NATURAL RESOURCES

Puget Sound Submerged Vegetation Monitoring Project

2008 Monitoring Report

October 2009

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

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The following document fulfills tasks identified in the 2007-2009 Puget Sound Conservation and Recovery Plan and provides information on the status and trends of one of the indicators of environmental health in the Puget Sound Partnership's Action Agenda.

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 ship time collecting data for the project.

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All contributors are staff of the Washington State Department of Natural Resources (DNR) unless otherwise indicated.

Copies of this report may be obtained from
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 recognized the important functions and values *Z. marina* provides to nearshore systems and established the Submerged Vegetation Monitoring Project (SVMP) to track this valuable resource. The SVMP uses a statistically robust sampling design and underwater videography to monitor *Z. marina* on an annual basis. This report presents the monitoring results from the 2008 field season.

Key Findings:

1. The results from the SVMP indicate a pattern of slight decline in *Z. marina* throughout Puget Sound. This result is supported by three main findings:
    a. there were twice as many sites with significant declining long-term trends in *Z. marina* area over a period of four years or greater compared to increases,
    b. there were more sites with significant year-to-year declines in *Z. marina* area than increases in seven of eight sampling intervals, and
    c. the region assessment identified three different levels of concern for *Z. marina* decline based on a proportion of tests that indicated significant evidence of change and decline. The *Hood Canal Region* had the highest level of concern for *Z. marina* decline, the *San Juan-Straits* and *Central Puget Sound Regions* had moderate levels of concern for *Z. marina* decline, and the *Saratoga-Whidbey* and the *North Puget Sound Regions* had low levels of concern for *Z. marina* decline.
2. Multiple indications suggest a pattern of slight *Z. marina* decline throughout Puget Sound, however, the magnitude of the observed changes were not sufficient to cause a significant year-to-year or long-term decrease in the total sound-wide *Z. marina* area estimate. The current *Z. marina* area estimate in Puget Sound is 22,800 ± 4,500 hectares.
3. The Focus Area effort in the *North Puget Sound Region* completed the project's initial sampling of all 5 regions in the study area. There are 9,859 ± 2,603 ha of *Z. marina* in the *North Puget Sound Region* and nearly 91% of this resource is located in large, shallow embayments.

The SVMP has observed a greater prevalence of significant yearly and long-term declines in *Z. marina* area at individual sites throughout Puget Sound. Although the cumulative loss of *Z. marina* area has not affected the overall sound-wide estimate, the consistent occurrence and sound-wide distribution of sites with significant declines compared to sites with gains is of concern. 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.

Priorities

The primary priorities for the SVMP to meet its monitoring mandate include:

1. Monitor the status and trends in *Z. marina* throughout Puget Sound to meet the goals identified by DNR and the Puget Sound Partnership.
2. Analyze and compare the 2004 and 2009 data from the San Juan County – Cypress Island Focus Area, located in the *San Juan–Straits Region*, and continue monitoring the next focus area in the 5-year rotation.
3. Provide timely reporting of *Z. marina* status and trends in annual SVMP reports so that information is rapidly available to researchers and managers who are assessing the condition of Puget Sound's resources.
4. Provide technical support and data to collaborators and management on the status and trends of *Z. marina* and on sites and regions of concern.
5. Collaborate with the Eelgrass Stressor – Response Project, academics, citizen groups, and other researchers who investigate the causes of *Z. marina* decline in Puget Sound.

Finally, with additional funding, the SVMP should extend the *Z. marina* baseline previous to 2000 through analysis of historical data. This work would likely be restricted to certain sub-areas within Puget Sound due to limited availability of historical *Z. marina* data.

1 Introduction

The overall goal of the Submerged Vegetation Monitoring Program (SVMP) is to monitor the status and trends of *Z. marina* 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). Previous work has demonstrated its usefulness as an indicator of habitat condition and impacts from anthropogenic stressors (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) and represents a key component of the agency's contribution to Puget Sound Partnership monitoring. 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. The legislature has stipulated management guidelines for these lands that balance various uses of state aquatic resources with "ensuring environmental protection" (RCW 79.105.030). Given the key ecological functions of *Z. marina* and its value as a resource under DNR's management, the tracking of seagrass resources by the SVMP serves DNR's direct mandate as well as that of the Puget Sound Partnership's mandates to track indicators of health and conduct coordinated, integrated monitoring and assessment.

The SVMP is one component of PSAMP, a program coordinated by the Puget Sound Action Team historically and, more recently, by the Puget Sound Partnership (2002a). PSAMP is a multi-agency effort mandated by the state legislature (RCW 90.71.060) to monitor diverse physical and biotic aspects of the Puget Sound ecosystem. It is currently being combined into a broader monitoring program under the direction of the Puget Sound Partnership's Science Panel (RCW 90.71.270; 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).

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 in implementing the state Shoreline Management Act (RCW 90.58). In 2009, the Puget Sound Partnership recognized *Z. marina* as an important provisional ecosystem indicator in the Action Agenda (Puget Sound Partnership 2009). The Partnership is using DNR's eelgrass monitoring data, along with other data sources, to evaluate the condition of Puget Sound in its 2009 State of the Sound Report. The Partnership is in the process of identifying a final set of indicators that will determine if it is achieving its goal to protect and restore Puget Sound.

In order to satisfy a broad range of data needs, the SVMP produces results at a range of spatial scales (site, region, and sound-wide 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 sound-wide scale (3,610 km of shoreline).

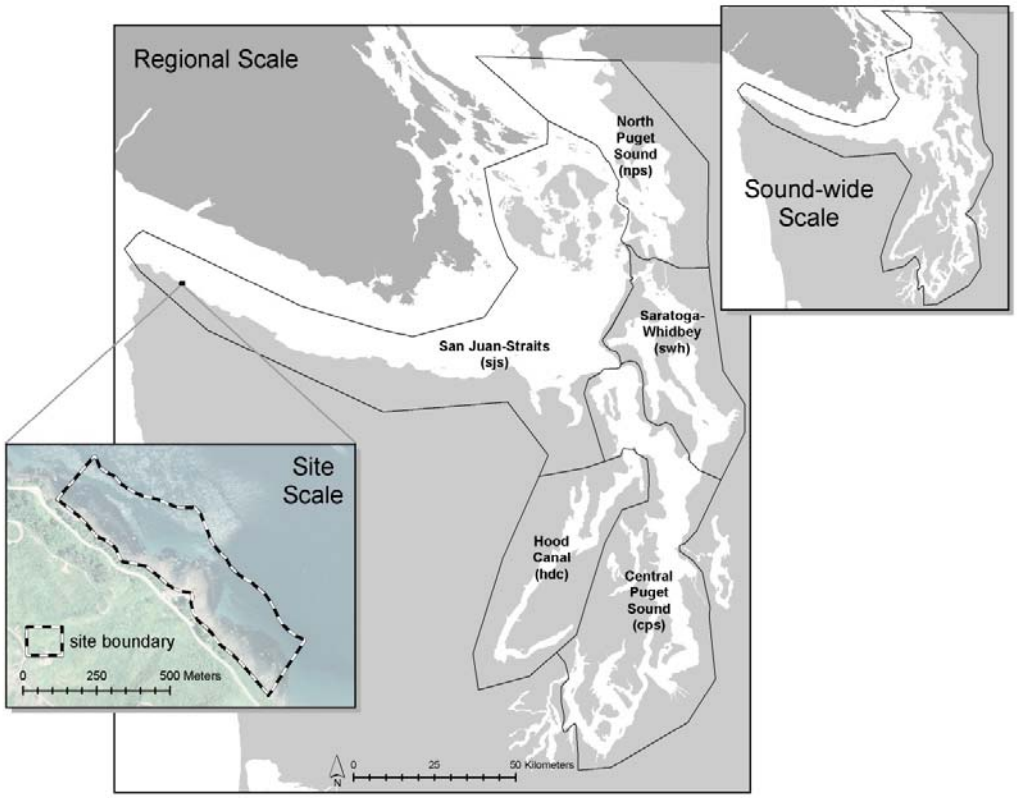

Figure 1-1. The SVMP produces monitors *Z. marina* condition at sound-wide, regional, and site scales throughout greater Puget Sound, WA. Letters in parentheses indicate the regional prefix for site codes (see Table 2-2).

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, Skalski 2003, Dowty 2005, Dowty et al. 2005, Gaeckle et al. 2007, 2008). The sound-wide and focus area sampling designs, including specific changes for the 2008 sampling efforts, are outlined below.

2.2 Sound-Wide Sampling Design

2.2.1 Stratification and Sampling Frames

All potential *Z. marina* habitat within the study area was delineated using the best available state-wide spatial data. Potential habitat was defined as the area between high water and the -6 m bathymetry contour. However, the actual extent of eelgrass, delineated with underwater video reconnaissance, is surveyed without regard to the depth boundaries of the state-wide 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 further changes were made to the fringe and flats strata to improve eelgrass 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).

Six sites from the total number of sites (2466) were non-randomly selected and designated as core sites for long-term sampling (Table 2-1; Berry et al. 2003). The core stratum contains sites in the fringe and flats geomorphic categories. 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 2008. Detailed explanations of SVMP sampling frame corrections and updates can be found in earlier reports (Dowty 2006a, Dowty 2006b, Gaeckle et al. 2007, 2008).

Geomorphic Category	Sampling Frame	No. Sites in Frame	Stratum	No. Sites in Stratum
fringe	fringe frame	2393	core	2
			narrow fringe	2028
			wide fringe	363
flats	flats frame	73	core	4
			persistent flats	3
			rotational flats	66

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). The core stratum and the persistent flats stratum are not subject to rotation and are completely surveyed each year (Table 2-3; Dowty et al. 2005).

2.2.3 Sound-wide Sites

A total of 79 sites were selected in 2008 as part of the sound-wide 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 65 matching

sites from 2007 to 2008 that were used to calculate the sound-wide change estimate (Table 2-3).

The annual sound-wide sampling does not have a sufficient number of sites to reliably calculate annual regional *Z. marina* area status estimates. Regional *Z. marina* condition is evaluated annually using a multiple parameter assessment and change is evaluated at five year intervals as part of the focus area effort (Section 2.3).

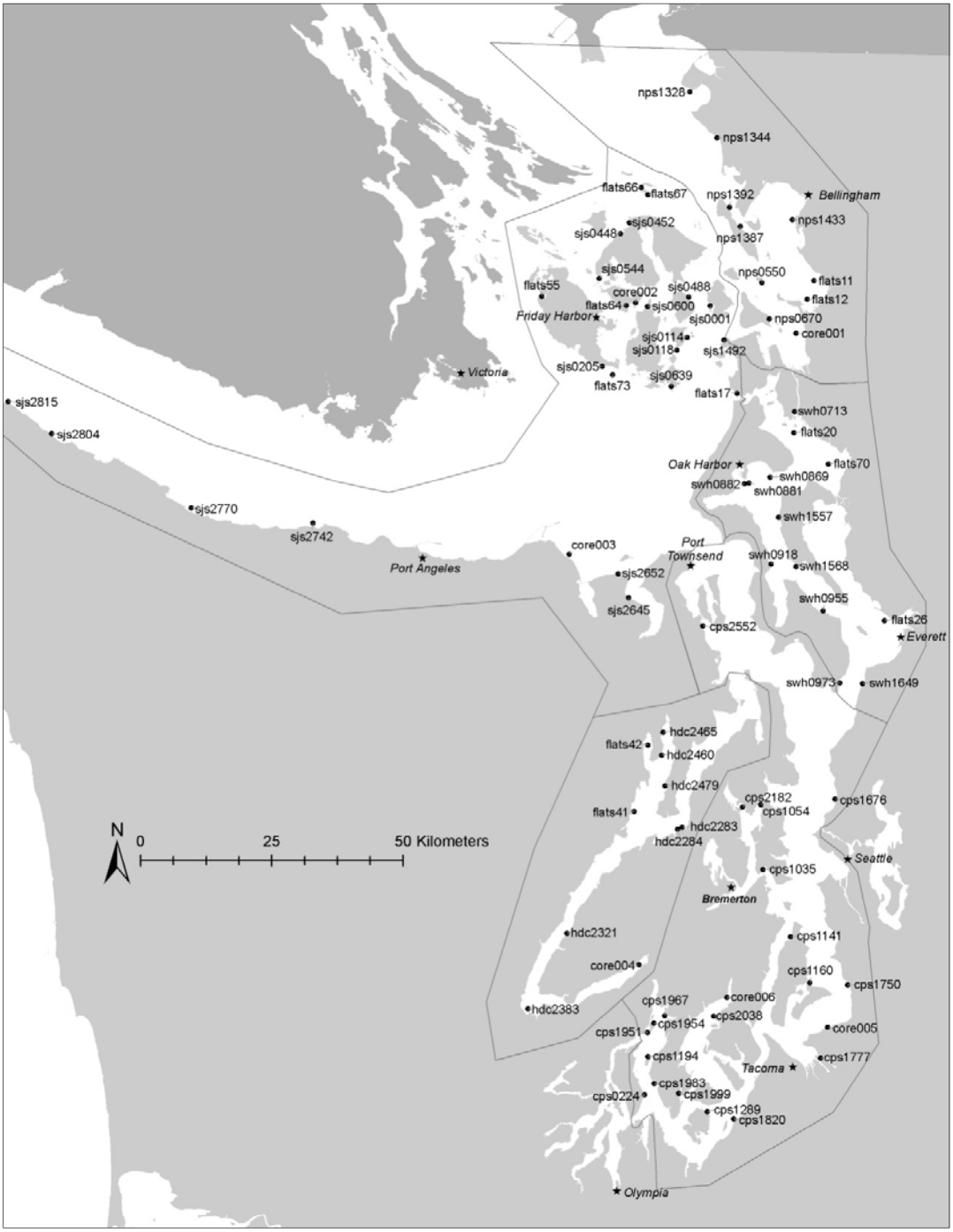

Figure 2-1. Sites sampled in 2008 for the SVMP sound-wide study.

Table 2-3. Distribution of the 2008 sample sites by stratum and region. The distribution of the 2007 – 2008 matching sites used to calculate the annual change estimate is also listed.

2008	CPS	HDC	NPS	SJS	SWH	Total
SOUND-WIDE						
core	0	1	1	2	0	4
flats – persistent	0	0	2	0	1	3
flats – rotational	0	2	0	6	2	10
narrow fringe	19	4	4	14	5	46
wide fringe	2	3	3	3	5	16
						79
2007 – 2008 Matching Sites						
flats	0	3	3	6	3	15
fringe	15	7	7	12	9	50
						65

2.3 Focus Area Sampling Design and Site Selection: 2008 North Puget Sound Region

Each year, one of the five regions in greater Puget Sound (Figure 1-1) is sampled on a rotating basis at higher intensity to estimate regional status and to assess change every five years. The SVMP focus area for 2008 was the *North Puget Sound Region* (Figure 2-2). The sampling effort goal for the focus areas was based on the sampling effort in previous years (Gaeckle et al. 2007, 2008). A more detailed description of the site selection for the 2008 focus area is outlined in Appendix J.

2.3.1 Stratification and Site Selection

The total effort set for focus area sampling is 36 fringe equivalents (the nominal effort to sample one fringe site). This effort is allocated among sampling strata based on available information on variance within the strata, as well as a region-specific conversion factor that relates the effort to sample a flats site to the effort to sample a fringe site (Figure 2-2, Table 2-4, Appendix J). For the *North Puget Sound Region* focus area the conversion factor was set at 2 (i.e., a flat site requires 2 times the effort of a fringe site).

Figure 2-2. Sites sampled for the focus area *Z. marina* estimate in the 2008 *North Puget Sound Region* (n = 38).

Table 2-4. The total number of sites used to calculate the *Z. marina* area in the *North Puget Sound Region*. The total was calculated as the combination of the final allocation of the sampling effort by stratum for the focus area sampling (Focus *n*) in each region as well as sites sampled as part of the sound-wide study (Sound-wide *n*).

	2008 North Puget Sound Focus Area			
	Stratum	**Focus *n***	**Sound-wide *n***	**Total *n***
flats strata	flats	5	1	6
fringe strata	narrow	21	3	24
	wide	5	3	8
total		31	7	38

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 a sample area that represents the general location of *Z. marina* presence within a site that was delineated from reconnaissance, available data from previous years, and other sources (e.g., Puget Sound Environmental Atlas 1987, ShoreZone Inventory 2001). 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 estimates sampled at the site.

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 within each region.

A 5 m aluminum work 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 the BioSonics echosounder echogram in concert with drop-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).

2.5 Video Data Processing and Analysis

Technicians review the video from the random transects at each site and classify the *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; Reeves et al. 2006).

2.5.1 Data Analysis

Zostera marina Area Estimation

Zostera marina area estimation at the site-level follows procedures described in Appendix L of the first SVMP report (Berry et al. 2003, Skalski 2003). 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 sound-wide basis. Status estimates for regions are not produced annually because the insufficient number of sites sampled in each region to produce a reliable estimate. Instead, 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 sound-wide sampling that are located in the focus area (Table 2-4; 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 sound-wide scales using a test for a significant linear regression slope. For the sound-wide analysis, a weighted regression is used due to changes in variance across the data record. 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 regression analysis of status estimates. Year-to-year change analysis methods vary depending on the scale of the site- and sound-wide data.

At the site-level, year-to-year change was assessed and tested for significance based on the calculation of relative change in three parameters (area, mean minimum depth and mean maximum depth) for consecutive years. Confidence intervals, measures of estimate precision, were calculated using analytical statistics.

At the sound-wide 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 the condition of *Z. marina* 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 2008. 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 positive or negative change. Each region was classified based on high, moderate, or low concern for *Z. marina* decline. In addition to the annual multiple parameter regional assessment, status and trends in each region are explored in detail through 5-year rotating focus area studies.

Multiple Parameter Assessment of Site-Level Change

All sites sampled between 2000 and 2008 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 2001 – 2008, and the results of five-year trend analyses were added to the assessment for 2005 through 2008. Sites with greater than 20% negative change were classified as having strong evidence of *Z. marina* decline. Sites with negative change between 10 – 20% were classified as having evidence of *Z. marina* decline.

3 Results

3.1 Field Effort Summary

In 2008, the SVMP sampled 107 sites over 61 days from June through September (Table 3-1). The level of effort in 2008 remained consistent with the previous years; 79 sites were sampled as part of the sound-wide effort while an additional 31 sites were added for the focus area effort in the *North Puget Sound Region* (Table 3-1; 3 focus area sites were already in the annual sound-wide sample pool).

Table 3-1. Summary of the SVMP sampling effort for 2000-2008. 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

Two sites in 2008 were sampled from a 5 m aluminum work skiff with the Biosonics echosounder (instead of a towed video camera) due to large rocks (*nps2918-Lily Point Center*) and the potential for extensive shoaling (*nps1322-Semiahmoo Spit Tidelands South*). Three sites, *sjs2770-West of Deep Creek* (wide fringe), *sjs2804-West of Sekiu River* (narrow fringe), and *sjs2815-Bullman Creek* (wide fringe), were not sampled due to navigational obstructions. The average number of random videography transects per sites was 13 (Table 3-1) and ranged from 7 – 20 (*flats09-Nooksack Delta N.* and *flats20-Skagit Bay N)*, respectively).

3.2 Status of Zostera marina

3.2.1 Sound-wide Zostera marina Area

In 2008, the estimate of *Z. marina* in Puget Sound was 22,800 ± 4,500 ha (± 95% CI) and was not significantly different from the 2007 sound-wide estimate (Figure 3-1, Appendix D). At the site level, the average *Z. marina* fraction ranged from 0.03 (*cps1035-NE Point White*) to 0.89 (*flats11-Samish Bay N.*) with an average of 0.46 (Appendix A and Appendix B). The *Z. marina* area estimates for individual sites ranged from 0.05 ha (*cps1035-NE of White Point*) to 3440 ha (*core001-Padilla Bay*) (Appendix A and Appendix B).

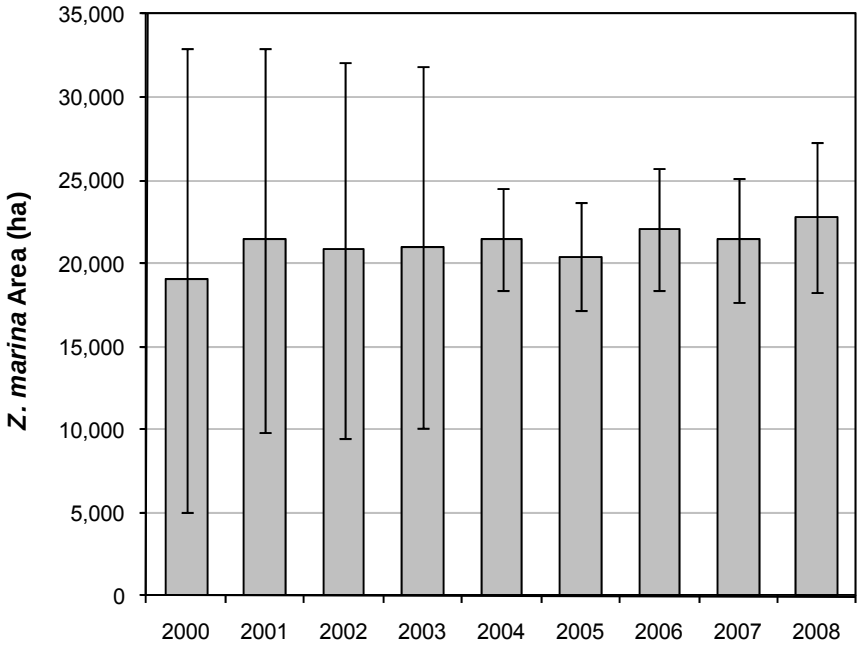

Figure 3-1. Estimates of total *Z. marina* area in the study area from 2000-2008. Error bars are 95% confidence intervals.

3.2.2 North Puget Sound Focus area

Results from a total of 38 sites (7 sound-wide effort, 31 focus area effort) were used to produce the 2008 estimates for the *North Puget Sound Region* (Appendix A and Appendix B). The *North Puget Sound Region* focus area *Z. marina* estimate was 9,859 ± 2,603 ha (95% CI, Table 3-2, Figure 3-2). Ninety-one percent of the *Z. marina* area in the *North Puget Sound Region* was estimated to be in the flats stratum (35% at *core001-Padilla Bay* and 56% in the remaining five flats, Appendix B). The amount of *Z. marina* in the narrow fringe and wide fringe strata was similar with 4% and 5%, respectively (Table 3-2, Figure 3-2).

Table 3-2. Estimates of *Z. marina* area and uncertainty by stratum for the *North Puget Sound* 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	s.e.	c.v.	95% CI	Proportion of North Puget Sound *Z. marina* area
Core	1/1	3,440	26,763	164	0.05	321	35%
Flats	5/13	5,549	1,696,433	1302	0.23	2553	56%
Narrow Fringe	24/124	400	13,076	114	0.29	224	4%
Wide Fringe	8/60	470	27,208	165	0.35	323	5%
Total	38/198	9,859	1,763,480	1,328	0.13	2,603	

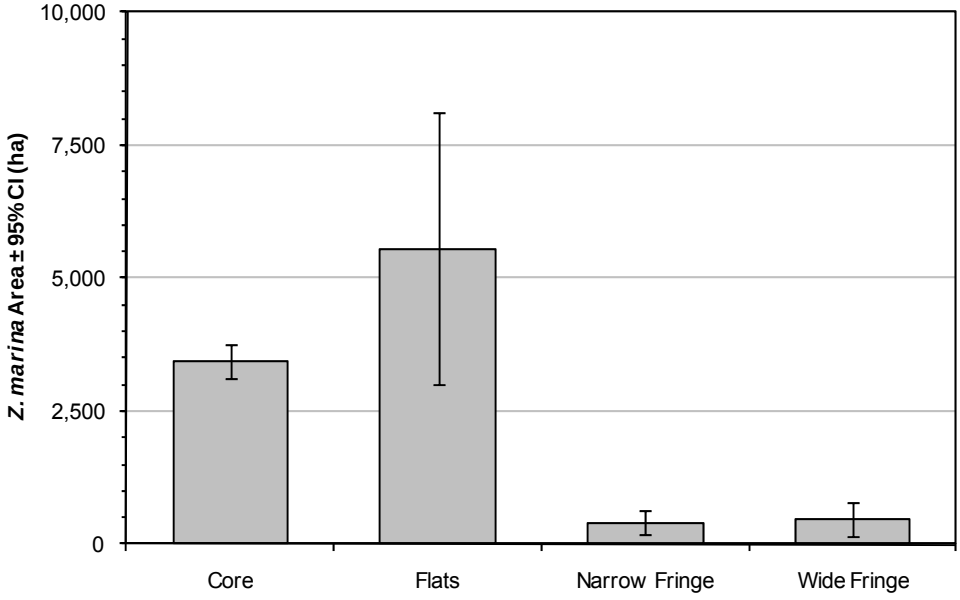

Figure 3-2. Estimates of *Z. marina* area by stratum for the *North Puget Sound* focus area. Error bars are 95% confidence intervals.

3.3 Sound-wide and Site-Level Change in Zostera marina Area

3.3.1 Sound-Wide Change in Zostera marina Area

The *Z. marina* area change estimate based on 65 matching sites between 2007 and 2008 was +6.5% (± 10.4%, Monte Carlo 95% confidence intervals). The sound-wide change in *Z. marina* was not statistically significant ($\alpha = 0.05$; Figure 3-3).

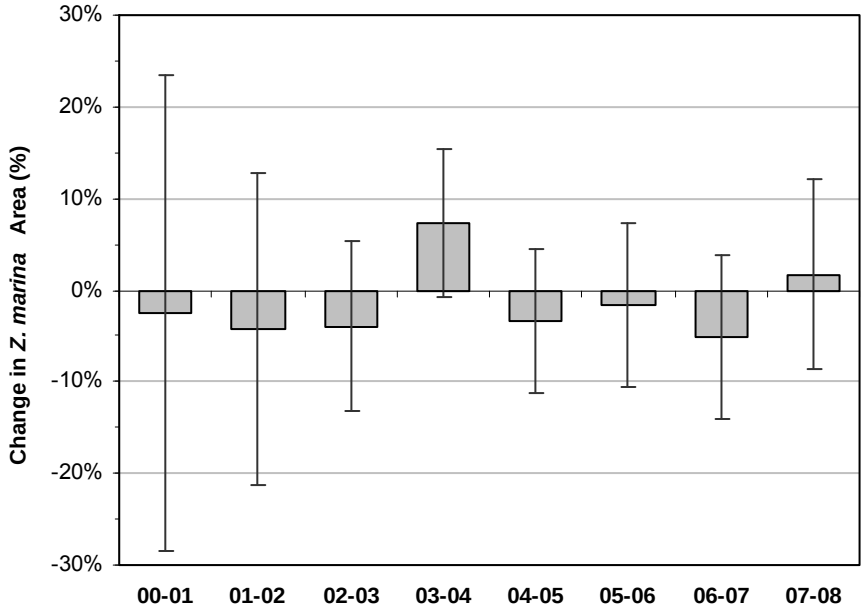

Figure 3-3. Overall sound-wide annual change in *Z. marina* area from 2000 - 2008. Error bars are Monte Carlo 95% confidence intervals. Error bars that overlap the 0% line indicate that the change for the time period is not significant.

A weighted regression was used to assess the sound-wide trend in *Z. marina* area from 2000 to 2008 (Figure 3-4). The weighted regression analysis did not detect a significant trend (two-tailed test) or a declining trend (one-tailed test) in sound-wide *Z. marina* area over the last nine sampling efforts.

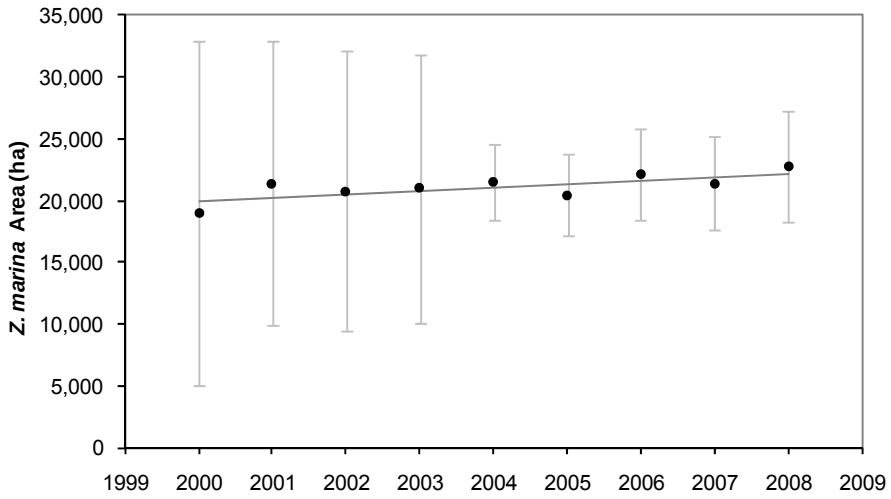

Figure 3-4. Sound-wide trend analysis in *Z. marina* area from 2000 to 2008. There was no significant trend in sound-wide *Z. marina* area since 2000 (α=0.05). Error bars are Monte Carlo 95% confidence intervals.

However, there is evidence of a pattern of sound-wide decline observed in year-to-year site level changes in *Z. marina* area. From the period between 2000 and 2007, 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). In the most recent time interval, from 2007 to 2008, a greater number of sites (2) increased in *Z. marina* compared to sites (1) that decreased in area.

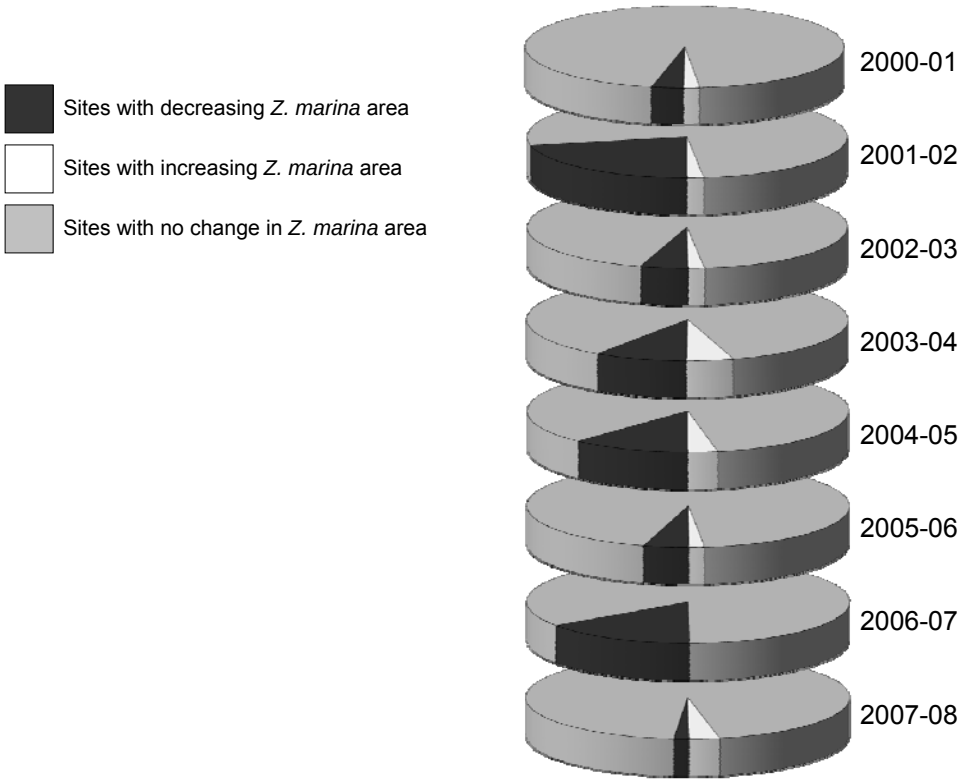

Figure 3-5. Proportion of sites with statistically significant increases and decreases in *Z. marina* area (α=0.05). Sites with no significant change in *Z. marina* area are also shown. The number of sites compared each year ranged from 60-67. This figure has been adjusted slightly from a previously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

The statistical validity of these results was tested to determine the probability of obtaining 7 years with more sites decreasing in *Z. marina* area than increasing against the null hypothesis that there would be equal number of years with decreasing or increasing *Z. marina* area (Dowty 2009). The rejected null hypothesis (P = 0.0128) provides strong statistical evidence that there is a preponderance of declining sites.

3.3.2 Site-Level Change in Zostera marina Area

Year-to-Year Change in Zostera marina Area

There were 65 sites sampled in 2007 and 2008 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 2007-2008, one

site showed a decrease and two sites showed an increase in *Z. marina* area (α=0.05; Figure 3-6, Figure 3-7).

Seven additional sites had significant changes (5 increased, 2 decreased) from 2007 to 2008 in *Z. marina* area when tested at α=0.2 (Figure 3-6, Figure 3-7, Appendix C).

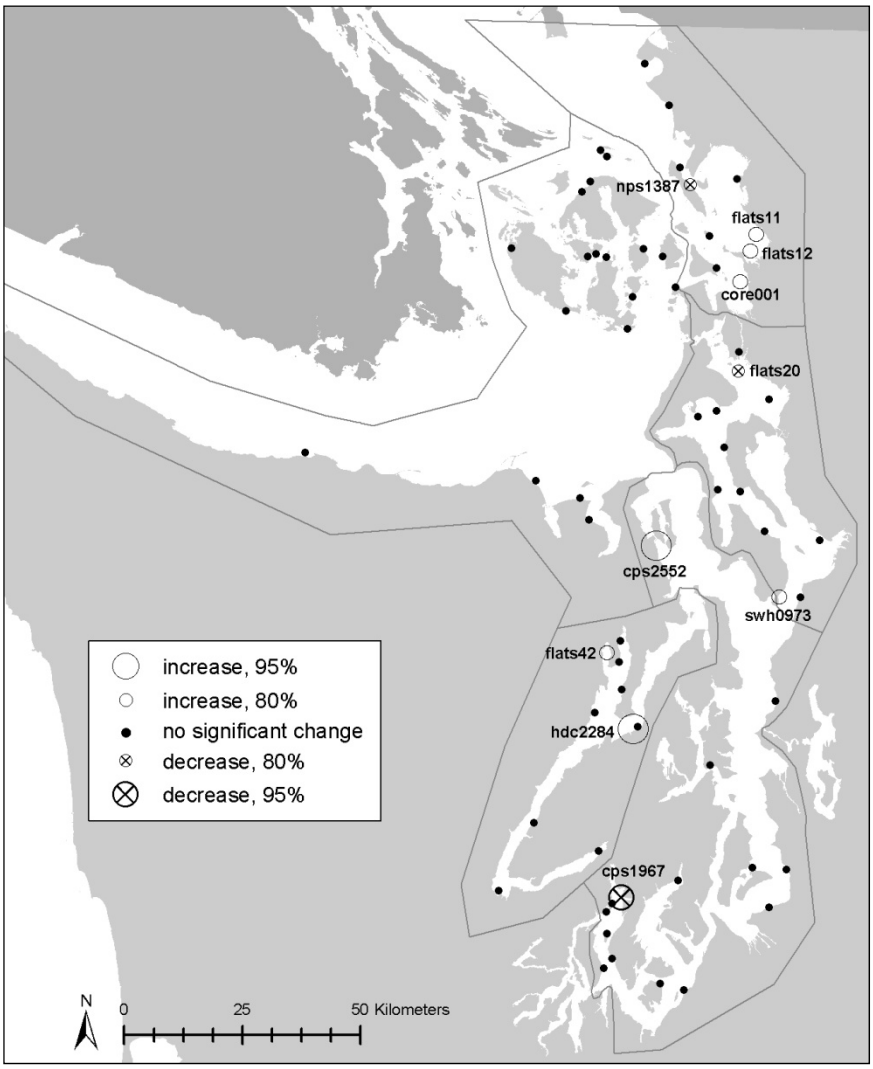

Figure 3-6. Sites with significant relative change in *Z. marina* area from 2007 to 2008 (α=0.2 and α=0.05, n = 65). Sites that were tested but exhibited no significant change are also shown.

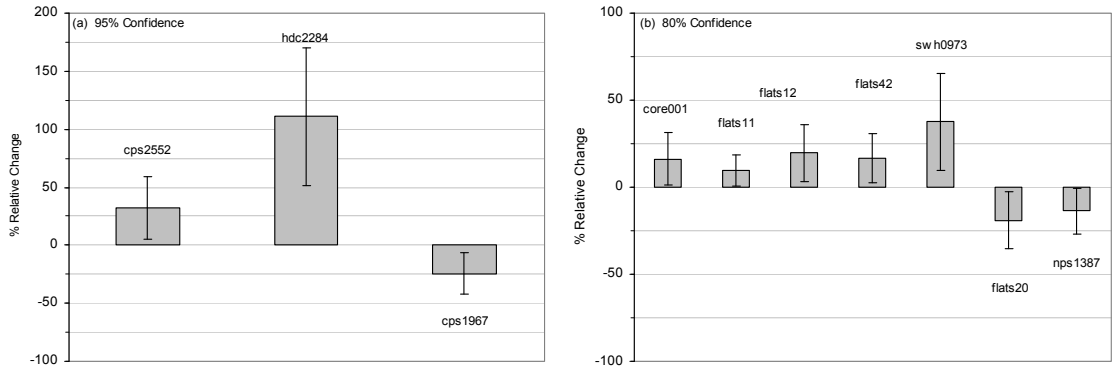

Figure 3-7. Estimated relative change in *Z. marina* area from 2007 to 2008 for sites with significant change (α=0.2 and α=0.05). Error bars are associated 95% confidence intervals.

Trends in Site-Level Zostera marina Area

Through 2008, 34 sites were sampled for four years or more and tested for trends in *Z. marina* area. Eleven sites had significant trends when tested at α=0.05 (Table 3-3, Figure 3-8, Appendix G), seven additional sites had significant trends when tested at α=0.2 (Table 3-3, Figure 3-8, Appendix H), and 16 sites showed no trend in *Z. marina* area (Table 3-3, Figure 3-8, Appendix I).

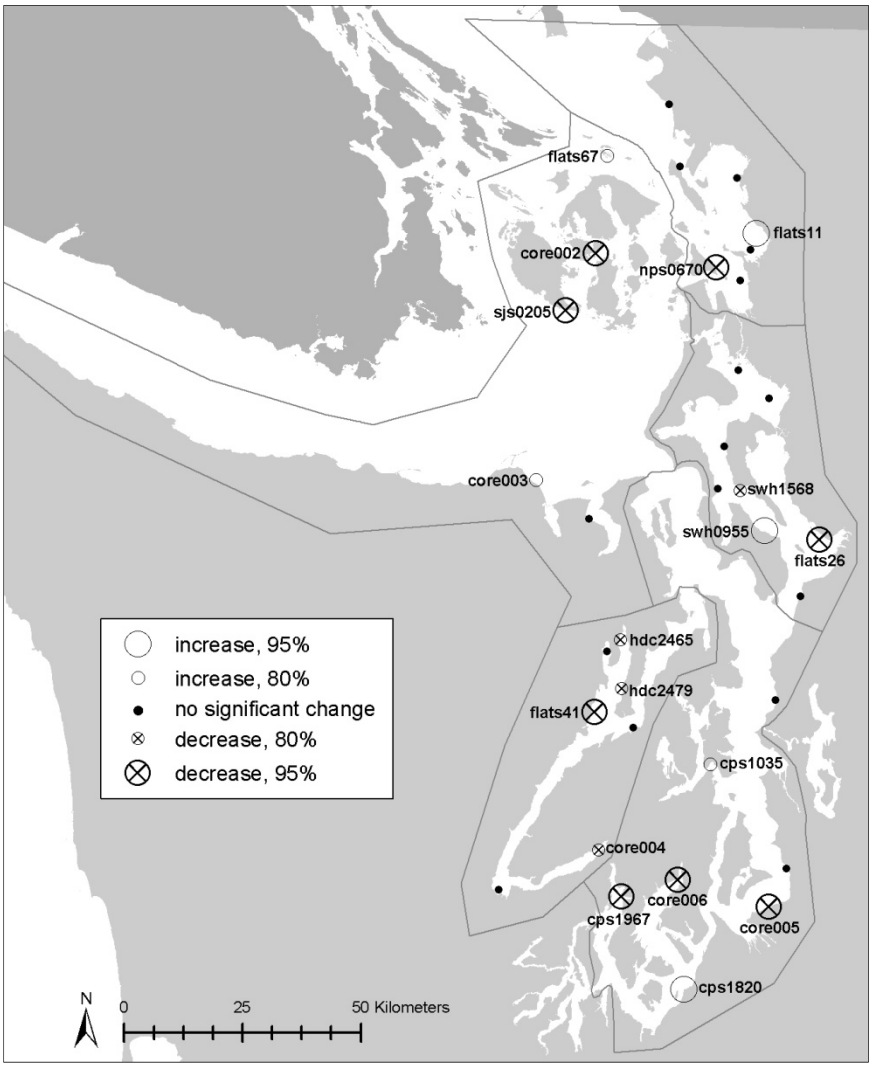

Figure 3-8. Sites sampled in 2008 with significant trends in *Z. marina* for four years or more (α=0.2 and α=0.05). Sites that were tested but exhibited no significant trend are also shown.

Table 3-3. *Zostera marina* area trends observed for four years or more through 2008 at two levels of significance. The estimated trends are based on the regression slope. The percentage change values are relative to the *Z. marina* area calculated the first year the site was sampled.

Direction of Trend	Site code	Site name	Years of data	p - value	α	Estimated trend (ha yr^{-1})	Equivalent annual relative change (% yr^{-1})
increasing area	flats11	Samish Bay N.	8	0.006	0.05	+23.2	+2.0
	cps1820	Gordon Point	5	0.004	0.05	+0.03	+1540.6
	swh0955	West of Langley	4	0.021	0.05	+0.7	+10.8
	core003	Jamestown	9	0.073	0.2	+9.4	+2.5
	flats67	Fossil Bay	5	0.054	0.2	+0.5	+10.4
	cps1035	NE of Point White	4	0.052	0.2	+0.01	+124.5
decreasing area	core002	Picnic Cove	9	0.005	0.05	-0.2	-4.1
	core005	Dumas Bay	9	0.036	0.05	-0.2	-6.9
	core006	Burley Spit	9	0.005	0.05	-0.6	-11.8
	flats26	Snohomish Delta N.	4	0.039	0.05	-16.2	-10.8
	flats41	Dosewallips	5	0.023	0.05	-6.0	-5.6
	cps1967	Vaughn Bay	5	0.022	0.05	-0.5	-15.3
	nps0670	Boat Harbor	5	0.045	0.05	-0.1	-6.1
	sjs0205	E. of Eagle Point	4	0.041	0.05	-1.1	-8.6
	core004	Lynch Cove	9	0.113	0.2	-4.3	-3.8
	hdc2465	SE of Dabob Bay	5	0.103	0.2	-0.2	-3.3
	hdc2479	Toanados Peninsula	5	0.162	0.2	-0.1	-1.2
	swh1568	Lowell Point	4	0.074	0.2	-0.01	-7.5
no trend	core001	Padilla Bay	8				
	flats12	Samish Bay S.	5				
	flats20	Skagit Bay N.	9				
	flats42	Quilcene Bay	4				
	flats70	South Fork Skagit River	5				
	cps1676	Broadview	4				
	cps1750	Des Moines Beach	5				
	hdc2284	Warrenville	4				
	hdc2383	Anna's Bay	5		no trend	no trend	no trend
	nps1344	E. of Ferndale	4				
	nps1392	Lummi Point	5				
	nps1433	Post Point	5				
	sjs2645	Gardiner	5				
	swh0918	Pratts Bluff	5				
	swh1557	Rockaway Beach	5				
	swh1649	Nelson's Corner	4				

Yearly Long-term Trends in Site-Level Zostera marina Area

Long-term trends in *Z. marina* area have been documented since 2004. Between 2004 to 2008, there have been more sites with significant decreasing 5 year, long-term trends in *Z. marina* area relative to sites with increasing trends ($\alpha = 0.05$, Figure 3-9).

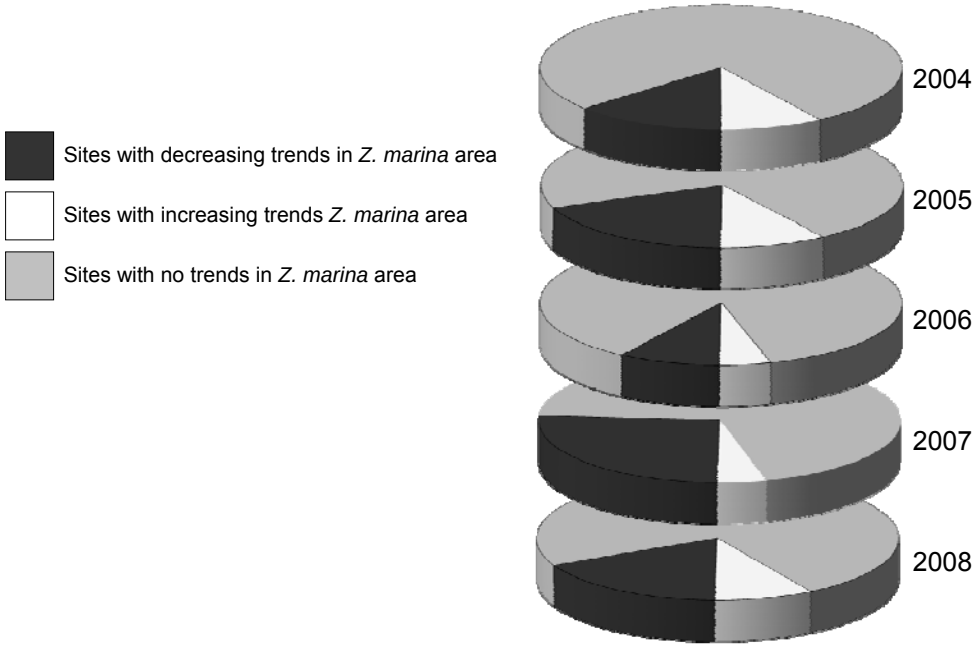

Figure 3-9. Proportion of sites with statistically significant 5-year increasing and decreasing trends in *Z. marina* area (α=0.05). Sites with no significant change in *Z. marina* area are also shown.

3.4 Zostera marina Depth Distribution

3.4.1 2008 *Zostera marina* Depth Distribution

Regions

The shallowest *Z. marina* depth observed in 2008 was +0.7 m (MLLW) at *swh0973-North Possession* and *flats26-Snohomish Delta N.* and the deepest observed depth was -11.0 m (MLLW) at *flats73-Salmon Bank* (Appendix E). The *Saratoga-Whidbey Basin Region* cumulative mean minimum *Z. marina* depth range from 2000 to 2007 increased in 2008 (Table 3-4). The cumulative range of mean maximum *Z. marina* depths in the *Hood Canal Region* also increased in 2008 (Table 3-4).

Table 3-4. The absolute and range of mean maximum and minimum *Z. marina* depths (MLLW) for all strata by region in 2000-2008. Bold values indicate changes in the absolute depth and expansion of the minimum and maximum mean depth range since 2007.

Region	Minimum Depth (m)		Maximum Depth (m)	
	Absolute	Range in Site Means	Absolute	Range in Site Means
Central Puget Sound	+1.6	+1.1 to -3.5	-11.9	-0.5 to -6.9
Hood Canal	+1.8	+1.1 to -2.6	-7.6	-1.4 to **-5.0** (-4.8)
North Puget Sound	+1.4	+0.6 to -3.3	-8.4	-0.7 to -6.6
San Juan/Straits	+1.5	0.4 to -5.4	-12.4	-0.4 to -11.0
Saratoga/Whidbey	+1.3	0.5 to **-1.8** (-1.7)	-8.0	-0.3 to -4.5

Site-level

There were 65 matching sites sampled in 2007 and in 2008 that were tested for significant changes in the minimum and maximum depth distribution. There were no significant changes in the maximum depth at sites sampled in 2007 and 2008 when tested at α=0.2 and α=0.05. There was one site, *swh0973-North Possession*, that had a significant change in the minimum *Z. marina* depth from 2007 to 2008 when tested at α=0.05 (Table 3-5, Figure 3-10). Two additional sites, *hdc2284-Warrenville* and *sjs0452-S. of Pt. Doughty*, showed significant changes in the minimum depth of *Z. marina* when tested at α=0.2 (Table 4-2, Figure 4-1).

Table 3-5. Significant changes in mean minimum *Z. marina* depth (MLLW) between 2007 and 2008.

direction of change	site	α	mean minimum depth (m)		
			change	2007	2008
shallower (expanding)	swh0973	0.05	0.8	-5.3	-4.9
	hdc2284	0.2	0.6	-3.9	-3.3
	sjs0452	0.2	0.4	-3.8	-3.3

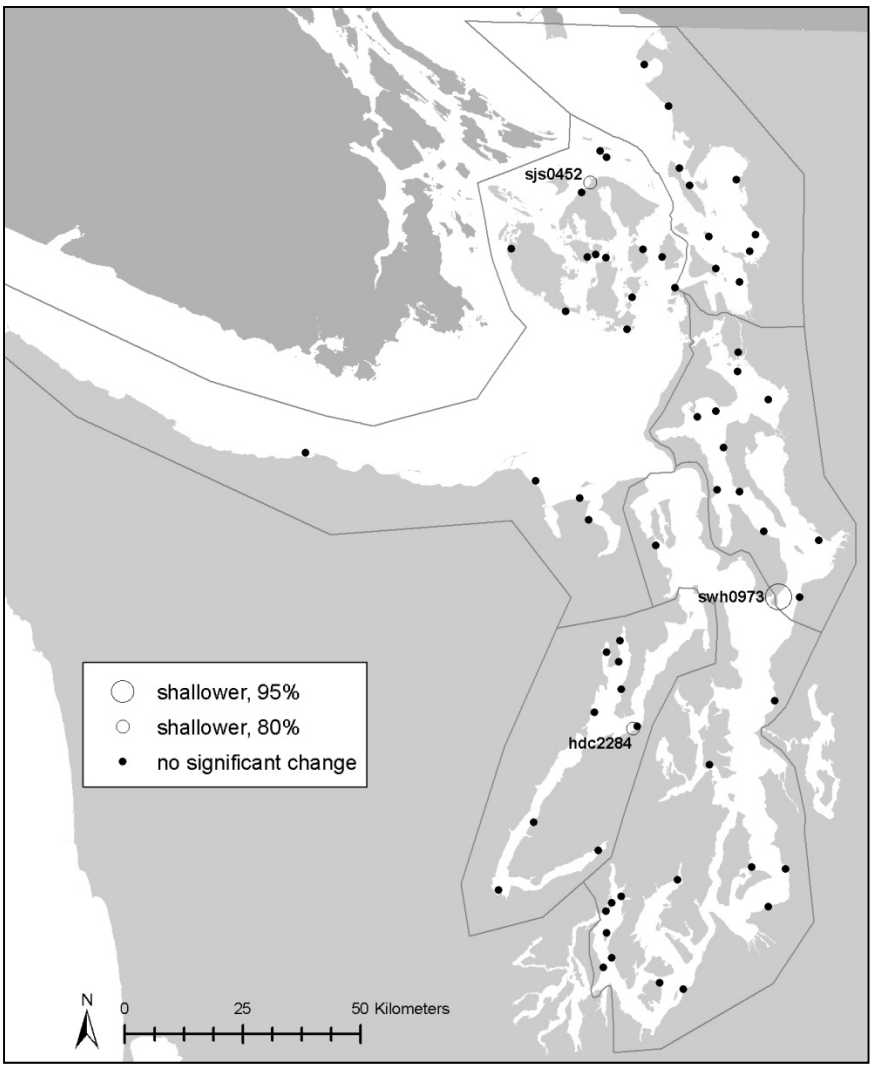

Figure 3-10. Sites with significant change in mean minimum *Z. marina* depth from 2007 to 2008 (α=0.2 and α=0.05). There was no significant change in the maximum depth at any of the 65 matching sites over the same period when tested at α = 0.02 and α = 0.05. Sites that were tested but exhibited no significant change are also shown.

3.5 Multiple Parameter Assessment

3.5.1 Assessment of Region-Level Zostera marina Change

The multiple parameter assessment evaluated regional trends by quantifying the proportion of significant changes among all *Z. marina* parameter tests within each region from 2000 to 2008 (Table 3-6). 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 3-6, Figure 3-11).

Every region exhibited both positive and negative changes for the measured parameters from 2000-2008 (Table 3-6).

The *Hood Canal Region* had the largest proportion of significant changes and negative changes in *Z. marina* parameters compared to the other four regions in the study area (Table 3-6, Figure 3-11). 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 variable and in decline but not at a level similar to the *Hood Canal Region*. There is a moderate level of concern for *Z. marina* decline in these two regions. In contrast, the *Saratoga-Whidbey* and *North Puget Sound Regions* had nearly equal proportions of decreases and increases and the lowest frequency of change. The multiple parameter assessment has identified *Z. marina* in the *Saratoga-Whidbey* and *North Puget Sound Regions* as stable and at a low level of concern for decline (Table 3-6, Figure 3-11).

Table 3-6. **Results of multiple parameter assessment of regional *Z. marina* condition based on data collected from 2000 – 2008. The number of measurable changes within a region was quantified and compared to the number of significant positive or negative changes (α=0.05). The *Hood Canal Region* has been identified as the region of highest concern for *Z. marina* losses due to the high proportion of significant negative results.**

	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	147	10	1	9	72	15	2	13	70	8	3	5	133	14	1	13	89	10	4	6
Deep edge depth	122	12	4	8	69	8	0	8	65	7	4	3	112	12	2	10	83	8	5	3
Shallow edge depth	122	16	7	9	68	13	5	8	64	8	4	4	111	12	6	6	83	15	7	8
5-year area trends	25	6	2	4	15	6	0	6	16	2	1	1	19	6	2	4	13	2	0	2
Proportion of significant results	0.11				0.19				0.12				0.12				0.14			
Proportion of significant positive results	0.32				0.16				0.48				0.25				0.43			
Proportion of significant negative results	**0.68**				**0.84**				**0.52**				**0.75**				**0.57**			

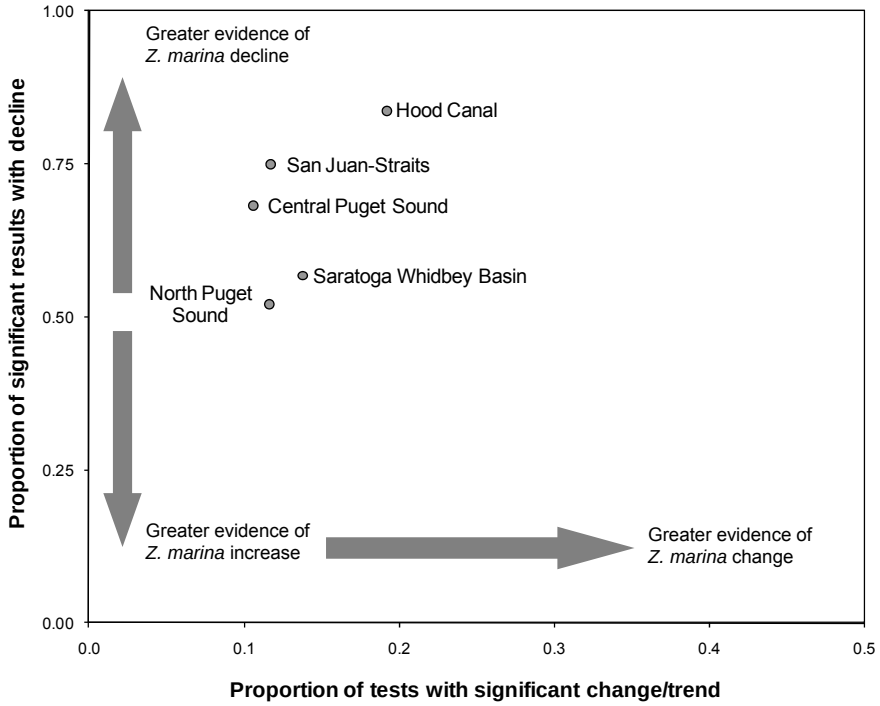

Figure 3-11. Proportion of significant declining results in the multiple parameter *Z. marina* assessment relative to the proportion of significant *Z. marina* parameter changes in each region from 2000 – 2008.

3.5.2 Assessment of Site-Level Zostera marina Change

A total of 14 sites assessed in 2008 were identified through a 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 19 sites were identified with evidence of decline (Table 3-7). The evidence of decline category included sites with 10 – 20% of the change tests in significant decline.

Table 3-7. Sites with evidence of *Z. marina* decline in 2008 as determined by the multiple parameter assessment. The last column indicates whether the site will be sampled in 2009 or when the site rotated out of the SVMP sampling after the year listed in parentheses ( ).

category	site code	site name	region	remains in 2009 sample pool?
strong evidence of decline	core002	Picnic Cove	sjs	yes
	core005	Dumas Bay	cps	yes
	cps1046	Battle Point	cps	no (2002)
	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)
	sjs0081	Broken Point	sjs	no (2005)
	sjs0351	NW Waldron Island	sjs	no (2004)
	sjs0365	Thatcher Pass	sjs	no (2003)
	core006	Burley Spit	cps	yes
	flats08	Portage Bay	nps	no (2007)
	flats18	Similk Bay	swh	no (2006)
	flats28	Snohomish Delta	swh	no (2002)
	flats43	Dabob Bay	hdc	no (2005)
	flats53*	Westcott Bay	sjs	no (2001)
	cps1967	Vaughn Bay	cps	no (2008)
	cps2215	Eglon, Kitsap	cps	no (2002)
	nps0059	Sinclair Island S.	nps	no (2005)
evidence of decline	nps1363	Lummi Island	nps	no (2004)
	sjs0635	Watmough Bay	sjs	no (2007)
	sjs0683	Brown Island N.	sjs	no (2007)
	sjs0819	N. of Partridge Point	sjs	no (2005)
	sjs2646	Discovery Bay	sjs	no (2004)
	sjs2813	Rasmusson Creek	sjs	no (2003)
	swh0973	North Possession	swh	yes
	swh1593	Cornell	swh	no (2005)
	swh1625	S. of Tulalip Bay	swh	no (2005)
	swh1647	Mukilteo	swh	no (2003)

* *flats53-Westcott Bay* was sampled from 2000-2001. During this period the site did not experience a significant decline in *Z. marina* area or depth distribution when tested at $\alpha = 0.05$. However, by 2003 there was a large die-off of *Z. marina* at *flats53-Westcott Bay*, but this decline was not documented by the annual monitoring effort because the site rotated out of the sample plan in 2001.

3.6 Observations of Zostera japonica and Phyllospadix spp.

In 2008, *Z. japonica* was observed at 23 sites throughout Puget Sound and *Phyllospadix* spp. was observed at three sites in the *San Juan-Straits Region* (Figure 3-12). Since 2000, *Z. japonica* was observed at 55 sampled sites and *Phyllospadix* spp. was observed at 11 sampled sites (Figure 3-12).

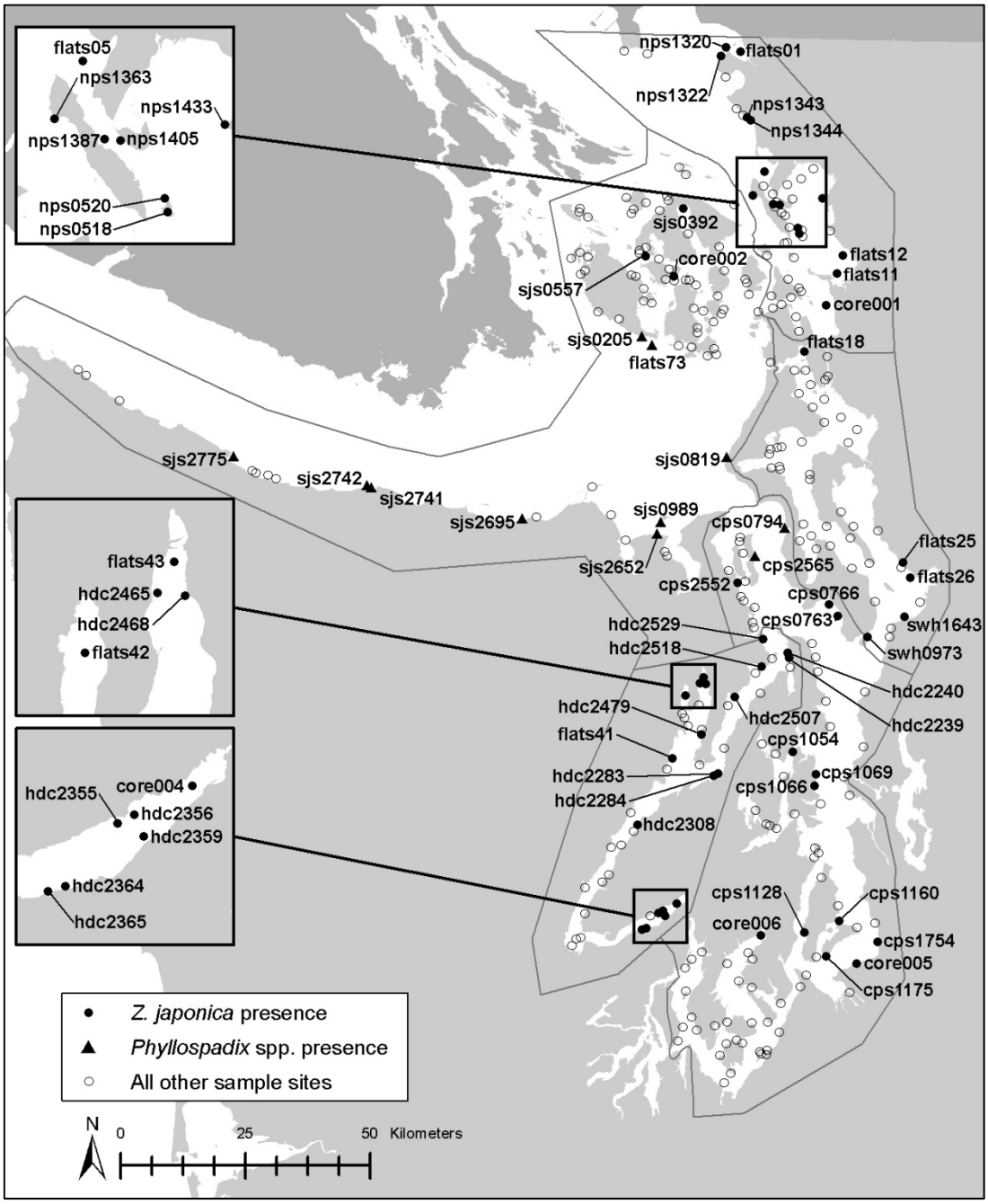

Figure 3-12. Sites where *Z. japonica* and *Phyllospadix* spp. was observed in the Puget Sound study area between 2000-2008.

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 SVMP provides a number of ways to assess status and trends in *Z. marina* abundance and depth distribution at different temporal and spatial scales. The latest SVMP results suggest a pattern of slight sound-wide decline in *Z. marina* area.

One indicator of sound-wide decline is the greater prevalence of long-term declining trends in *Z. marina* area than increasing trends at sites throughout Puget Sound (Figure 3-8, Table 3-3). In 2008, there were more sites, sampled for four years or more, that had significant long-term declining trends in *Z. marina* compared to sites with increasing trends. Additionally, three of six cores sites showed declines from 2007-2008. The core sites, sampled since program inception to representative changes in different habitat types throughout Puget Sound, have observed declines in *Z. marina*. Furthermore, each year since 2004, there have been a greater proportion of sites with statistically significant declines in *Z. marina* area over a 5-year period (Figure 3-9).

Another indicator of sound-wide decline is that in seven of the last eight years, the number of sites with significant year-to-year losses in area substantially outnumbered sites with increases (Figure 3-5). The significantly low probability of this result occurring by chance

and the sound-wide distribution of these sites support a pattern of a *Z. marina* decline throughout Puget Sound (Dowty 2009).

Lastly, the region level multiple parameter assessment found a high level of concern for *Z. marina* decline in the *Hood Canal Region*, and a moderate level of concern for declines throughout the *San Juan-Straits* and *Central Puget Sound Regions*. These findings further support patterns of *Z. marina* decline in Puget Sound (Table 3-6, Figure 3-11).

The indicators (declining long-term trends, losses at the site level, and the collective evidence of decline from the multiple parameter analyses) suggest a pattern of slight *Z. marina* decline throughout Puget Sound. However, the magnitude of the observed changes is not sufficient to cause a significant decrease in the total sound-wide *Z. marina* area estimate (Figure 3-4). The overall sound-wide *Z. marina* area estimate provides a robust assessment of sound-wide *Z. marina* abundance, but the results are disproportionately affected by the stability of large 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. These sites represent approximately 30% of the total *Z. marina* area in Puget Sound.

Trends in area provide an assessment of change in *Z. marina* area over time and insight as to whether observed annual change is 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

The detection of *Z. marina* change at the site-level on year-to-year and long-term time scales provides valuable information for managers prior to potentially irreversible seagrass loss (Kirkman 1996). A number of sites in Puget Sound are considered to be areas of concern due to a significant yearly decline in *Z. marina* area, a change in the shallow or deep *Z. marina* depth, or a long-term declining trend in *Z. marina*. *Zostera marina* loss at *flats53-Westcott Bay* and at sites in the *Hood Canal Region* (e.g. *core004-Lynch Cove*, *hdc2338-Across from Union*, *hdc2344-Great Peninsula*, *hdc2345-Sisters Point*, and *hdc2359-Lynch Cove Fringe*) has led to the initiation of more intensive research by the Eelgrass Stressor – Response Project. In addition, scientists from the University of Washington and the USGS have been investigating changes in *Z. marina* at *core002-Picnic Cove* and other embayments in the San Juan Archipelago. Additional sites of concern because of significant declines in year-to-year and 5-year trends of *Z. marina* area include: *core005-Dumas Bay, core006-Burley Spit,* and *cps1967-Vaughn Bay.* However, other sites (e.g., *flats18-Similk Bay* and *flats53-Westcott Bay*) with previously observed *Z. marina* decline have been removed from the sample pool due to the sampling with partial replacement design of the SVMP methods (Berry et al. 2003). Continued monitoring by

DNR, academics and other groups at sites throughout the greater Puget Sound study area will provide valuable data on causal or correlative factors for *Z. marina* loss at different spatial and temporal scales.

Regions

The multi-parameter assessment identified the *Hood Canal Region* as the area of greatest concern for *Z. marina* loss. These findings are particularly relevant given the current scientific and political focus on environmental degradation in Hood Canal. At the site-level, the multiple parameter results identified eight sites with significant evidence of *Z. marina* decline in the *Hood Canal Region* (Table 3-7). Additional research has to be conducted to identify factors that cause *Z. marina* decline in the *Hood Canal Region*.

The SVMP will continue to monitor *Z. marina* in the *Hood Canal Region* through the yearly rotational sound-wide sampling. The yearly sound-wide sampling will provide site specific year-to-year *Z. marina* changes in the region and an opportunity to compare the condition of *Z. marina* in the region relative to the other four regions. The next focus area effort in 2010 will provide a five-year *Z. marina* change assessment for the *Hood Canal Region* (Figure 4-1).

The *San Juan-Straits* and *Central Puget Sound Regions* also showed substantial evidence of *Z. marina* decline but the proportion of significant losses from the regional multiple parameter assessment was lower than observed in the *Hood Canal Region* (Figure 3-11). Furthermore, the proportion of significant tests, an indicator of *Z. marina* variability, for the *San Juan-Straits* and *Central Puget Sound Regions*, was lower than observed in the *Hood Canal Region.* The greater stability of *Z. marina* in the *San Juan-Straits* and *Central Puget Sound Regions* suggests a moderate level of concern for *Z. marina* decline in these regions. However, the indication of significant *Z. marina* decline from these tests still supports the need to investigate causal factors for *Z. marina* loss in these regions. The next intensive focus area sampling will take place in the *San Juan – Straits Region*, specifically in the San Juan County – Cypress Island Focus Area, in 2009 and in 2012 for the *Central Puget Sound Region* (Figure 4-1). These data will provide a detailed picture of status and changes in *Z. marina* abundance and distribution over 5 year periods.

The results of the multiple parameter regional assessment were similar for the *North Puget Sound* and *Saratoga-Whidbey Regions*. Both regions had nearly equal proportions of significant tests that decreased and increased and the lowest frequency of change compared to the other three regions. Based on the region level multiple parameter assessment, these two regions are considered stable and a low level of concern for *Z. marina* decline.

4.4 Focus Area Regional Assessment

The findings of the more intensive focus area studies are important baseline data for status and trend detection at the region level. The estimate of *Z. marina* area for each region, sampled at five year intervals, improves the ability to detect change at different spatial and temporal scales. The *North Puget Sound Region* will be sampled next in 2013 (Figure 4-1).

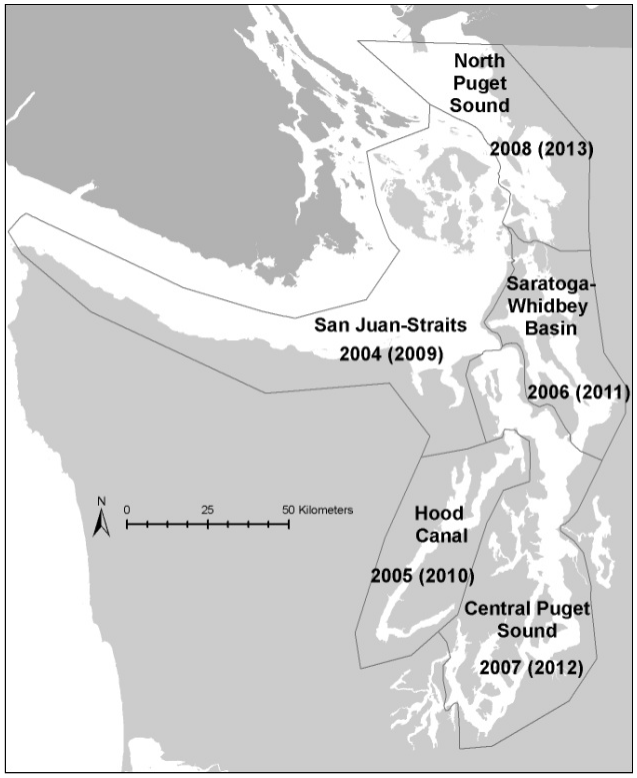

Figure 4-1. Map of study area regions and the year each region was sampled or will be sampled (year in parentheses).

The focus area results from the *North Puget Sound Region* provide important information on the unique characteristics of *Z. marina* habitat in this region for comparison with different areas of Puget Sound. *Zostera marina* in the *North Puget Sound Region* predominantly grows in the flats habitat type and provides a more expansive habitat resource than the narrow and wide fringe sites that are abundant in other regions such as the *Central Puget Sound Region* and *Hood Canal Region*.

In 2009, intensive sampling will return to the *San Juan – Straits*, the first region sampled in 2004 as part of the focus area effort. The intensive focus area studies will augment the sound-wide monitoring program through generation of estimates at the focus-area scale over five year intervals.

4.5 Current Priorities

The SVMP monitors *Z. marina* to determine the environmental health of Puget Sound for the DNR and the Puget Sound Partnership. The SVMP accomplishes a number of tasks to meet its mandate to monitor the status and trends of *Z. marina* in Puget Sound efficiently and successfully.

The primary priorities identified by the SVMP for future sampling include:

1. Continue to monitor the status and trends of *Z. marina* throughout Puget Sound and in the annual focus areas to fulfill the goals identified by DNR and the Puget Sound Partnership.
2. Provide timely reporting of *Z. marina* status and trends in annual SVMP reports so that information is rapidly available to researchers and managers who are assessing the condition of Puget Sound's resources.
3. Complete a power analysis and overall assessment of focus area sampling and recommend refinements to methodology.
4. Continue to provide technical support and data to collaborators and management on the status and trends of *Z. marina* and on sites and regions of concern.
5. Continue to work with the Eelgrass Stressor-Response Project, academics, concern citizen groups and other researchers who are investigating the causes of *Z. marina* decline.

With additional funding the SVMP should:

1. Continue to monitor sites with a strong evidence of *Z. marina* decline that rotate out of the annual sample pool.
2. Improve web-based data dissemination of detailed site level results.
3. Evaluate historical data describing *Z. marina* abundance and distribution to establish a more reliable baseline to assess long-term trends in the region.

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APPENDICES

Appendix A *Z. marina* Area Estimates at 2008 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 Variation	Estimated *Z. marina* Area Confidence Interval (hectares) 95% Lower Limit	95% Upper Limit
Core											
core001	Padilla Bay	48.521	-122.507	28-Jul	11	0.77	3439.71	26768.02	0.05	3119.04	3760.39
core002	Picnic Cove	48.565	-122.923	24-Jun	14	0.51	2.34	0.03	0.07	2.00	2.68
core003	Jamestown	48.131	-123.073	23-Sep	11	0.61	517.25	1037.84	0.06	454.11	580.39
core004	Lynch Cove	47.430	-122.863	19-Aug	15	0.56	128.72	140.26	0.09	105.51	151.93
core005	Dumas Bay	47.331	-122.383	5-Sep	13	0.30	1.26	0.05	0.17	0.83	1.69
core006	Burley Spit	47.378	-122.638	3-Sep	15	0.14	1.94	0.11	0.17	1.29	2.59
Persistent Flats											
flats11	Samish Bay N.	48.612	-122.465	30-Jun	9	0.89	1328.14	3593.43	0.05	1210.65	1445.63
flats12	Samish Bay S.	48.579	-122.480	30-Jun	11	0.73	836.30	4115.92	0.08	710.55	962.04
flats20	Skagit Bay N.	48.350	-122.507	4-Aug	20	0.29	197.79	577.62	0.12	150.68	244.89
Rotational Flats											
flats17	Bowman Bay	48.415	-122.655	28-Jun	16	0.09	1.34	0.16	0.30	0.55	2.12
flats26	Snohomish Delta N	48.032	-122.263	12-Aug	11	0.20	102.36	885.04	0.29	44.05	160.67
flats41	Dosewallips	47.693	-122.887	21-Aug	13	0.67	88.29	63.90	0.09	72.62	103.96
flats42	Quilcene Bay	47.808	-122.857	22-Aug	13	0.67	102.99	29.46	0.05	92.35	113.63
flats55	Mitchell Bay	48.571	-123.165	22-Jun	17	0.32	3.35	0.27	0.16	2.33	4.37
flats64	Squaw Bay	48.560	-122.946	26-Jun	17	0.35	1.52	0.05	0.15	1.07	1.96
flats66	Shallow Bay	48.763	-122.917	15-Jul	15	0.36	5.07	0.82	0.18	3.29	6.85
flats67	Fossil Bay	48.750	-122.900	15-Jul	17	0.46	6.38	2.22	0.23	3.46	9.30
flats70	South Fork Skagit River	48.297	-122.416	7-Aug	9	0.38	340.52	1036.03	0.09	277.44	403.61
flats73	Salmon Bank	48.440	-122.977	25-Jun	11	0.53	183.87	368.69	0.10	146.23	221.50
Narrow Fringe											
cps0224	Wilson Point	47.207	-122.839	2-Sep			0				
cps1035	NE of Point White	47.599	-122.557	26-Aug	15	0.02	0.05	0.00	0.68	-0.02	0.11
cps1054	Agate Pass Bridge SE	47.711	-122.567	25-Aug	12	0.30	0.65	0.01	0.16	0.44	0.85
cps1141	Fern Cove North	47.485	-122.482	26-Aug	12	0.38	4.06	0.62	0.19	2.52	5.59
cps1194	N. Herron Island	47.273	-122.834	2-Sep			0				
cps1289	Villa Beach N	47.181	-122.680	1-Sep			0				
cps1676	Broadview	47.724	-122.378	9-Sep	15	0.47	5.75	0.33	0.10	4.63	6.87
cps1750	Des Moines Beach	47.404	-122.335	8-Sep	12	0.47	4.59	0.43	0.14	3.30	5.88
cps1777	E. 11th St	47.278	-122.399	5-Sep			0				

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 (hectares) 95% Lower Limit	95% Upper Limit
cps1820	Gordon Point	47.170	-122.614	1-Sep	15	0.25	0.14	0.00	0.24	0.07	0.20
cps1951	S. of Stretch Island	47.314	-122.836	2-Sep			0				
cps1954	Stretch Pt State Park	47.331	-122.821	2-Sep			0				
cps1967	Vaughn Bay (Case Inlet)	47.344	-122.795	2-Sep	11	0.36	1.81	0.03	0.10	1.47	2.15
cps1983	N. Joemma Beach	47.226	-122.816	2-Sep			0				
cps1999	Filucy Bay	47.211	-122.753	4-Sep			0				
cps2038	Allen Point	47.345	-122.671	3-Sep	11	0.22	1.71	0.21	0.27	0.81	2.62
cps2182	Lemolo Shore Drive NE	47.706	-122.612	25-Aug			0				
cps2552	Oak Bay Ramp	48.015	-122.726	26-Sep	13	0.63	10.78	0.33	0.05	9.65	11.91
hdc2321	Across from Eagle Pt	47.479	-123.047	19-Aug			0				
hdc2460	Lindsay's Beach	47.791	-122.821	21-Aug	13	0.56	5.19	0.11	0.06	4.55	5.84
hdc2465	SE of Dabob Bay	47.830	-122.819	21-Aug	14	0.55	5.60	0.40	0.11	4.35	6.84
hdc2479	Toanados Peninsula	47.738	-122.811	20-Aug	11	0.57	7.39	0.35	0.08	6.23	8.56
nps0550	Vendovi East	48.605	-122.599	2-Jul			0				
nps0670	Boat Harbor (Guemes Island)	48.544	-122.577	25-Jul	11	0.37	0.10	0.00	0.21	0.06	0.15
nps1344	E. of Ferndale	48.852	-122.725	23-Jul	15	0.04	0.23	0.01	0.45	0.03	0.44
nps1392	Lummi Point (Lummi Island)	48.734	-122.688	8-Jul	15	0.64	14.36	0.92	0.07	12.48	16.24
sjs0001	Strawberry Bay North	48.563	-122.730	29-Jun	14	0.65	9.77	0.54	0.07	8.34	11.21
sjs0114	Decatur Head South	48.508	-122.787	30-Jul	16	0.69	10.79	0.41	0.06	9.53	12.04
sjs0118	SE Decatur Island	48.485	-122.813	27-Jun	14	0.51	26.21	2.42	0.06	23.17	29.26
sjs0205	E. of Eagle Point	48.455	-123.004	25-Jun	12	0.31	9.86	0.43	0.07	8.58	11.15
sjs0448	S. of West Beach	48.683	-122.968	16-Jul	14	0.57	5.16	0.03	0.03	4.83	5.48
sjs0452	S. of Pt. Doughty	48.702	-122.945	16-Jul	12	0.73	14.21	1.06	0.07	12.19	16.22
sjs0488	E. of Blakely Peak	48.578	-122.786	26-Jun			0				
sjs0544	Reef Island	48.605	-123.019	23-Jun	12	0.40	1.90	0.09	0.16	1.31	2.50
sjs0600	Odlin County Park	48.559	-122.892	17-Jul	20	0.47	2.55	0.12	0.13	1.89	3.22
sjs0639	Blind Island	48.424	-122.825	24-Jun			0				
sjs1492	Shannon Point W	48.506	-122.692	29-Jun	14	0.57	13.11	1.77	0.10	10.51	15.72
sjs2645	Gardiner	48.059	-122.918	24-Sep	15	0.45	0.50	0.01	0.18	0.32	0.67
sjs2652	Thompson Spit	48.100	-122.946	24-Sep	16	0.53	6.03	0.45	0.11	4.71	7.35
swh0713	Entrance Shelter Bay	48.386	-122.506	5-Aug	15	0.15	0.38	0.02	0.34	0.13	0.64
swh0973	North Possession	47.923	-122.373	14-Aug	11	0.61	13.42	2.39	0.12	10.39	16.45
swh1557	Rockaway Beach	48.205	-122.540	8-Aug	17	0.48	3.07	0.31	0.18	1.99	4.16
swh1568	Lowell Point	48.121	-122.492	11-Aug	20	0.30	0.14	0.00	0.15	0.10	0.18
swh1649	Nelson's Corner	47.923	-122.315	14-Aug	11	0.73	5.41	0.13	0.07	4.70	6.12

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 (hectares) 95% Lower Limit	95% Upper Limit
Wide Fringe											
cps1160	Tramp Harbor	47.407	-122.431	8-Sep	20	0.24	1.99	0.08	0.14	1.43	2.54
hdc2283	E. of Warrenville	47.668	-122.764	18-Aug	14	0.52	8.59	1.14	0.12	6.50	10.68
hdc2284	Warrenville	47.664	-122.775	18-Aug	14	0.62	9.57	0.77	0.09	7.85	11.29
hdc2383	Anna's Bay	47.349	-123.139	20-Aug	15	0.27	4.29	0.61	0.18	2.76	5.82
nps1328	W of Birch Bay	48.929	-122.799	22-Jul	15	0.24	2.48	0.34	0.24	1.33	3.63
nps1387	Sunrise Cove	48.701	-122.658	2-Jul	15	0.55	3.64	0.15	0.11	2.89	4.39
nps1433	Post Point	48.715	-122.524	3-Jul	18	0.61	2.88	0.05	0.08	2.44	3.33
sjs2742	Between Agate & Crescent Bay	48.168	-123.732	11-Sep			0				
swh0869	Polnell Point Light W	48.273	-122.564	6-Aug	8	0.19	0.08	0.00	0.30	0.03	0.12
swh0881	Maylor Point	48.262	-122.618	6-Aug			0				
swh0882	West Maylor Point	48.260	-122.630	6-Aug			0				
swh0918	Pratts Bluff (Whidbey Island)	48.124	-122.555	11-Aug	11	0.72	14.86	0.85	0.06	13.05	16.67
swh0955	West of Langley	48.046	-122.420	11-Aug	11	0.76	8.23	0.19	0.05	7.37	9.08

Obstructed sites: *sjs2770-West of Deep Creek* (wide fringe), *sjs2804-West of Sekiu River* (narrow fringe), and *sjs2815-Bullman Creek* (wide fringe).

Appendix B *Z. marina* Area Estimates at 2008 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 (hectares) 95% Lower Limit	95% Upper Limit
Core											
core001	Padilla Bay	48.52069	-122.507	28-Jul	11	0.77	3439.71	26768.02	0.05	3119.04	3760.39
Flats*											
flats01	Drayton Harbor	48.97526	-122.758	13-Jul	9	0.58	271.43	572.62	0.09	224.53	318.33
flats05	Lummi Flats S.	48.75917	-122.685	12-Jul	10	0.69	501.09	559.94	0.05	454.71	547.47
flats09	Nooksack Delta W.	48.74783	-122.586	11-Jul	7	0.01	1.17	0.46	0.58	-0.15	2.50
flats12	Samish Bay S.	48.57917	-122.48	30-Jun	11	0.73	836.30	4115.92	0.08	710.55	962.04

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 (hectares) 95% Lower Limit	95% Upper Limit
Narrow Fringe											
nps0517	Eliza Island South	48.64356	-122.578	11-Jul			0				
nps0518	Eliza Island Southwest	48.64833	-122.585	10-Jul	12	0.41	4.54	0.17	0.09	3.74	5.35
nps0520	Eliza Island Northwest	48.65861	-122.589	8-Jul	12	0.39	6.46	1.09	0.16	4.41	8.51
nps0536	Viti Rocks West	48.63173	-122.625	18-Jul			0				
nps0537	Viti Rocks East	48.63264	-122.618	18-Jul			0				
nps0666	Guemes Island Tideflats South	48.56653	-122.614	26-Jul	11	0.57	10.59	0.30	0.05	9.51	11.66
nps0675	Deadman Bay West	48.53322	-122.604	26-Jul	15	0.46	6.00	1.31	0.19	3.76	8.24
nps1340	NW of Cherry Point	48.87211	-122.767	23-Jul	13	0.05	0.42	0.05	0.55	-0.03	0.87
nps1343	SE of Cherry Point	48.8563	-122.736	23-Jul	11	0.08	0.30	0.03	0.60	-0.05	0.66
nps1344	E. of Ferndale	48.85168	-122.725	23-Jul	15	0.04	0.23	0.01	0.45	0.03	0.44
nps1383	Smugglers Cove	48.6804	-122.626	9-Jul	10	0.29	0.24	0.00	0.23	0.14	0.35
nps1384	NW of Smugglers Cove	48.68558	-122.635	9-Jul	18	0.15	0.55	0.05	0.42	0.10	1.00
nps1386	SE of Echo Point	48.69535	-122.654	24-Jul	15	0.27	1.52	0.10	0.21	0.90	2.14
nps1405	NW Portage Bay #2	48.70075	-122.641	21-Jul	11	0.74	15.71	0.85	0.06	13.90	17.52
nps1412	Brant Point	48.71169	-122.607	7-Jul	16	0.50	8.80	0.94	0.11	6.91	10.70
nps1427	Marine Heritage Park Waterway North	48.74812	-122.492	3-Jul	11	0.21	0.33	0.01	0.28	0.15	0.51
nps1446	Wildcat Cove North	48.65511	-122.502	3-Jul	9	0.27	0.71	0.07	0.37	0.19	1.24
nps1485	Anacortes-Guemes Ferry	48.51918	-122.629	29-Jul	11	0.47	2.03	0.08	0.14	1.47	2.58
nps2913	Lighthouse Park South	48.96974	-123.079	14-Jul	11	0.18	0.65	0.03	0.25	0.34	0.97
Wide Fringe											
nps1322	Semiahmoo Spit Tideflats South	48.96665	-122.813	12-Jun	11	0.36	15.84	0.59	0.05	14.33	17.34
nps1402	Lummi Marine Park SE	48.71945	-122.661	25-Jul	11	0.85	24.43	0.25	0.02	23.45	25.42
nps1404	NW Portage Island #1	48.7052	-122.651	22-Jul	11	0.68	7.72	0.14	0.05	6.98	8.46
nps1487	Loverick's Marina	48.51317	-122.652	29-Jul	11	0.60	4.73	0.21	0.10	3.82	5.63
nps2918	Lily Point	48.96653	-123.016	12-Jun	11	0.18	0.29	0.00	0.18	0.18	0.39

* - Values from flats11-Samish Bay N. sampled in the sound-wide effort were also used to calculate the North Puget Sound Focus Area *Z. marina* estimate.

Appendix C Change in *Z. marina* Area for Sites Sampled in 2007 and 2008

Site	2007 *Z. marina* area (ha)	2007 variance	2008 *Z. marina* area (ha)	2008 variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
core001	2957.0	67396.2	3439.7	26762.6	16.3	134.9	11.6	14.9	22.8	80% inc
core002	2.3	0.0	2.3	0.0	2.8	123.7	11.1	14.3	21.8	ns
core003	437.8	2282.3	517.2	1037.6	18.1	220.3	14.8	19.0	29.1	ns
core004	113.9	127.4	128.7	140.2	13.0	233.5	15.3	19.6	29.9	ns
core005	1.1	0.1	1.3	0.0	17.2	1,363.7	36.9	47.3	72.4	ns
core006	2.0	0.2	1.9	0.1	-2.2	692.0	26.3	33.7	51.6	ns
cps0224	0	0	0	0						ns
cps1035	0.1	0.0	0.0	0.0	-14.4	6,137.4	78.3	100.4	153.6	ns
cps1160	2.3	0.1	2.0	0.1	-15.3	244.6	15.6	20.1	30.7	ns
cps1194	0	0	0	0						ns
cps1289	0	0	0	0						ns
cps1676	5.5	0.2	5.7	0.3	4.7	193.0	13.9	17.8	27.2	ns
cps1750	5.3	0.1	4.6	0.4	-12.7	191.8	13.9	17.8	27.1	ns
cps1820	0.1	0.0	0.1	0.0	67.6	9,482.9	97.4	124.8	190.9	ns
cps1951	0	0	0	0						ns
cps1954	0	0	0	0						ns
cps1967	2.4	0.0	1.8	0.0	-24.5	81.0	9.0	11.5	17.6	95% dec
cps1983	0	0	0	0						ns
cps2552	8.1	0.5	10.8	0.3	32.5	190.9	13.8	17.7	27.1	95% inc
flats11	1211.8	3055.5	1328.1	3592.7	9.6	49.5	7.0	9.0	13.8	80% inc
flats12	698.6	2631.1	836.3	4115.1	19.7	161.6	12.7	16.3	24.9	80% inc
flats20	244.0	585.1	197.8	577.5	-18.9	161.6	12.7	16.3	24.9	80% dec
flats26	102.9	878.9	102.4	884.9	-0.5	1,657.3	40.7	52.2	79.8	ns
flats41	85.8	186.1	88.3	63.9	2.9	354.0	18.8	24.1	36.9	ns
flats42	88.2	45.8	103.0	29.5	16.8	118.3	10.9	13.9	21.3	80% inc
flats55	3.4	0.4	3.3	0.3	-4.8	514.2	22.7	29.1	44.4	ns
flats64	1.6	0.0	1.5	0.1	-2.5	366.9	19.2	24.6	37.5	ns
flats66	3.7	0.3	5.1	0.8	36.2	982.8	31.3	40.2	61.4	ns
flats67	6.8	1.4	6.4	2.2	-5.7	761.9	27.6	35.4	54.1	ns
flats70	332.9	1126.0	340.5	1035.8	2.3	199.8	14.1	18.1	27.7	ns
hdc2283	8.0	1.7	8.6	1.1	7.0	478.1	21.9	28.0	42.9	ns
hdc2284	4.5	0.3	9.6	0.8	110.9	920.3	30.3	38.9	59.5	95% inc
hdc2321	0	0	0	0						ns
hdc2383	3.4	0.5	4.3	0.6	25.8	1,203.3	34.7	44.5	68.0	ns
hdc2460	5.1	0.1	5.2	0.1	2.2	95.6	9.8	12.5	19.2	ns
hdc2465	6.1	0.3	5.6	0.4	-8.1	176.6	13.3	17.0	26.0	ns
hdc2479	7.4	0.1	7.4	0.4	-0.4	88.5	9.4	12.1	18.4	ns
nps0550	0	0	0	0						ns
nps0670	0.1	0.0	0.1	0.0	2.5	958.7	31.0	39.7	60.7	ns

Site	2007 *Z. marina* area (ha)	2007 variance	2008 *Z. marina* area (ha)	2008 variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
nps1328	0.6	0.1	2.5	0.3	294.2	53,269.4	230.8	295.9	452.4	ns
nps1344	0.1	0.0	0.2	0.0	128.4	23,797.2	154.3	197.8	302.4	ns
nps1387	4.2	0.0	3.6	0.1	-13.8	103.3	10.2	13.0	19.9	80% dec
nps1392	15.4	0.6	14.4	0.9	-6.9	60.4	7.8	10.0	15.2	ns
nps1433	3.2	0.0	2.9	0.1	-8.9	68.4	8.3	10.6	16.2	ns
sjs0001	9.5	0.6	9.8	0.5	3.4	135.5	11.6	14.9	22.8	ns
sjs0118	26.1	2.1	26.2	2.4	0.5	67.4	8.2	10.5	16.1	ns
sjs0205	10.1	0.6	9.9	0.4	-2.8	94.3	9.7	12.5	19.0	ns
sjs0448	5.4	0.1	5.2	0.0	-4.2	39.5	6.3	8.1	12.3	ns
sjs0452	14.6	0.4	14.2	1.1	-2.5	69.1	8.3	10.7	16.3	ns
sjs0488	0	0	0	0						ns
sjs0600	2.9	0.1	2.6	0.1	-12.8	220.9	14.9	19.1	29.1	ns
sjs0639	0	0	0	0						ns
sjs1492	13.2	1.1	13.1	1.8	-0.9	160.4	12.7	16.2	24.8	ns
sjs2645	0.5	0.0	0.5	0.0	-6.9	480.1	21.9	28.1	42.9	ns
sjs2652	5.5	0.3	6.0	0.5	9.4	262.5	16.2	20.8	31.8	ns
sjs2742	0	0	0	0						ns
swh0713	0.3	0.0	0.4	0.0	11.1	2,966.9	54.5	69.8	106.8	ns
swh0869	0.1	0.0	0.1	0.0	25.1	6,844.0	82.7	106.1	162.1	ns
swh0881	0	0	0	0						ns
swh0918	13.7	0.5	14.9	0.9	8.6	79.4	8.9	11.4	17.5	ns
swh0955	7.7	0.1	8.2	0.2	6.6	43.4	6.6	8.4	12.9	ns
swh0973	9.8	1.1	13.4	2.4	37.6	476.9	21.8	28.0	42.8	80% inc
swh1557	3.8	0.2	3.1	0.3	-19.8	306.4	17.5	22.4	34.3	ns
swh1568	0.1	0.0	0.1	0.0	8.0	867.8	29.5	37.8	57.7	ns
swh1649	5.0	0.1	5.4	0.1	8.2	112.9	10.6	13.6	20.8	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 Total *Z. marina* area estimates from 2000 – 2008

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

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 E *Z. marina* Depth Estimates at 2008 SVMP Sample Sites

		Minimum *Z. marina* Depth					Maximum *Z. marina* Depth				
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	0.2	0.4	11	-4.2	-3.2	0.6	1.1
core002	Picnic Cove	14	-0.5	-1.9	1.4	2.8	14	-5.7	-4.8	0.4	0.8
core003	Jamestown	11	0.2	0.0	0.1	0.3	11	-7.8	-6.3	1.4	2.8
core004	Lynch Cove	15	0.2	-0.4	0.4	0.8	15	-3.8	-3.1	0.5	1.0
core005	Dumas Bay	12	-0.4	-0.8	0.3	0.6	12	-1.9	-1.6	0.1	0.2
core006	Burley Spit	15	-0.6	-1.0	0.2	0.4	15	-2.6	-2.0	0.4	0.7
Persistent Flats											
flats11	Samish Bay N.	8	0.5	0.1	0.3	0.7	9	-4.7	-3.4	0.5	1.1
flats12	Samish Bay S.	11	0.6	0.4	0.3	0.5	11	-3.4	-3.2	0.2	0.3
flats20	Skagit Bay N.	15	-0.1	-0.5	0.2	0.3	15	-2.6	-1.6	0.5	0.9
Rotational Flats											
flats17	Bowman Bay	9	0.1	-1.2	1.2	2.4	9	-3.9	-2.2	1.1	2.1
flats26	Snohomish Delta N	11	0.7	0.0	0.3	0.7	11	-2.6	-1.9	0.6	1.2

Site	Location	Minimum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	Maximum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
flats41	Dosewallips	12	0.1	-0.4	0.4	0.9	12	-6.5	-4.5	0.9	1.8
flats42	Quilcene Bay	13	0.5	0.0	0.3	0.6	13	-7.0	-3.1	1.2	2.3
flats55	Mitchell Bay	15	-0.9	-2.8	1.2	2.3	15	-5.7	-4.2	1.2	2.4
flats64	Squaw Bay	13	-0.9	-1.2	0.4	0.7	13	-3.3	-2.1	0.6	1.2
flats66	Shallow Bay	13	-0.1	-1.9	1.4	2.8	13	-5.7	-3.0	1.8	3.6
flats67	Fossil Bay	3	-2.8	-2.9	0.2	0.3	3	-4.1	-4.0	0.3	0.6
flats70	South Fork Skagit River	9	0.2	-0.1	0.2	0.3	9	-3.5	-2.7	0.4	0.9
flats73	Salmon Bank	8	-3.7	-4.6	0.5	1.1	11	-11.0	-9.8	0.8	1.5
Narrow Fringe											
cps0224	Wilson Point	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1035	NE of Point White	2	-1.3	-2.8	5.2	10.1	2	-4.7	-3.2	4.9	9.6
cps1054	Agate Pass Bridge SE	12	0.3	-0.5	0.5	1.0	12	-3.6	-2.6	0.6	1.1
cps1141	Fern Cove North	11	-0.9	-1.9	1.2	2.4	12	-6.0	-3.8	1.0	1.9
cps1194	N. Herron Island	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1289	Villa Beach N	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1676	Broadview	15	0.3	-0.7	0.5	0.9	15	-5.8	-4.5	0.8	1.6
cps1750	Des Moines Beach	10	-0.1	-0.6	0.5	1.0	10	-4.6	-3.5	0.9	1.9
cps1777	E. 11th St	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1820	Gordon Point	11	-0.7	-1.2	0.3	0.5	11	-2.4	-1.6	0.6	1.2
cps1951	S. of Stretch Island	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1954	Stretch Pt State Park	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1967	Vaughn Bay (Case Inlet)	11	-0.5	-0.9	0.4	0.8	11	-2.7	-2.3	0.4	0.7
cps1983	N. Joemma Beach	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps1999	Filucy Bay	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps2038	Allen Point	11	-0.4	-0.9	0.3	0.6	11	-2.2	-1.9	0.4	0.8
cps2182	Lemolo Shore Drive NE	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
cps2552	Oak Bay Ramp	13	0.2	-0.1	0.2	0.3	13	-8.0	-4.0	2.4	4.6
hdc2321	Across from Eagle Pt	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
hdc2460	Lindsay's Beach	13	-0.3	-0.9	0.4	0.8	13	-7.5	-5.0	0.7	1.4
hdc2465	SE of Dabob Bay	14	-0.7	-1.1	0.2	0.4	14	-4.9	-3.6	0.6	1.1

Site	Location	Minimum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	Maximum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
hdc2479	Toanados Peninsula	10	-0.8	-1.0	0.2	0.3	11	-5.3	-4.2	0.7	1.4
nps0550	Vendovi East	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps0670	Boat Harbor (Guemes Island)	10	-0.5	-0.9	0.2	0.5	10	-2.7	-2.2	0.6	1.1
nps1344	E. of Ferndale	7	-0.8	-1.9	0.9	1.8	7	-2.8	-2.1	1.1	2.2
nps1392	Lummi Point (Lummi Island)	15	0.1	-0.6	0.6	1.2	15	-4.0	-3.5	0.3	0.7
sjs0001	Strawberry Bay North	12	-0.5	-1.4	1.1	2.1	12	-6.6	-6.0	0.5	0.9
sjs0114	Decatur Head South	11	-0.7	-1.6	0.6	1.2	16	-8.2	-7.1	0.7	1.4
sjs0118	SE Decatur Island	12	-1.8	-3.2	1.2	2.3	14	-8.7	-7.8	0.3	0.5
sjs0205	E. of Eagle Point	12	-3.0	-5.2	1.4	2.7	12	-11.0	-10.4	0.4	0.9
sjs0448	S. of West Beach	12	-0.3	-0.7	0.3	0.6	13	-7.3	-6.1	0.9	1.8
sjs0452	S. of Pt. Doughty	11	-0.8	-1.0	0.1	0.3	12	-8.2	-6.9	0.9	1.9
sjs0488	E. of Blakely Peak	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
sjs0544	Reef Island	8	-1.0	-1.5	0.5	1.1	8	-7.4	-5.1	1.9	3.8
sjs0600	Odlin County Park	19	0.1	-0.7	0.4	0.8	20	-6.9	-4.5	1.2	2.4
sjs2645	Gardiner, Discovery Bay	11	-0.5	-0.9	0.1	0.3	11	-4.9	-4.1	0.2	0.3
sjs2652	Thompson Spit	14	-0.2	-1.1	1.2	2.4	14	-7.8	-5.2	1.4	2.8
swh0713	Entrance Shelter Bay	9	0.2	-1.0	0.7	1.3	9	-3.0	-2.2	0.6	1.2
swh0973	North Possession	11	0.7	0.3	0.2	0.4	11	-4.5	-3.4	1.3	2.5
swh1557	Rockaway Beach	12	-0.2	-0.8	0.4	0.9	12	-4.9	-3.6	0.7	1.4
swh1568	Lowell Point	16	-0.7	-1.8	0.6	1.1	16	-4.1	-3.2	0.4	0.7
swh1649	Nelson's Corner	11	0.4	-0.1	0.4	0.8	11	-3.4	-3.0	0.4	0.7
Wide Fringe											
cps1160	Tramp Harbor	17	0.1	-0.1	0.2	0.3	17	-1.7	-1.0	0.4	0.7
hdc2283	E. of Warrenville	14	-0.2	-0.5	0.2	0.5	14	-3.6	-2.9	0.3	0.5
hdc2284	Warrenville	14	0.5	0.2	0.3	0.5	14	-4.0	-3.2	0.3	0.6
hdc2383	Anna's Bay	12	0.0	-0.5	0.3	0.6	12	-3.7	-1.9	0.9	1.8
nps1328	W of Birch Bay	13	-0.6	-1.2	0.5	0.9	13	-3.5	-2.7	0.5	1.1
nps1387	Sunrise Cove	13	0.5	-0.6	0.9	1.8	13	-4.5	-2.8	1.0	1.9
nps1433	Post Point	17	-0.1	-0.6	0.5	0.9	17	-4.3	-3.2	0.5	1.0
sjs2742	Between Agate & Crescent Bay	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999

Site	Location	Minimum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	Maximum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
swh0869	Polnell Point Light W	6	-0.7	-0.8	0.1	0.3	6	-1.4	-1.2	0.2	0.3
swh0881	Maylor Point	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
swh0882	West Maylor Point	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
swh0918	Pratts Bluff (Whidbey Island)	11	-0.1	-0.4	0.2	0.3	11	-3.8	-3.4	0.3	0.5
swh0955	West of Langley	7	-0.1	-0.4	0.3	0.6	11	-4.9	-4.0	0.5	1.1

Note: -9999 = eelgrass not present at site

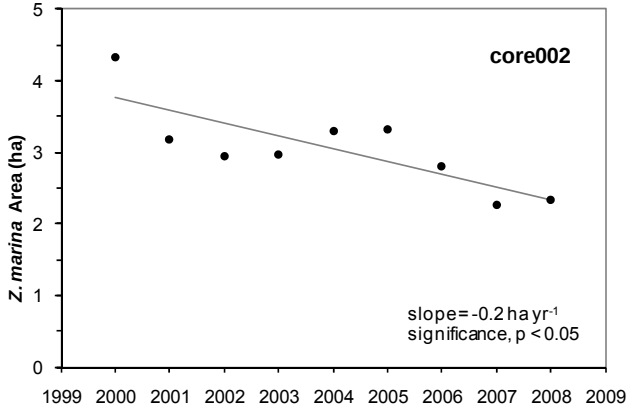
Appendix F *Z. marina* Depth Estimates at 2008 Focus Area Sample Sites

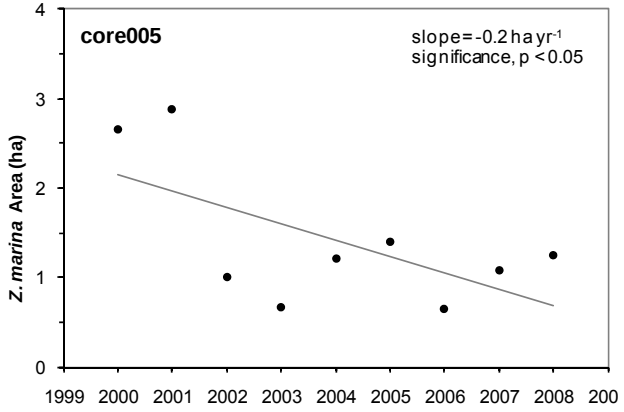
Site	Location	Minimum *Z. marina* Depth n	Minimum *Z. marina* Depth Absolute Depth (m)	Minimum *Z. marina* Depth Mean Depth (m)	Minimum *Z. marina* Depth Standard Error	Minimum *Z. marina* Depth 95% CI Interval (m)	Maximum *Z. marina* Depth n	Maximum *Z. marina* Depth Absolute Depth (m)	Maximum *Z. marina* Depth Mean Depth (m)	Maximum *Z. marina* Depth Standard Error	Maximum *Z. marina* Depth 95% CI Interval (m)
Core											
core001	Padilla Bay	11	0.6	0.4	0.2	0.4	11	-4.2	-3.2	0.6	1.1
Rotational Flats											
flats01	Drayton Harbor	9	0.3	-0.1	0.3	0.6	9	-2.9	-2.2	0.7	1.4
flats05	Lummi Flats S.	10	0.6	0.4	0.1	0.2	10	-3.8	-3.0	0.4	0.8
flats09	Nooksack Delta W.	4	-0.4	-1.3	2.1	4.1	4	-4.3	-2.7	2.2	4.3
flats12	Samish Bay S.	11	0.6	0.4	0.3	0.5	11	-3.4	-3.2	0.2	0.3
Narrow Fringe											
nps0517	Eliza Island South	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps0518	Eliza Island Southwest	10	0.2	-0.8	1.3	2.5	11	-4.7	-4.1	0.4	0.7
nps0520	Eliza Island Northwest	12	-0.2	-1.2	1.4	2.8	12	-5.0	-4.2	0.5	1.1
nps0536	Viti Rocks West	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps0537	Viti Rocks East	0	-9999	-9999	-9999	-9999	0	-9999	-9999	-9999	-9999
nps0666	Guemes Island Tideflats South	4	0.0	-0.3	0.3	0.6	11	-5.4	-4.4	0.8	1.6
nps0675	Deadman Bay West	12	-0.3	-1.0	0.6	1.2	15	-5.4	-3.8	1.0	1.9
nps1340	NW of Cherry Point	5	-0.9	-1.6	0.9	1.8	5	-2.9	-2.5	0.4	0.7
nps1343	SE of Cherry Point	4	-0.7	-2.1	1.7	3.4	4	-4.3	-3.2	2.6	5.1
nps1344	E. of Ferndale	7	-0.8	-1.9	0.9	1.8	7	-2.8	-2.1	1.1	2.2
nps1383	Smugglers Cove	9	-0.4	-1.7	0.9	1.7	9	-4.3	-3.3	0.6	1.1
nps1384	NW of Smugglers Cove	8	-0.7	-1.9	0.8	1.5	8	-4.3	-3.3	0.8	1.6
nps1386	SE of Echo Point	14	-0.4	-1.0	0.5	1.0	14	-4.0	-3.6	0.4	0.7
nps1405	NW Portage Bay #2	11	0.0	-0.1	0.1	0.1	11	-4.1	-3.2	0.7	1.3
nps1412	Brant Point	15	-0.5	-1.0	0.4	0.8	15	-3.5	-2.9	0.6	1.1
nps1427	Marine Heritage Park Waterway North	8	-0.9	-1.1	0.3	0.6	8	-2.4	-1.9	0.4	0.7
nps1446	Wildcat Cove North	7	-0.6	-1.8	0.8	1.7	7	-3.3	-2.7	0.6	1.2
nps1485	Anacortes-Guemes Ferry	10	0.4	-0.4	0.9	1.8	10	-4.7	-3.5	1.3	2.5
nps2913	Lighthouse Park South	9	-2.8	-3.2	0.3	0.5	9	-4.7	-4.2	0.5	1.0

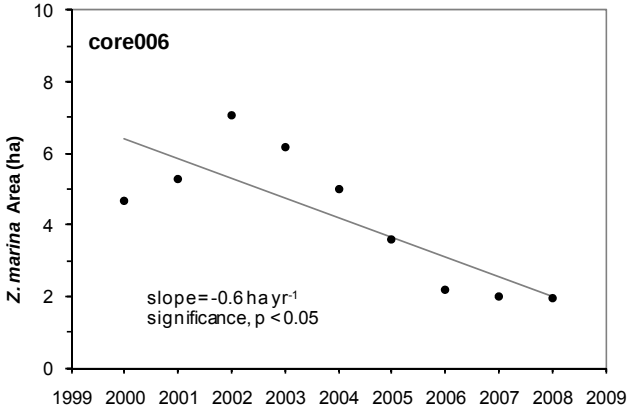
Site	Location	Minimum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)	Maximum *Z. marina* Depth n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% CI Interval (m)
Wide Fringe											
nps1322	Semiahmoo Spit Tideflats South	11	0.3	0.1	0.1	0.3	11	-4.1	-3.7	0.2	0.4
nps1402	Lummi Marine Park SE	11	0.0	-0.3	0.4	0.7	11	-4.0	-3.8	0.2	0.4
nps1404	NW Portage Island #1	11	0.3	-0.2	0.3	0.6	11	-3.1	-2.6	0.4	0.7
nps1487	Unknown Marina	10	0.2	-0.1	0.2	0.5	10	-4.1	-3.0	0.6	1.2
nps2918	Lily Point	11	-1.2	-1.9	0.6	1.1	11	-3.2	-2.8	0.5	0.9

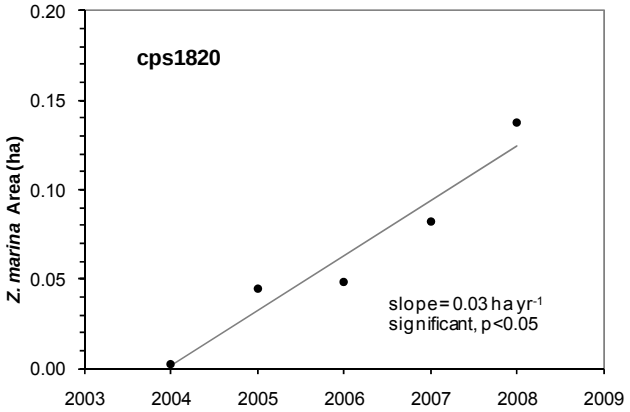
Note: -9999 = eelgrass not present at site

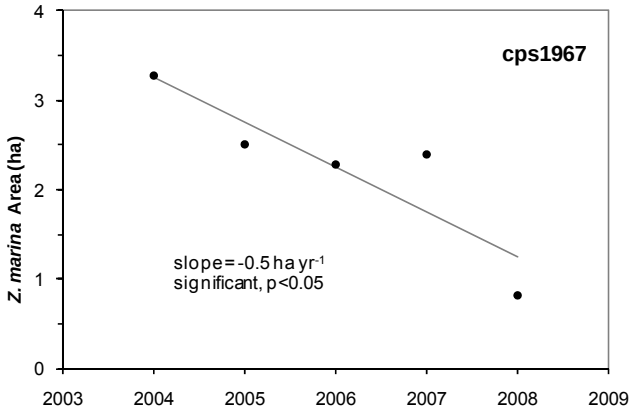
Appendix G 2008 Site Level Trend Analysis – 4 to 5 years ($p < 0.05$)

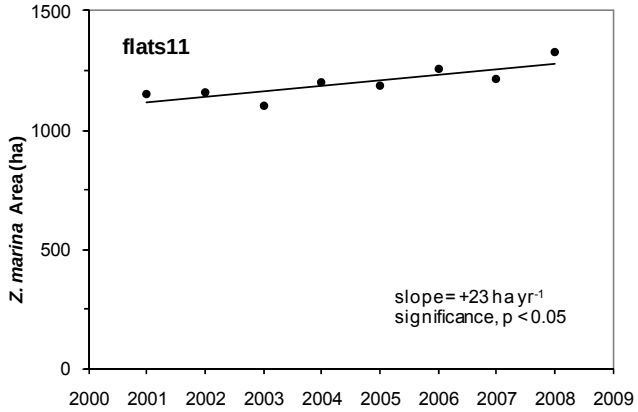


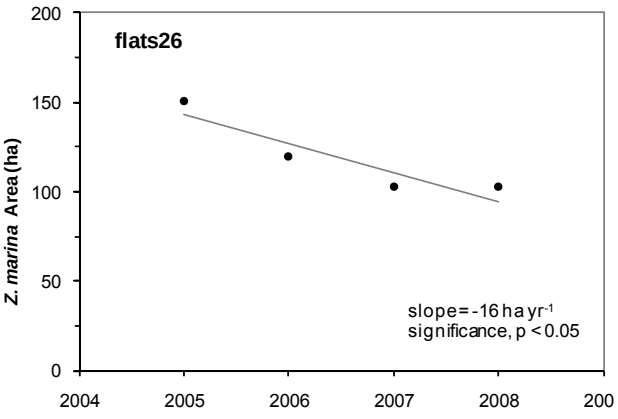


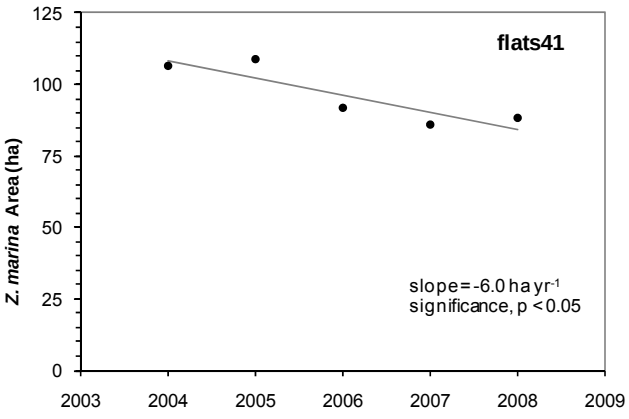


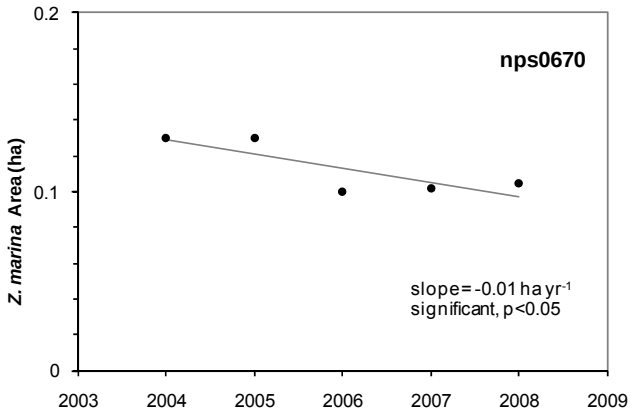


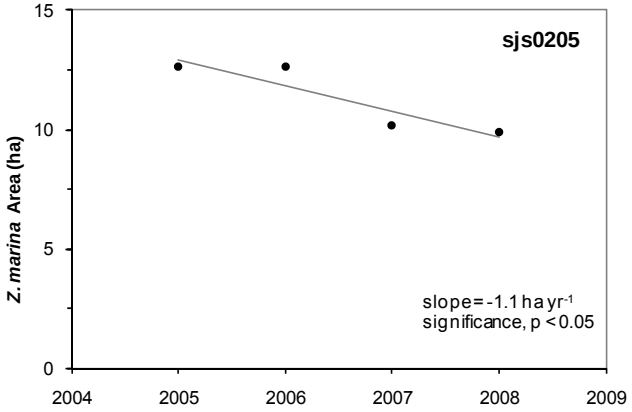


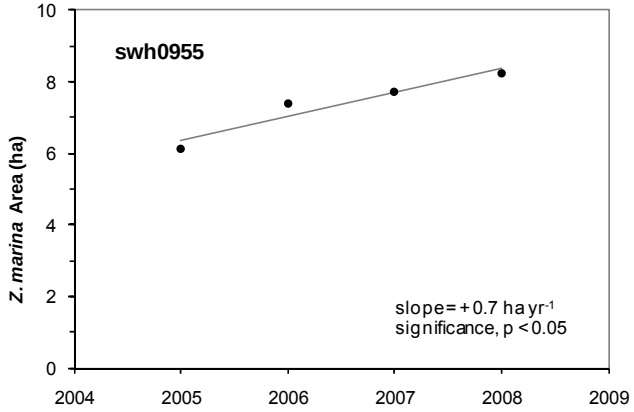




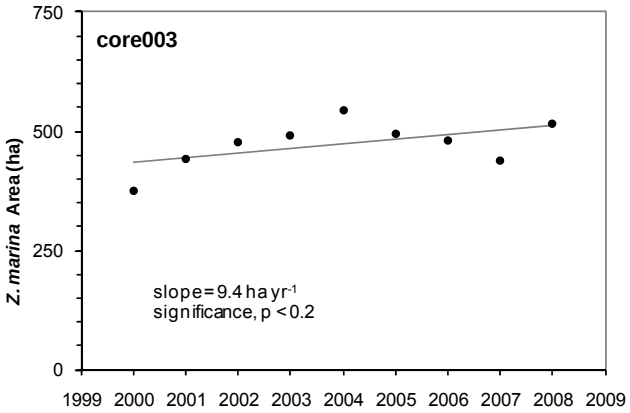


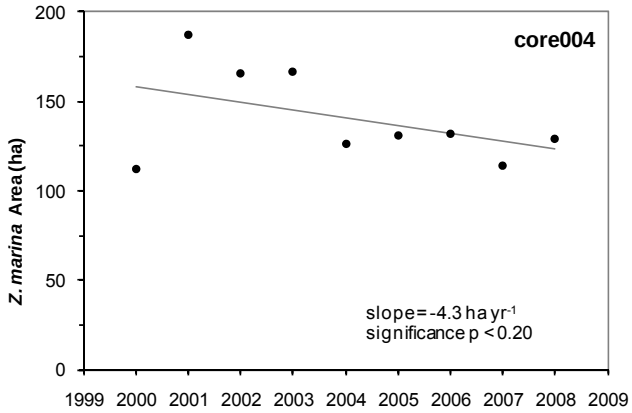


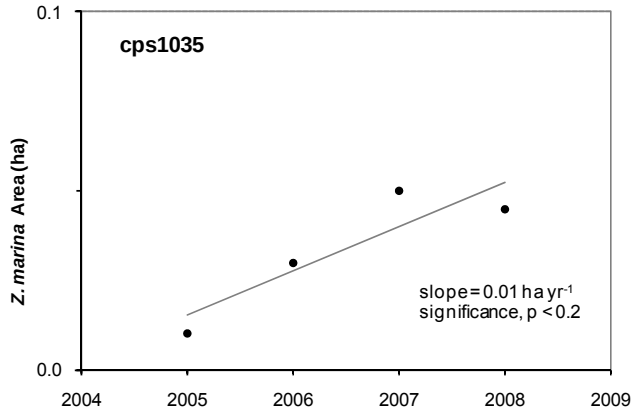

sjs0205
Z. marina Area (ha)
15
10
5
0
2004
2005
2006
2007
2008
2009
slope = -1.1 ha yr-1
significance, p < 0.05

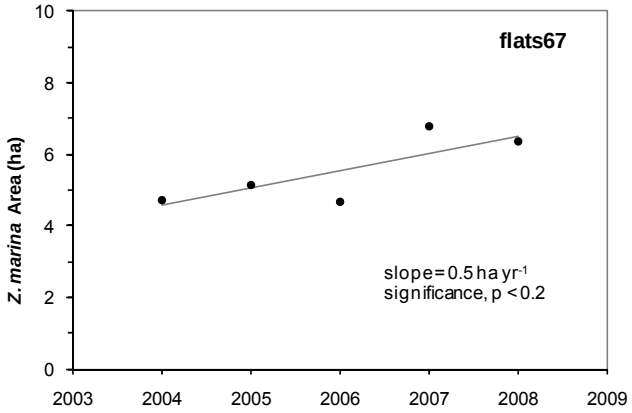

swh0955
Z. marina Area (ha)
10
8
6
4
2
0
2004
2005
2006
2007
2008
2009
slope = + 0.7 ha yr-1
significance, p < 0.05

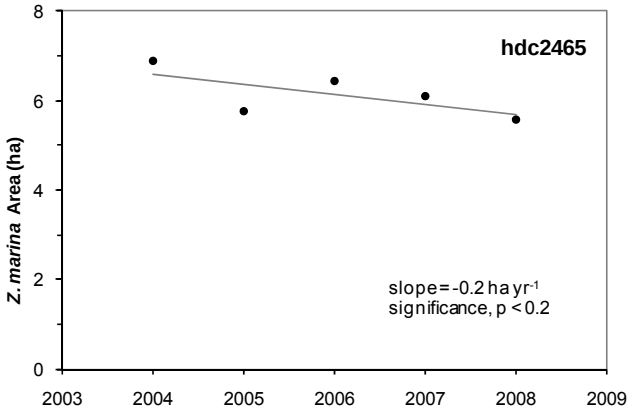
Appendix H 2008 Site Level Trend Analysis (p < 0.20)

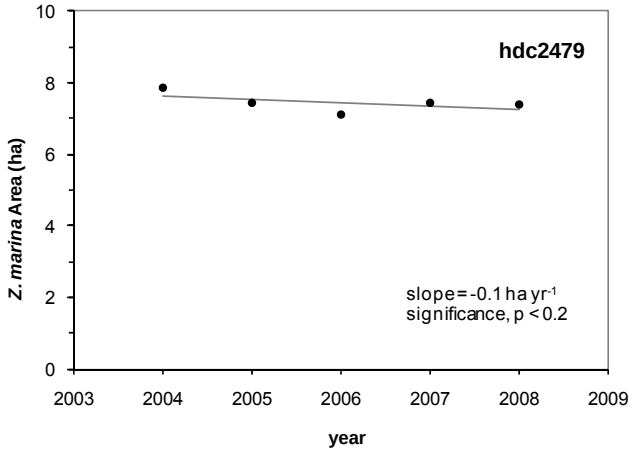


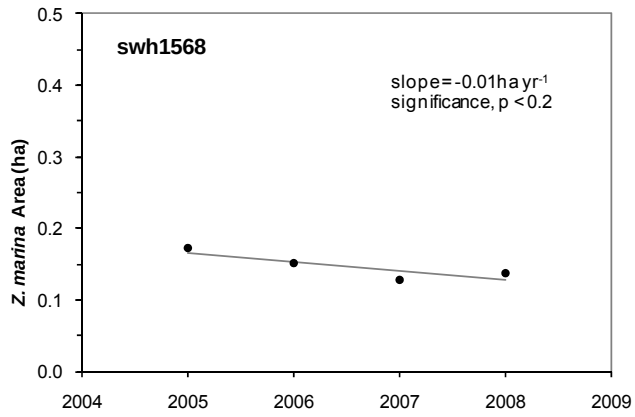




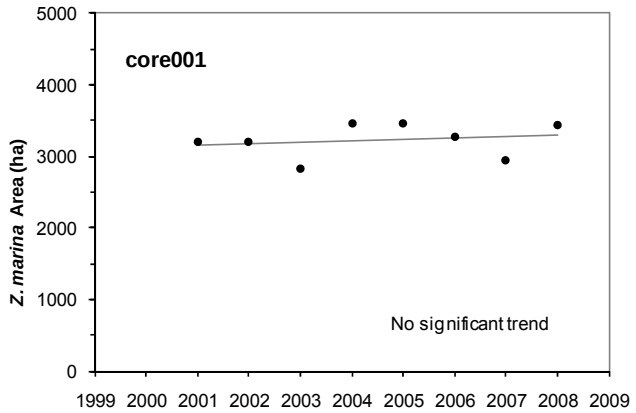


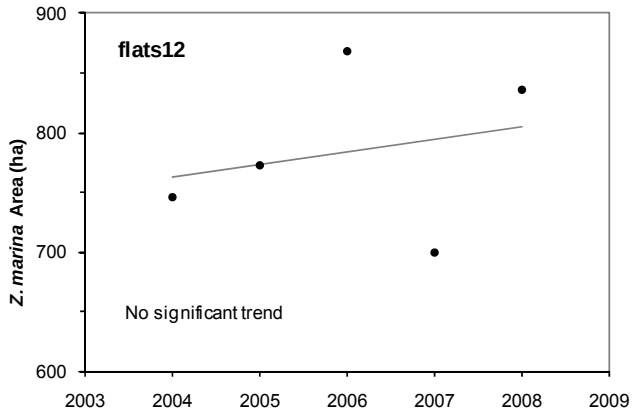


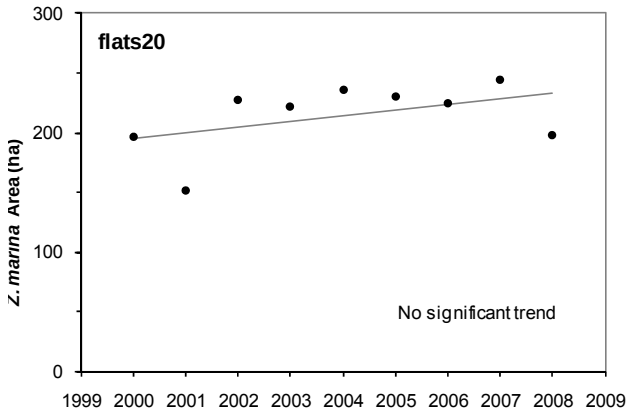


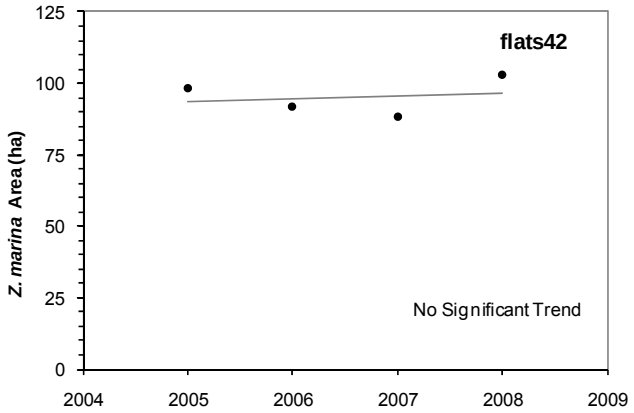


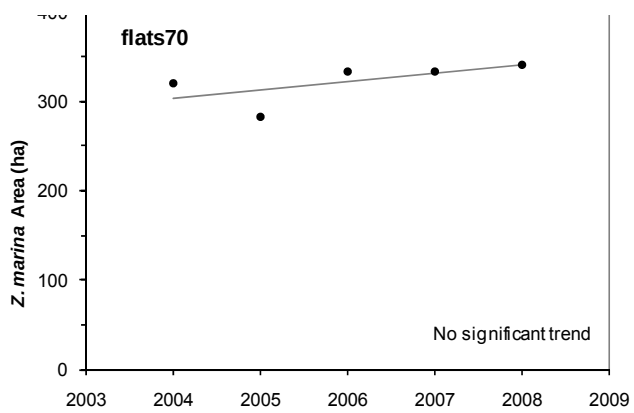
Appendix I 2008 Site Level Trend Analysis (no significant trend)

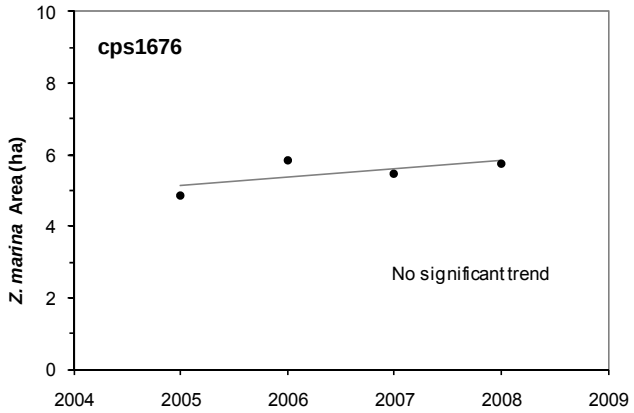


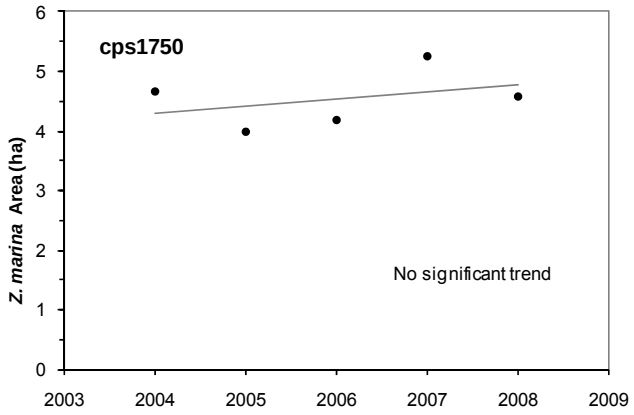


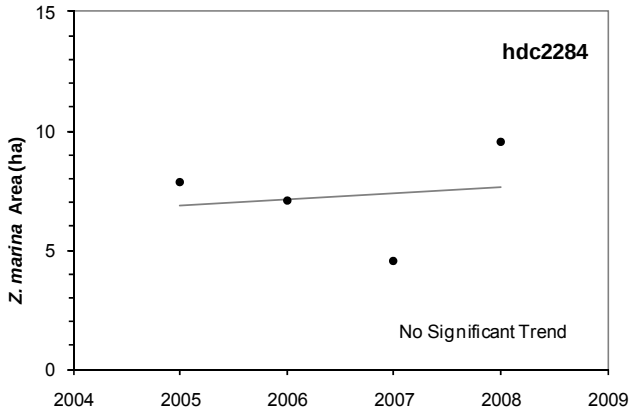


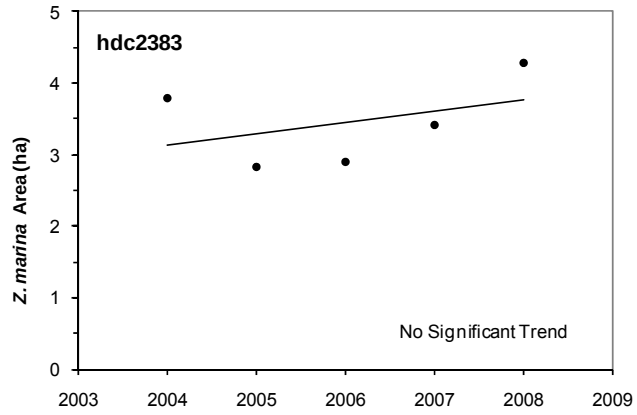


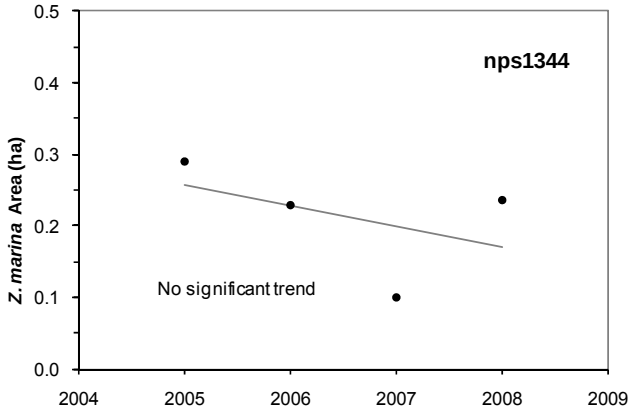


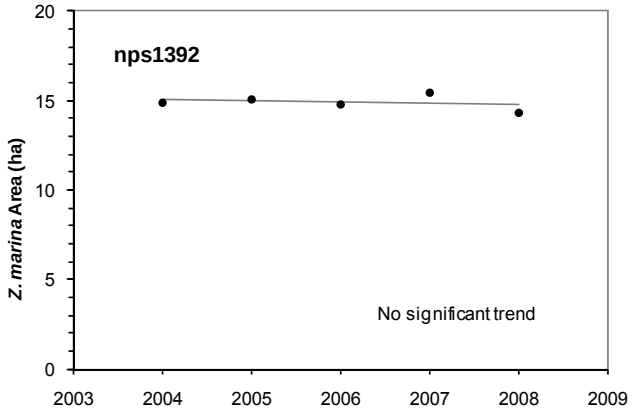


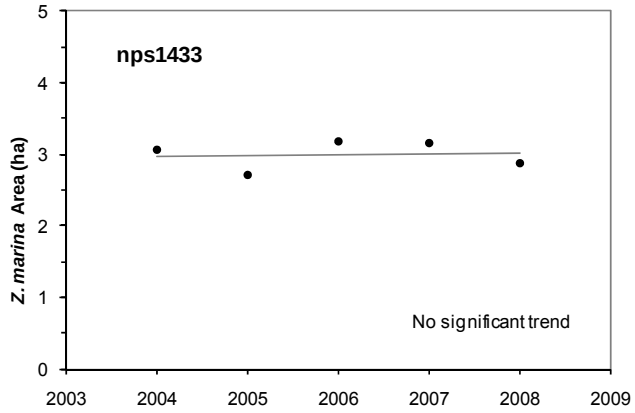


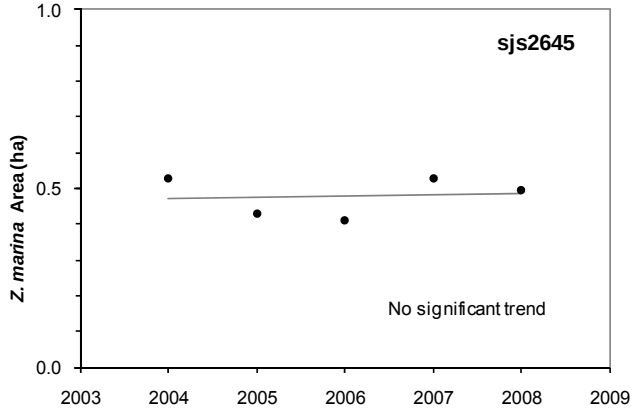


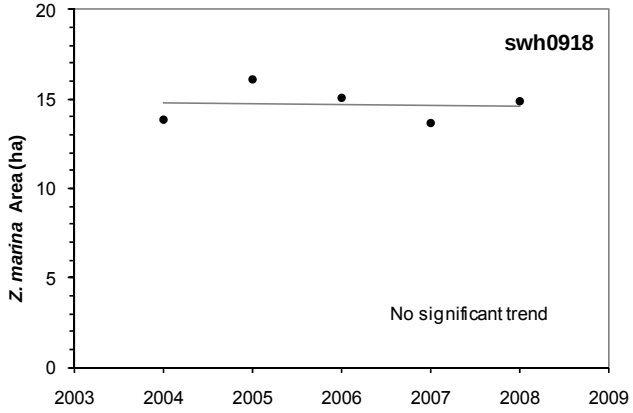


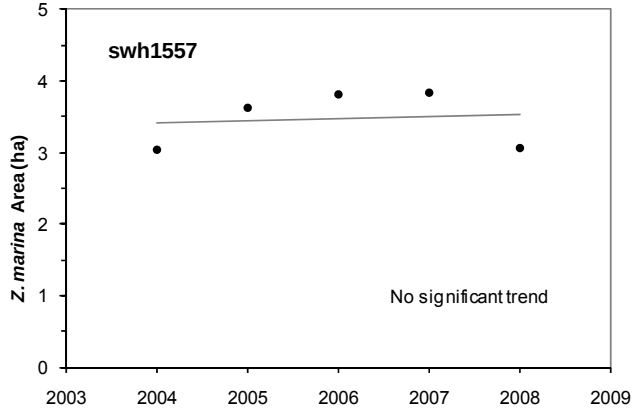

nps1344
Z. marina Area (ha)
No significant trend
0.5
0.4
0.3
0.2
0.1
0.0
2004
2005
2006
2007
2008
2009


nps1392
Z. marina Area (ha)
No significant trend
20
15
10
5
0
2003
2004
2005
2006
2007
2008
2009


nps1433
Z. marina Area (ha)
No significant trend
5
4
3
2
1
0
2003
2004
2005
2006
2007
2008
2009


sjs2645
Z. marina Area (ha)
No significant trend
1.0
0.5
0.0
2003
2004
2005
2006
2007
2008
2009


swh0918
Z. marina Area (ha)
No significant trend
20
15
10
5
0
2003
2004
2005
2006
2007
2008
2009


swh1557
Z. marina Area (ha)
No significant trend
5
4
3
2
1
0
2003
2004
2005
2006
2007
2008
2009

Appendix J 2008 North Puget Sound Region Focus Area Site Selection

The initial task in the *North Puget Sound Region* site selections process was to match the total focus area effort of 36 fringe-equivalents. A fringe-equivalent is the nominal effort to sample one fringe site, and is used as an accounting aid for managing sampling effort from year to year. Therefore, if the time it takes to sample two fringe sites is equivalent to one flats site then the sampling effort to sampling the flats site is two fringe-equivalents.

The *North Puget Sound Region* had 14 available flats sites and five were selected to be sampled in 2008. Due to the large size of the flats sites in the region, a multiplier of 2.0 was used to achieve an allocation of 36 fringe-equivalents across the strata. Based on the 2.0:1 effort ratio (fringe:flats), 26 additional fringe sites (21 narrow fringe and 5 wide fringe) were selected to make the *North Puget Sound Region* focus area sampling effort consistent with previous effort in focus areas (Table J-1).

Fringe Stratification

Zostera marina area estimates for the narrow and wide fringe sites from 2000 to 2007 were compared prior to site selection in the *North Puget Sound* focus area to determine whether the fringe strata should be stratified or pooled. A significant difference in the mean *Z. marina* area between the narrow and wide fringe strata justified maintaining the stratification of the fringe sites (Gaeckle et al. 2007).

Site selection

The allocation of effort between the strata was determined and the respective numbers of sites were randomly selected from the pool of eligible sites in each stratum. Since sites for the sound-wide sampling were randomly selected, data from sites that fell within the focus area could be used in the focus area *Z. marina* analysis and estimates.

Table J-1. Allocation of sampling effort among the flats and fringe frames in 2004, 2005, 2006, 2007, and 2008. Sites were selected on the basis that 1) overall focus area effort in 2008 will be the same as previous years, and 2) the effort to sample a typical flats site is 2.0:1 in 2008. Number in parentheses in flats stratum is the fringe equivalents. A fringe equivalent is the nominal effort to sample one fringe site.

	San Juan Focus Area 2004	Hood Canal Focus Area 2005	Saratoga – Whidbey Focus Area 2006	Central Puget Sound Focus Area 2007	North Puget Sound Focus Area 2008
flats	8(16)	5 (10)	8 (20)	4 (8)	5 (10)
fringe	20	26	16	28	26
total effort (fringe equivalents)	36	36	36	36	36

Appendix K Sites used in the North Puget Sound Region Focus Area Analysis

Table K-1. Complete list of the 38 sites used to calculate the 2008 *North Puget Sound Region* 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	sound-wide stratum
fringe	focus area study	nps0517	narrow fringe
		nps0518	narrow fringe
		nps0520	narrow fringe
		nps0536	narrow fringe
		nps0537	narrow fringe
		nps0666	narrow fringe
		nps0675	narrow fringe
		nps1322	wide fringe
		nps1340	narrow fringe
		nps1343	narrow fringe
		nps1344	narrow fringe
		nps1380	narrow fringe
		nps1383	narrow fringe
		nps1384	narrow fringe
		nps1386	narrow fringe
		nps1402	wide fringe
		nps1404	wide fringe
		nps1405	narrow fringe
		nps1412	narrow fringe
		nps1427	narrow fringe
		nps1436	narrow fringe
		nps1446	narrow fringe
		nps1485	narrow fringe
		nps1487	wide fringe
		nps2913	narrow fringe
		nps2918	wide fringe
	sound-wide study	nps0550	narrow fringe
		nps0670	narrow fringe
		nps1328	wide fringe
		nps1387	wide fringe
		nps1392	narrow fringe
		nps1433	wide fringe
flats	focus area study	flats01	rotational flats
		flats05	rotational flats
		flats09	rotational flats
	sound-wide study	core001*	flats
		flats11	persistent flats
		flats12*	persistent flats

* core001 and flats12 were selected as focus area sites during the *North Puget Sound Region* focus area site selection process