	0.08	0.09	0.09	0.10	0.08
Conf. Interval (95%)	±13,970	±11,570	±11,330	±10,880	±3,090	±3,300	±3,700	±3,700	±4,500	±3,600

Note: Values listed for 2000 to 2004 reflect the inclusion of Pt. Roberts, Salmon Bank and Wyckoff Shoal and differ slightly from values published in previous reports (Berry et al. 2003, Dowty et al. 2005).

Appendix F *Z. marina* Depth Estimates at 2009 SVMP Sample Sites

		Minimum *Z. marina* Depth (MLLW)					Maximum *Z. marina* Depth (MLLW)				
Site	Location	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
Core											
core001	Padilla Bay	11	0.6	0.4	0.1	0.2	11	-4.2	-3.5	0.2	0.3
core002	Picnic Cove	13	-0.2	-2.0	0.5	0.9	13	-5.7	-4.7	0.2	0.3
core003	Jamestown	11	0.4	-0.4	0.3	0.6	11	-7.6	-5.7	0.5	0.9
core004	Lynch Cove	14	0.3	-0.5	0.2	0.3	14	-4.2	-3.0	0.2	0.4
core005	Dumas Bay	12	-0.4	-0.8	0.1	0.2	12	-2.0	-1.7	0.0	0.1
core006	Burley Spit	15	-0.9	-1.3	0.1	0.2	15	-2.8	-2.3	0.1	0.2
Persistent Flats											
flats11	Samish Bay N.	9	0.4	0.0	0.1	0.2	9	-3.5	-3.3	0.1	0.1
flats12	Samish Bay S.	11	0.7	0.4	0.0	0.1	11	-3.3	-3.1	0.0	0.1
flats20	Skagit Bay N.	16	0.7	-0.1	0.1	0.2	16	-3.0	-1.2	0.2	0.4
Rotational Flats											
flats03	Birch Bay	12	0.4	-0.2	0.1	0.2	12	-3.8	-3.2	0.1	0.2
flats15	Fidalgo Bay	26	0.3	-0.6	0.2	0.3	26	-5.6	-2.2	0.3	0.6
flats17	Bowman Bay	17	0.5	-0.7	0.3	0.6	18	-4.5	-2.1	0.3	0.6

Site	Location	Minimum *Z. marina* Depth (MLLW) n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	Maximum *Z. marina* Depth (MLLW) n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
flats26	Snohomish Delta N	11	0.5	-0.1	0.1	0.2	11	-2.9	-2.0	0.2	0.5
flats42	Quilcene Bay	13	0.5	0.0	0.1	0.2	13	-7.5	-3.6	0.4	0.8
flats55	Mitchell Bay	19	-0.7	-3.5	0.3	0.7	19	-5.9	-5.1	0.2	0.4
flats64	Squaw Bay	16	-0.9	-1.2	0.1	0.1	16	-3.3	-2.3	0.2	0.4
flats66	Shallow Bay, Sucia	20	0.0	-1.5	0.3	0.6	20	-5.1	-2.6	0.3	0.7
flats73	Salmon Bank	12	-2.2	-4.4	0.2	0.5	12	-10.8	-9.4	0.2	0.4
Narrow Fringe											
cps0224	Wilson Point	0					0				
cps1035	NE of Point White	4	-1.3	-1.8	0.5	0.9	4	-3.2	-2.0	0.4	0.8
cps1054	Agate Pass Bridge SE	11	-0.2	-0.5	0.0	0.1	11	-4.1	-3.0	0.4	0.7
cps1141	Fern Cove North, Vashon Island	16	-0.1	-1.6	0.3	0.6	16	-6.1	-3.9	0.2	0.5
cps1194	N. Herron Island	0					0				
cps1289	Villa Beach N	0					0				
cps1676	Broadview	13	0.6	-0.4	0.2	0.3	14	-4.9	-3.9	0.2	0.4
cps1777	E. 11th St, Hylebos Waterway	0					0				
cps1951	S. of Stretch Island	0					0				
cps1954	Stretch Point State Park	0					0				
cps1983	N. Joemma Beach	0					0				
cps1999	Filucy Bay, Longbranch	0					0				
cps2038	Allen Point, Carr Inlet	14	-0.4	-0.7	0.1	0.1	14	-2.7	-1.6	0.2	0.3
cps2068	Point Fosdick NE	8	-1.4	-2.1	0.4	0.7	8	-4.9	-4.0	0.3	0.5
cps2182	Lemolo Shore Dr. NE, Lemolo	0					0				
cps2552	Oak Bay Ramp	13	0.6	0.2	0.1	0.2	13	-6.1	-3.3	0.4	0.8
hdc2321	Across from Eagle Pt	0					0				
hdc2364	Forest Beach	7	-1.7	-2.1	0.1	0.2	7	-3.8	-3.4	0.1	0.2
hdc2408	Jorsted Creek South	11	-0.6	-1.0	0.1	0.2	11	-5.9	-5.0	0.2	0.4
hdc2460	Lindsay's Beach	12	-0.6	-1.7	0.1	0.3	12	-5.2	-4.6	0.3	0.5
nps0550	Vendovi East, Light	0					0				
nps1344	E. of Ferndale	8	-0.5	-1.5	0.2	0.4	8	-2.9	-1.9	0.3	0.6

		Minimum *Z. marina* Depth (MLLW)					Maximum *Z. marina* Depth (MLLW)				
Site	Location	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
sjs0001	Strawberry Bay North	13	-0.1	-1.0	0.3	0.6	13	-6.6	-5.9	0.1	0.3
sjs0114	Decatur Head South	15	-0.8	-2.0	0.2	0.4	18	-8.0	-7.1	0.1	0.3
sjs0118	SE Decatur Island	13	-1.7	-3.4	0.3	0.6	13	-8.2	-7.6	0.1	0.2
sjs0133	Mulno Cove	14	-0.2	-1.9	0.5	0.9	14	-5.9	-3.9	0.4	0.7
sjs0176	White Point	11	-0.8	-1.0	0.1	0.1	11	-7.2	-6.4	0.2	0.4
sjs0191	Edward's Reef, San Juan Island	10	-2.8	-3.8	0.2	0.5	10	-9.0	-7.0	0.5	1.0
sjs0205	E. of Eagle Point	11	-4.0	-4.7	0.1	0.3	11	-11.2	-10.1	0.1	0.3
sjs0448	S. of West Beach	13	-0.1	-0.7	0.1	0.2	14	-8.0	-6.0	0.3	0.5
sjs0452	S. of Pt. Doughty	13	-0.5	-1.1	0.1	0.2	13	-7.9	-6.1	0.3	0.7
sjs0488	E. of Blakely Peak	0					0				
sjs0544	Reef Island	14	-1.0	-1.7	0.1	0.2	14	-6.9	-4.5	0.4	0.8
sjs0600	Odlin County Park	15	0.2	-0.6	0.1	0.3	15	-6.9	-4.5	0.4	0.8
sjs0639	Blind Island	0					0				
sjs1492	Shannon Point W	12	-2.6	-4.1	0.4	0.9	12	-8.5	-6.9	0.3	0.7
sjs2605	Chinese Gardens Lagoon	11	-1.4	-3.1	0.3	0.6	11	-7.7	-6.8	0.3	0.5
sjs2628	Between Adelma & Madrona Beach Dr	11	0.1	-0.3	0.1	0.2	11	-5.1	-4.1	0.2	0.4
sjs2632	Between Sunset & City Lakes	1	-2.4	-2.4			1	-2.4	-2.4		
sjs2652	Thompson Spit, Discovery Bay	13	-0.6	-1.6	0.4	0.8	13	-8.2	-5.5	0.4	0.9
sjs2784	5 sites SE of Slip Point	7	-3.7	-4.6	0.3	0.6	7	-8.3	-6.8	0.4	0.7
swh0713	Entrance Shelter Bay	11	0.4	-0.7	0.2	0.4	11	-2.9	-2.2	0.1	0.2
swh0973	North Possession	11	0.6	0.2	0.1	0.2	11	-4.3	-3.3	0.4	0.8
swh1568	Lowell Point	14	-0.7	-1.4	0.1	0.2	14	-3.8	-3.0	0.1	0.3
swh1649	Nelson's Corner	11	0.3	-0.1	0.2	0.3	11	-3.9	-3.2	0.1	0.3
Wide Fringe											
cps1160	Tramp Harbor	19	0.3	-0.2	0.1	0.2	19	-1.7	-1.1	0.1	0.2
cps2105	Yukon Harbor Center	6	0.4	-0.7	0.4	0.9	6	-2.3	-1.7	0.3	0.6
cps2565	N of E County Park	1	-1.1	-1.1			1	-2.9	-2.9		
hdc2283	E. of Warrenville	14	0.3	0.0	0.0	0.1	14	-3.6	-3.0	0.1	0.2
hdc2284	Warrenville	14	0.7	-0.1	0.2	0.5	14	-4.0	-3.1	0.1	0.2
nps0652	Kellys Point South	8	-0.8	-1.1	0.2	0.3	8	-5.4	-3.4	0.6	1.1

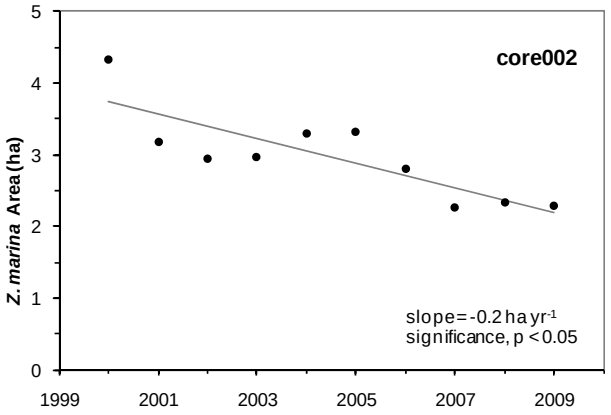
		Minimum *Z. marina* Depth (MLLW)					Maximum *Z. marina* Depth (MLLW)				
Site	Location	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
nps1328	W of Birch Bay	14	-0.7	-1.4	0.1	0.2	14	-3.6	-2.5	0.2	0.4
nps1387	Sunrise Cove	13	0.3	-0.5	0.2	0.4	13	-3.9	-2.9	0.3	0.6
nps1487	Loverick's	9	0.0	-0.3	0.1	0.2	10	-4.4	-3.1	0.3	0.6
sjs0829	Joseph Whidbey State Park	10	-3.8	-4.7	0.2	0.4	10	-7.2	-5.9	0.2	0.5
sjs2742	Between Agate & Crescent Bay	0					0				
swh0869	Polnell Point Light W	9	-0.7	-1.0	0.1	0.2	9	-1.5	-1.3	0.1	0.1
swh0881	Maylor Point, Whidbey Island	0					0				
swh0882	West Maylor Point, Whidbey Island	0					0				
swh0955	West of Langley	11	0.1	-0.1	0.1	0.2	11	-4.7	-3.7	0.2	0.3

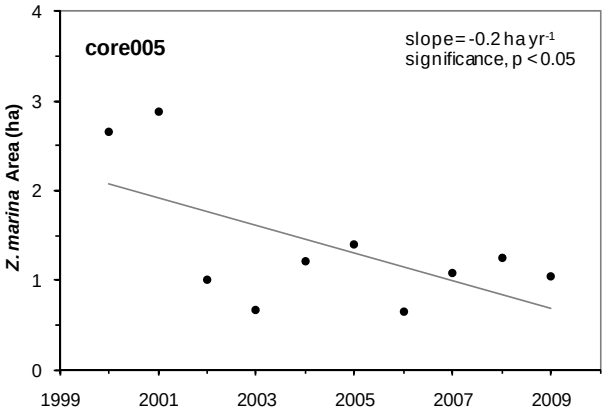
Appendix G *Z. marina* Depth Estimates at 2009 Focus Area Sample Sites

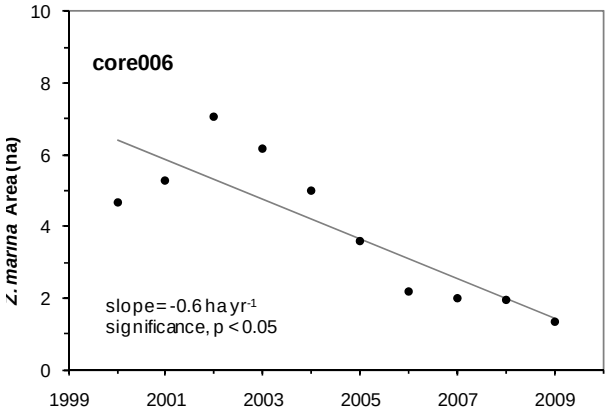
Site	Location	Minimum *Z. marina* Depth (MLLW) n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	Maximum *Z. marina* Depth (MLLW) n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
Flats											
flats51	Provost Harbor (Stuart Island)	18	-0.5	-1.3	0.1	0.3	18	-6.6	-4.5	0.2	0.3
flats52	Nelson Bay	16	-1.0	-2.6	0.3	0.5	16	-9.3	-7.0	0.5	1.1
flats54	Garrison Bay	13	-1.4	-1.8	0.1	0.2	13	-3.4	-2.4	0.2	0.3
flats55	Mitchell Bay	19	-0.7	-3.5	0.3	0.7	19	-5.9	-5.1	0.2	0.4
flats56	False Bay (San Juan Island)	15	-0.6	-1.1	0.2	0.4	15	-7.6	-5.9	0.3	0.6
flats58	Barlow Bay	13	-0.1	-0.8	0.1	0.2	13	-3.1	-2.3	0.1	0.2
flats61	Shoal Bay	13	0.2	-0.3	0.1	0.2	19	-6.4	-3.0	0.5	1.0
flats63	Blind Bay	18	-1.2	-2.0	0.1	0.2	18	-5.3	-3.3	0.3	0.5
flats67	Fossil Bay	15	-2.8	-3.4	0.2	0.3	0				
Fringe											
sjs0002	S. Strawberry Bay (Cypress Island)	10	-0.6	-2.6	0.6	1.1	10	-6.9	-5.9	0.2	0.3
sjs0115	White Cliff (Decatur Island)	11	-0.7	-1.4	0.2	0.3	12	-7.9	-7.2	0.2	0.4
sjs0138	North side of North Bay	14	-1.1	-3.1	0.4	0.8	14	-6.7	-4.7	0.4	0.7
sjs0140	Pear Point (San Juan Island)	11	0.2	-3.0	0.6	1.2	11	-7.8	-5.9	0.5	0.9
sjs0153	San Juan Channel, Terrace	0					0				
sjs0154	San Juan Channel, N. of Terrace Dr.	15	-1.5	-3.1	0.4	0.7	15	-8.3	-4.9	0.4	0.7
sjs0182	Smugglers Cove (San Juan Island)	13	-1.6	-3.8	0.4	0.8	14	-8.1	-6.8	0.4	0.7
sjs0192	S of Edwards Reef (San Juan Island)	11	-4.3	-5.4	0.4	0.7	11	-8.7	-8.0	0.2	0.4
sjs0311	Clark Island	12	-0.3	-0.8	0.2	0.3	12	-5.2	-4.0	0.3	0.6
sjs0345	Point Disney (Waldron Island)	0					0				
sjs0346	Waldron Dock (Waldron Island)	9	-1.2	-2.5	0.3	0.6	9	-7.5	-6.5	0.2	0.5
sjs0359	S of Mail Bay (Waldron Island)	9	-2.2	-3.4	0.3	0.6	9	-6.7	-5.0	0.4	0.9
sjs0392	E. Sound County Park (Orcas Island)	12	-0.3	-1.5	0.3	0.5	12	-4.7	-3.6	0.2	0.4
sjs0400	Across from Rosaria (Orcas Island)	0					0				
sjs0434	Deer Harbor (Orcas Island)	15	-0.5	-0.9	0.1	0.2	15	-5.5	-4.3	0.3	0.6

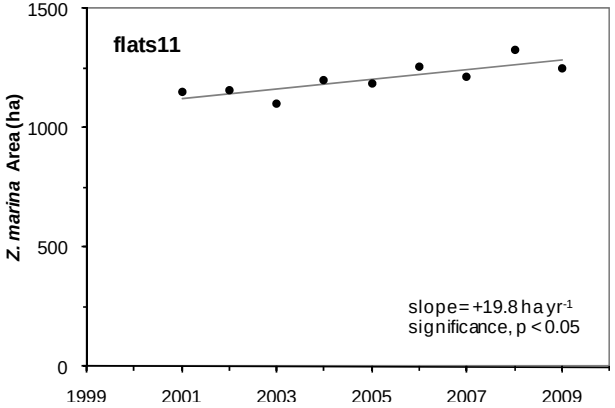
		Minimum *Z. marina* Depth (MLLW)					Maximum *Z. marina* Depth (MLLW)				
Site	Location	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
sjs0437	Steep Point (Orcas Island)	14	-0.8	-1.4	0.1	0.2	14	-8.1	-5.3	0.5	1.1
sjs0453	Point Doughty (Orcas Island)	10	-0.7	-1.7	0.3	0.5	11	-6.2	-4.8	0.2	0.5
sjs0499	NW John's Island	10	-0.3	-1.0	0.2	0.4	10	-7.9	-5.9	0.6	1.1
sjs0557	North of Crane Island	10	-2.1	-3.2	0.3	0.6	10	-7.8	-6.1	0.5	0.9
sjs1303	NW of Kellett Bluff (Henry Island)	0					0				

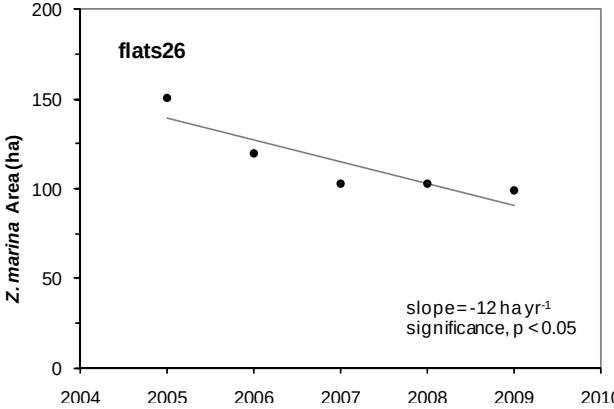
Appendix H 2009 Site Level Trend Analysis (p < 0.05)

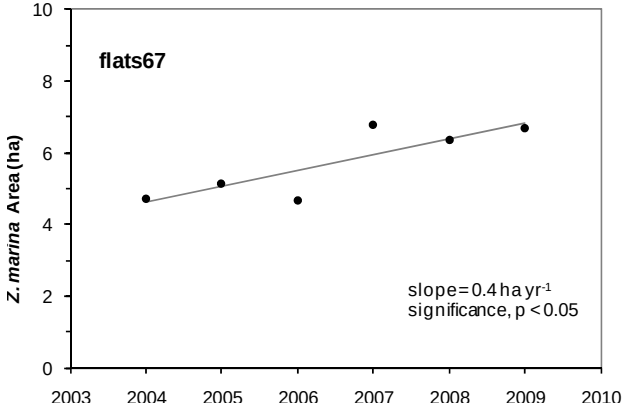


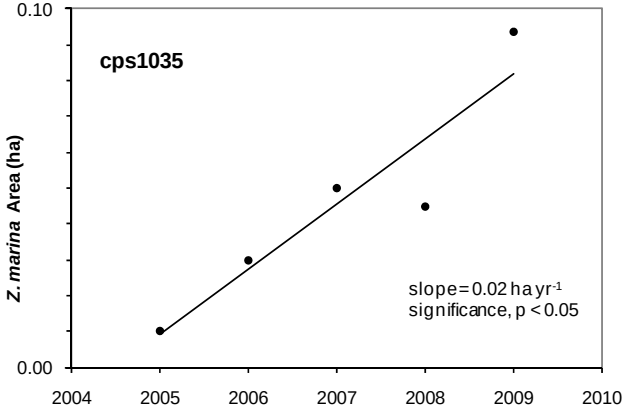


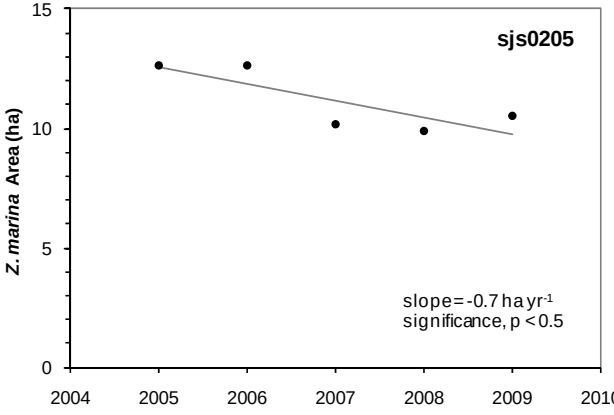


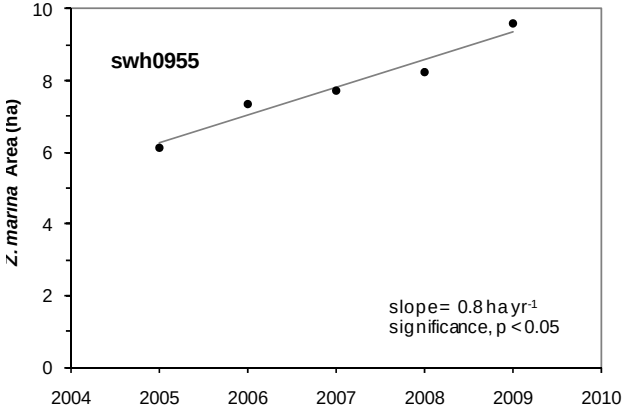




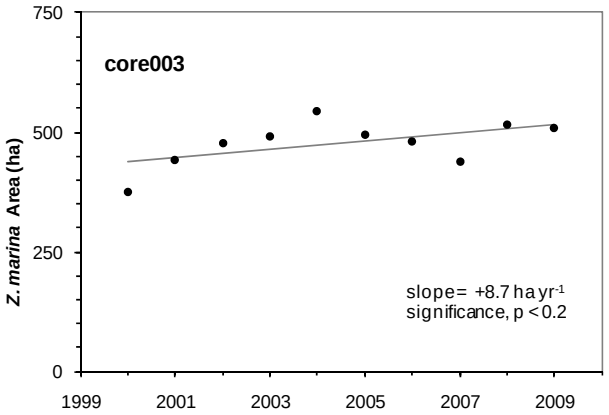


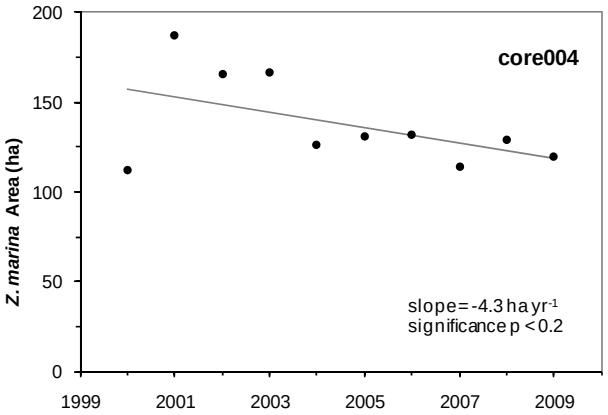


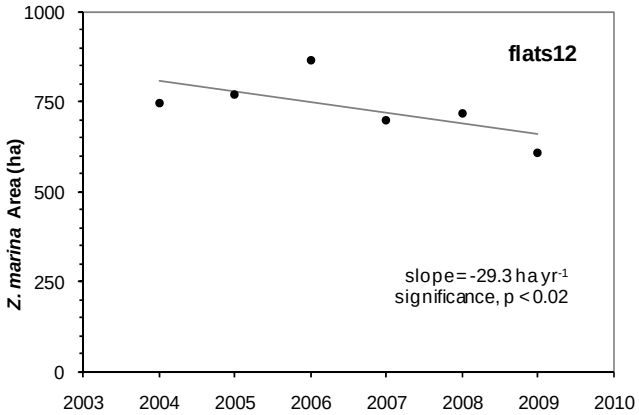


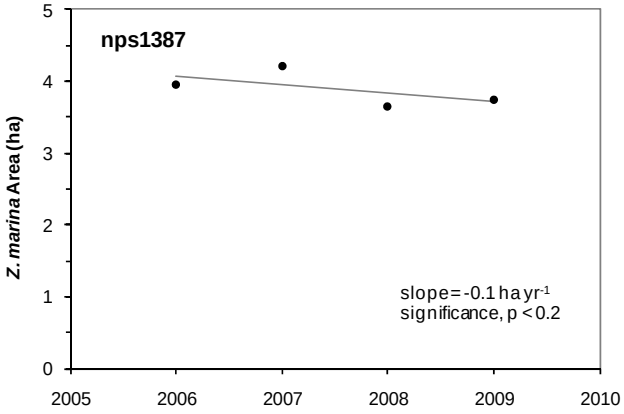


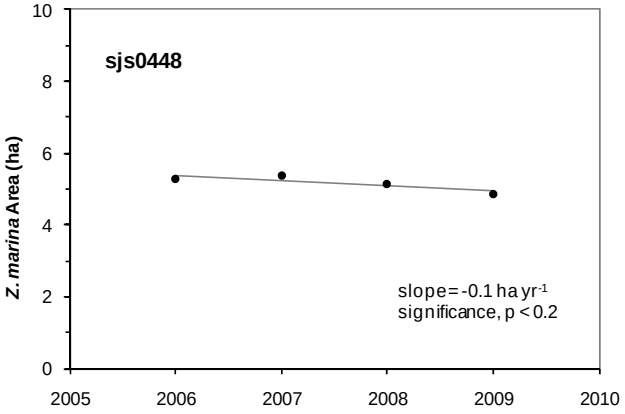
Appendix I 2009 Site Level Trend Analysis (p < 0.20)

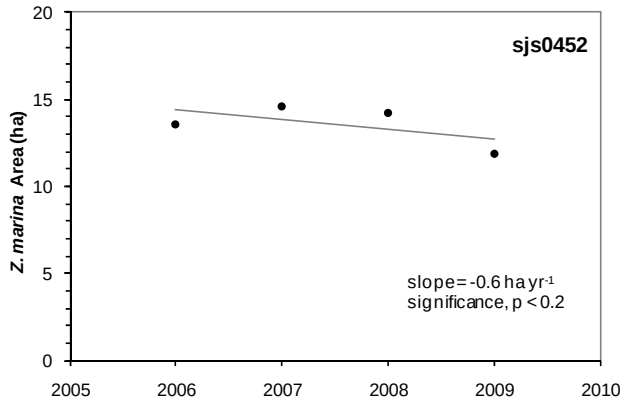


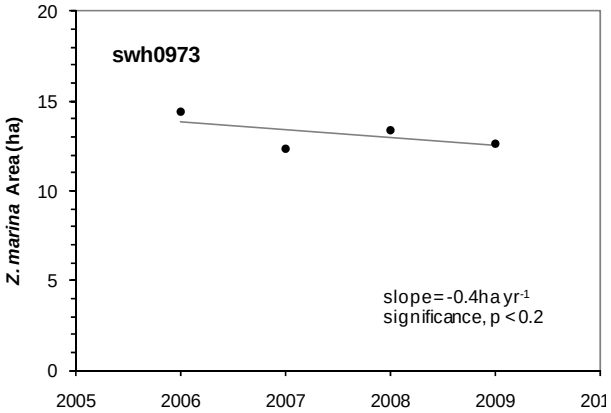


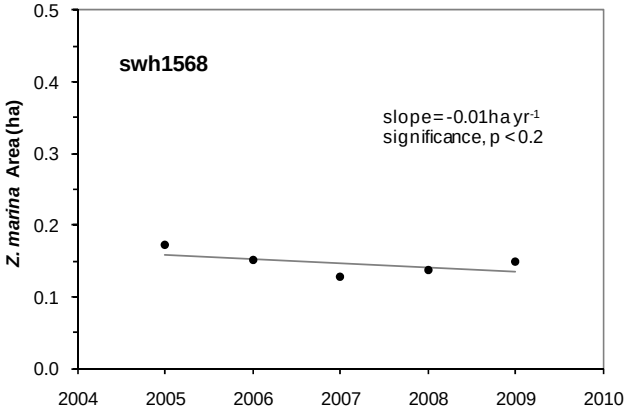


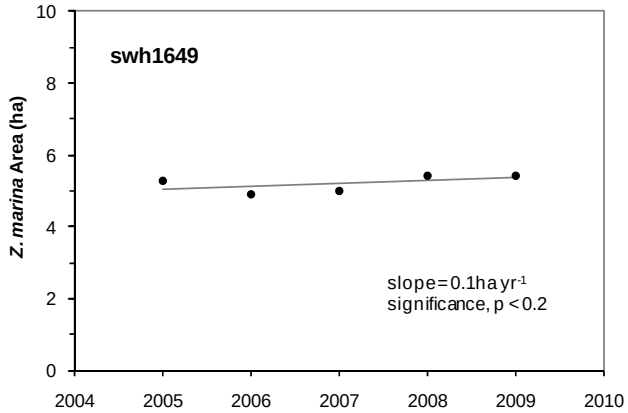




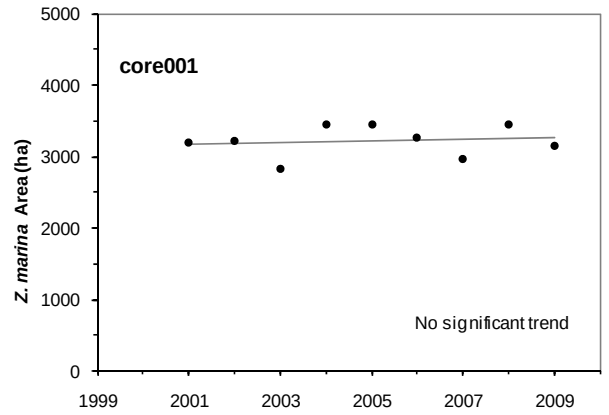


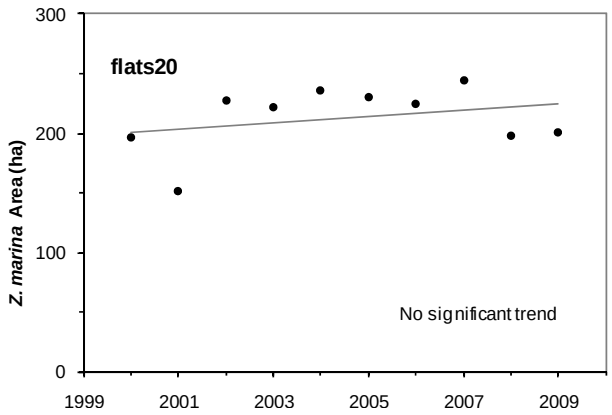


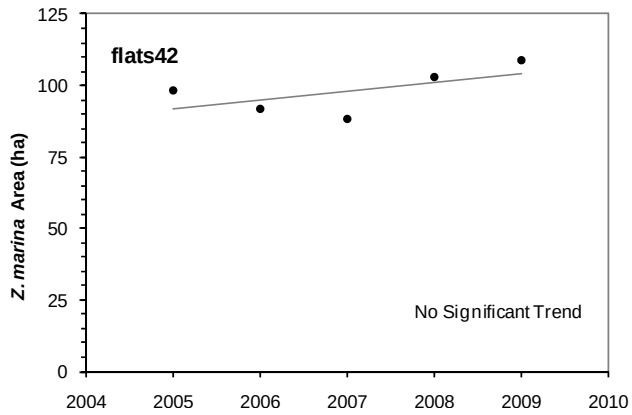


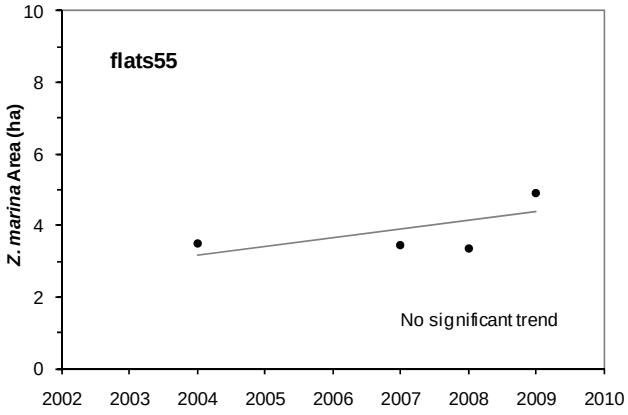


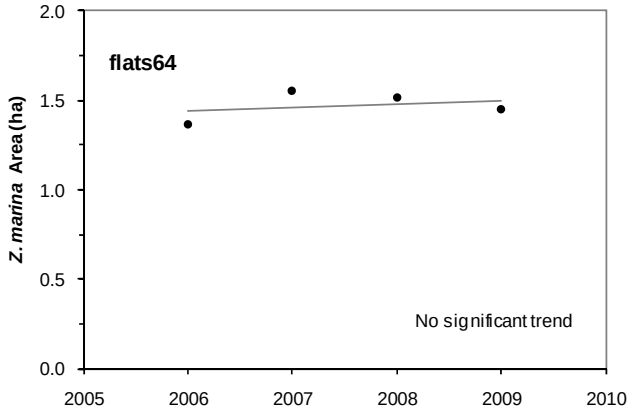
Appendix J 2009 Site Level Trend Analysis (no significant trend)

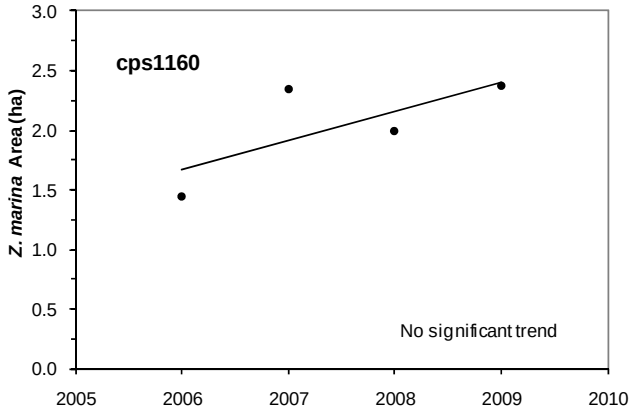


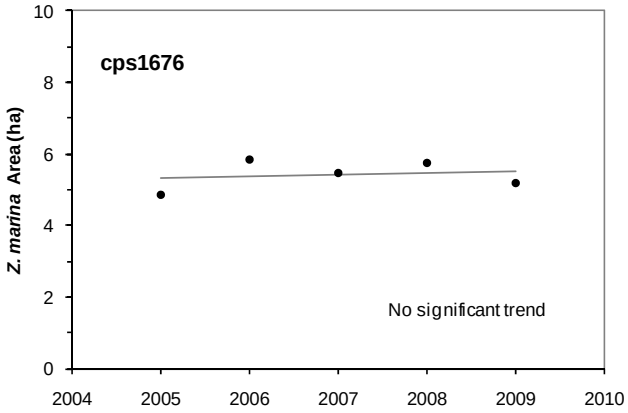


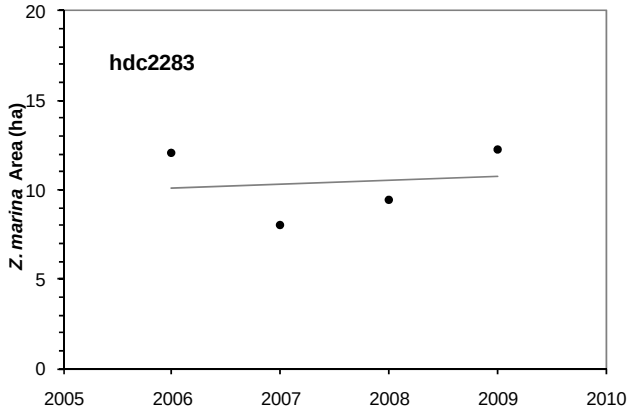


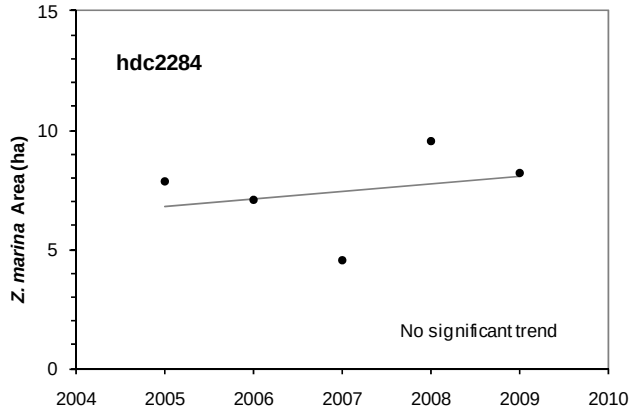


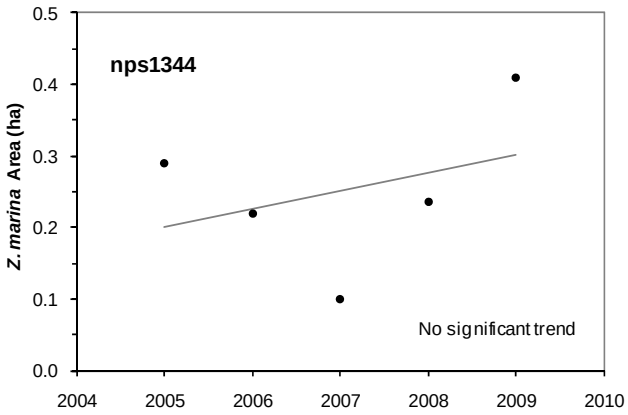


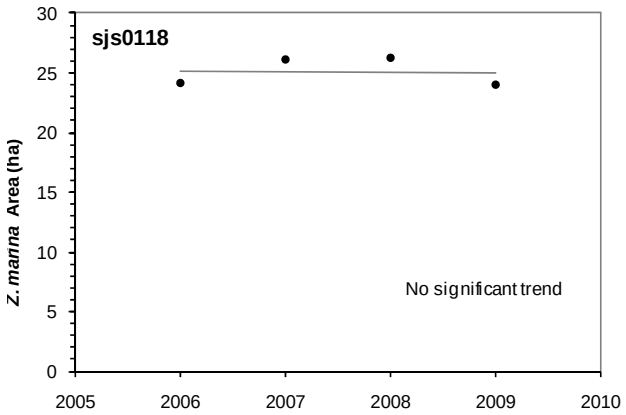


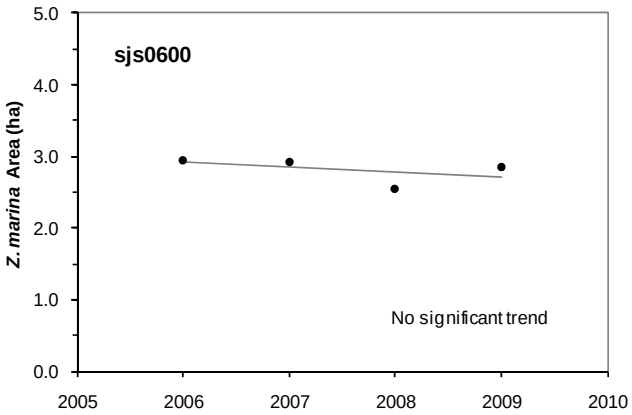


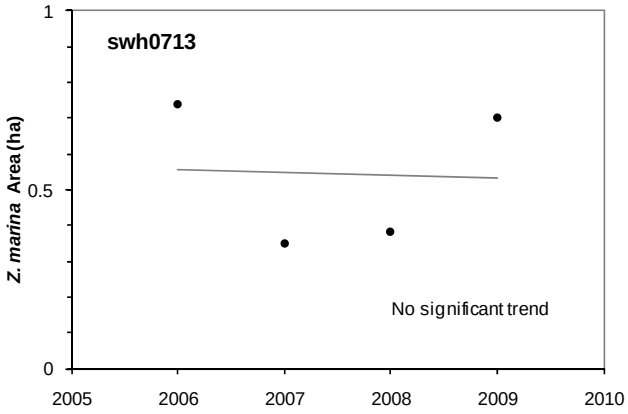












Note: Seven additional sites did not have a significant 4-5 year trend due to the absence of *Z. marina*. These sites include: *cps1194-N. Herron Island, cps1951-S. Stretch Island, cps1983-N. Joemma Beach, nps0550-Vendovi East Light, sjs0488-E. Blakely Peak, sjs0639-Blind Island,* and *sjs2742-Between Agate and Crescent Bays*.

Appendix K 2009 *San Juan County–Cypress Island* Focus Area Site Selection

The *San Juan County–Cypress Island* focus area was sampled previously in 2004 (Dowty et al. 2005). At the time, the site selection process focused on maximizing the precision in focus area results. In 2009, the sites selected in 2004 for the *San Juan County–Cypress Island* focus area effort were identical and the randomly selected soundwide sites that are subject to 20% rotation every five years differed. The list of the 45 sites (28 Focus Area sites and 17 soundwide sites) can be found in Table K-1.

Table K-1. Complete list of the 45 sites used to calculate the 2009 *San Juan County–Cypress Island* focus area status estimate. The list includes sites sampled as part of the focus area study and sites sampled as part of the Puget Sound study.

geomorphic category	study	Site	soundwide stratum
fringe	focus area study	sjs0002	narrow fringe
		sjs0115	narrow fringe
		sjs0138	narrow fringe
		sjs0140	narrow fringe
		sjs0153	narrow fringe
		sjs0154	narrow fringe
		sjs0182	narrow fringe
		sjs0192	narrow fringe
		sjs0311	narrow fringe
		sjs0345	narrow fringe
		sjs0346	narrow fringe
		sjs0359	narrow fringe
		sjs0392	narrow fringe
		sjs0400	narrow fringe
		sjs0434	narrow fringe
		sjs0437	narrow fringe
		sjs0453	narrow fringe
		sjs0499	narrow fringe
		sjs0557	narrow fringe
		sjs1303	narrow fringe
	soundwide study	sjs0001	narrow fringe
		sjs0114	narrow fringe
		sjs0118	narrow fringe
		sjs0133	narrow fringe
		sjs0176	narrow fringe
		sjs0191	narrow fringe
		sjs0205	narrow fringe
		sjs0448	narrow fringe
		sjs0452	narrow fringe
		sjs0488	narrow fringe
		sjs0544	narrow fringe
		sjs0600	narrow fringe
		sjs0639	narrow fringe
flats	focus area study	flats51	rotational flats
		flats52	rotational flats
		flats55	rotational flats
		flats56	rotational flats
		flats58	rotational flats

	flats61	rotational flats
	flats63	rotational flats
	flats67	rotational flats
soundwide study	core002	flats
	flats64	rotational flats
	flats66	rotational flats
	flats73	rotational flats