Puget Sound
Submerged Vegetation Monitoring Project
2003-2004 Monitoring Report

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
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PSAMP
Puget Sound Ambient Monitoring Program

The Submerged Vegetation Monitoring Project is implemented by the Nearshore Habitat Program. It is a component of the Puget Sound Ambient Monitoring Program.

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EXECUTIVE SUMMARY

In this report we present new 2003-2004 results from the Submerged Vegetation Monitoring Project (SVMP) on the abundance and distribution of eelgrass, *Zostera marina*, in greater Puget Sound. We monitor *Z. marina* because it provides valuable nearshore habitat to economically important species and species currently under federal and state protection. These new results extend our overall data record to five years, 2000-2004.

In 2004, we added a major component to our sampling – an ongoing focus area study that will rotate through the five regions of our study area on a five-year schedule. We initiated the focus area study in an area that includes the San Juan Islands and Cypress Island since this area has previously been identified as an area of concern (Wyllie-Echeverria et al. 2003). This additional sampling will allow us to produce robust results at the scale of individual regions within the study area every five years.

In this 2003-04 period we also made several adjustments to our sampling and analysis methods based on recommendations from our first report (Berry et al. 2003) as well as those from a detailed statistical study that we completed (Dowty 2005). Some important changes included enhanced sampling for maximum depth of *Z. marina*, a change to our stratification to improve precision and the elimination of water quality and plant characteristics sampling. We continue to rely on underwater videography as our primary method of data collection.

KEY FINDINGS

1. Results from the Hood Canal region suggest that *Z. marina* area has declined there for three consecutive years.
2. The other four regions either have not changed measurably in *Z. marina* area or have displayed what is most likely natural variability with no consistent trend.
3. While there is no overall trend in the region that includes the San Juan Islands, we have observed a pattern of sharp declines in several shallow embayments in this area that include herring spawning sites.
4. A multi-parameter assessment of site-level results identified 14 sites with strong evidence of declining *Z. marina*. These sites are dispersed among all the five regions of the study area but none were identified in the Strait of Juan de Fuca portion of the San Juan – Straits region.
5. In greater Puget Sound overall *Z. marina* area is stable. We found no evidence of a decline in total *Z. marina* area or evidence that a significant number of locations in the study area are experiencing *Z. marina* decline. On the contrary, in 2003-04 we had our first observation of significant sound-wide change and it was an increase of 7%.
6. Our most recent estimates of the overall amount of *Z. marina* in Puget Sound are consistent with our previous estimates of approximately 20,000 hectares (49,000 acres).
7. We estimate that the San Juan Islands and Cypress Island together account for approximately 7.5% of the total amount of *Z. marina* in the Puget Sound study area.

8. Our results continue to show that the distribution of *Z. marina* in Puget Sound is highly aggregated with more than a quarter of the total (27%) located in Padilla and Samish Bays.

Based on these findings, the entire Hood Canal region is an area of concern for *Z. marina* decline. Given the current interest in identifying the factors contributing to low dissolved oxygen conditions, it is important not only to examine the factors causing *Z. marina* decline but also to characterize the role of *Z. marina* in the Hood Canal oxygen budget.

Shallow embayments of the San Juan Islands are a second area of concern for *Z. marina* decline. This area was identified through a collaborative effort that considered SVMP data in concert with other data sources. We continue our collaborative work to document declines in this area and to identify causal factors.

In addition, we identified 14 sites with strong evidence of *Z. marina* decline. These represent localized areas of concern. In 2005 we will continue to monitor most of these sites but for the few that have rotated out of the sample it is important to develop a mechanism to ensure some level of continued monitoring.

The contrasting results across spatial scales indicate that the observed declines are not sufficiently widespread to cause overall declines in Puget Sound *Z. marina*. They also indicate that in general declines are of a localized nature except in the case of Hood Canal and the specific case of shallow embayments in an area of the San Juan Islands.

FUTURE PRIORITIES

Given these findings and our overall assessment of the project, we have identified several priorities to guide our current efforts.

1. Complete 2005 focus area sampling in Hood Canal and examine results for corroborating evidence of decline in *Z. marina*. Develop process studies and pursue partnerships to identify causal factors.
2. Increase effort in current collaboration with the University of Washington and the FRIENDS of the San Juans to identify factors causing *Z. marina* decline in shallow embayments of the San Juan Islands.
3. Build partnerships to ensure sites with strong evidence of declining *Z. marina* continue to be monitored when these sites rotate out of the SVMP sample.
4. Complete Monte Carlo estimates of precision in the regional change estimates to improve reliability.
5. Further develop multi-parameter assessment of change at sites with significant declines in the 5-year trend analyses.
6. Enhance web-based data dissemination including site-level data.
7. Complete Monte Carlo assessment of the reliability of the retrospective adjustment procedure and investigate benefits of restricting application to a subset of the strata.
8. Complete comparative analysis of options for site rotation and change analysis in the focus areas.

1 Introduction

The primary purpose of this report is to present our recent monitoring results and analysis from Puget Sound, Washington produced as part of the Submerged Vegetation Monitoring Project (SVMP). The SVMP monitors the abundance and distribution of *Zostera marina*, a seagrass commonly known as eelgrass that is found in intertidal and shallow subtidal areas. This is the second monitoring report produced by the project since monitoring began in 2000.

This chapter provides a brief introduction to the project and summarizes key developments during 2003-2004. The first monitoring report provides additional background on the project (Berry et al. 2003).

1.1 The Submerged Vegetation Monitoring Project

The overall goal of the SVMP is to monitor status and trends of *Z. marina* in Puget Sound. We are focusing on *Z. marina* because it is an important nearshore resource that provides spawning grounds for Pacific herring (*Clupea harengus pallasi*), out migrating corridors for juvenile salmon (*Oncorhynchus spp*.) and important feeding and foraging habitats for waterbirds such as the Black Brant (*Branta bernicla*) and Great Blue Heron (*Ardea herodias*) (Phillips 1984; Simenstad 1994; Wilson and Atkinson 1995; Butler 1995).

In addition, *Z. marina* is distributed throughout our study area and it has a rich monitoring literature (for example, Orth and Moore 1988; Krause-Jensen et al. 2003; Kemp et al. 2004, 2005). Previous work has demonstrated its usefulness as an indicator of habitat condition and marine impacts from anthropogenic stressors (Dennison et al. 1993). *Z. marina* also has strong cultural significance for both Native Americans and First Nation People in the Pacific Northwest as both a valued hunting ground and important ceremonial food (Suttles 1951; Kuhnlein and Turner 1991; Wyllie-Echeverria and Ackerman 2003).

The SVMP is one component of the Puget Sound Ambient Monitoring Program (PSAMP), a program coordinated by the Puget Sound Action Team (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 system. The legislature further intended that PSAMP data be used to

> "*track quantifiable performance measures that can be used by the governor and the legislature to assess the effectiveness over time of programs and actions initiated under the [Puget Sound management] plan to improve and protect Puget Sound water quality and biological resources*" RCW 90.71.060.

Currently, SVMP data on the status and trends of *Z. marina* provide the basis for a key ecosystem indicator that is used for integrated assessments of Puget Sound (Puget Sound Action Team 2005, 2002b).

The SVMP is implemented by the Washington State Department of Natural Resources (DNR) and represents a key component of this agency's contribution to PSAMP. DNR initiated this monitoring as a natural complement to its role as manager of state-owned aquatic lands, which include 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 79.90.455). Given the key ecological functions of *Z. marina* mentioned above and subsequently its value as a resource under DNR's management, the tracking of this resource by SVMP serves DNR's direct mandate as well as that of the broader PSAMP.

The actions of other state agencies also reflect the recognized value of *Z. marina* as an aquatic resource. The Washington Department of Fish and Wildlife has designated areas of *Z. marina* as habitats of special concern (WAC 220-110-250) under its statutory authority over hydraulic projects (RCW 77.55.100). Similarly, the Washington Department of Ecology has 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 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; see Figure 1-1) based on sampling at randomly selected sites. It was also designed to produce results at annual and long-term (5- and 10-year) temporal scales although the data record is not yet sufficient to support the long-term trend analyses. SVMP monitoring began in 2000.

Our primary programmatic performance measure is our ability to detect a decline in *Z. marina* abundance over 10 years at the sound-wide scale, which coincides with our entire study area and includes 2620 km (1630 miles) of shoreline. While we currently do not have enough data to test for a 10-year decline, we use projections of our detection capability as our performance measure based on our existing data. We currently project that we will meet our target of achieving the ability to detect a 20% decline in *Z. marina* over 10 years with suitable levels of statistical power.

1.2 Climatic Conditions in 2003-2004

It is important to consider general climatic conditions when interpreting ecological monitoring results. Oviatt (2004), for example, argues that two periods of twentieth century *Z. marina* decline in an east coast estuary were not associated with anthropogenic effects but were related to periods of elevated marine water temperature and broad climatic patterns as captured by a North Atlantic climate index. Of course, changes in *Z. marina* at any given site may be dominated by local factors that overwhelm any broad climatic signal. Nevertheless, here we present two climate indices and stream flow records at four major rivers affecting the study area.

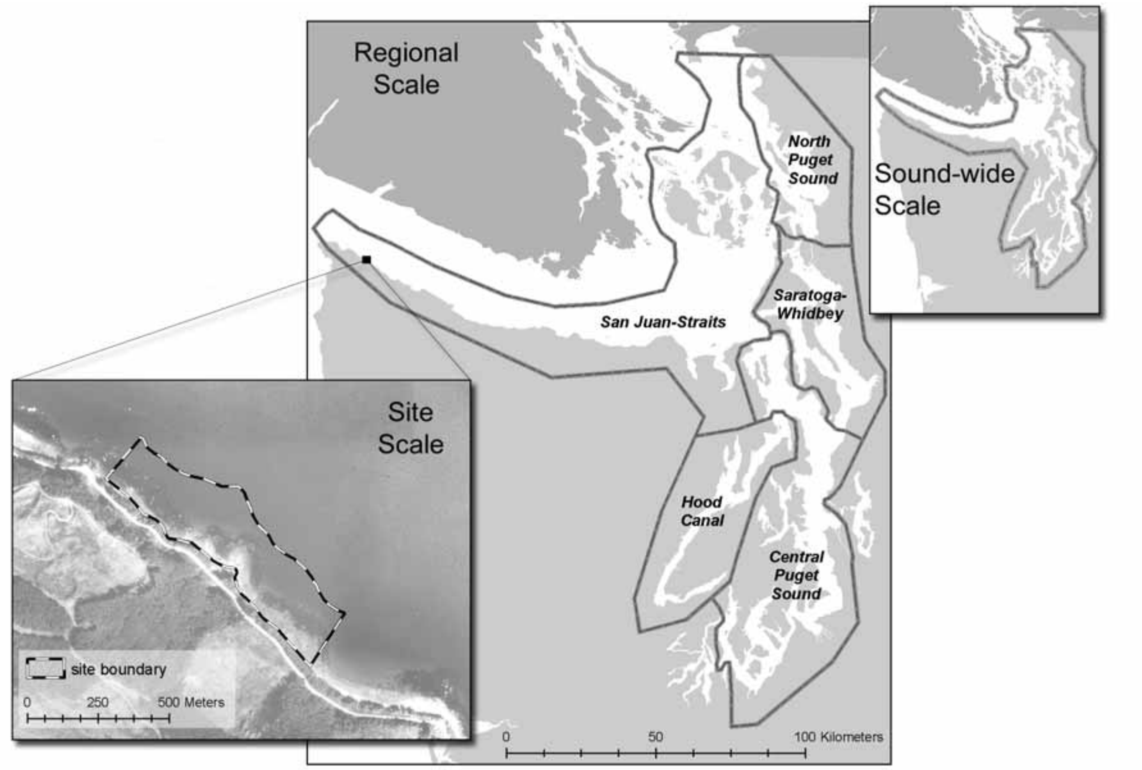

Figure 1-1. The sound-wide, regional and site scales at which the SVMP produces estimates of *Z. marina* conditions.

El Niño-Southern Oscillation conditions can have strong effects on regional climate and ecosystems, including seagrass communities (Ward et al. 2005; Johnson et al. 2003; Thom et al. 2003; Nelson 1997). In the 2003 SVMP sampling period, mild El Niño conditions gave way to neutral conditions (Figure 1-2). There were mild El Niño conditions throughout the 2004 sampling period.

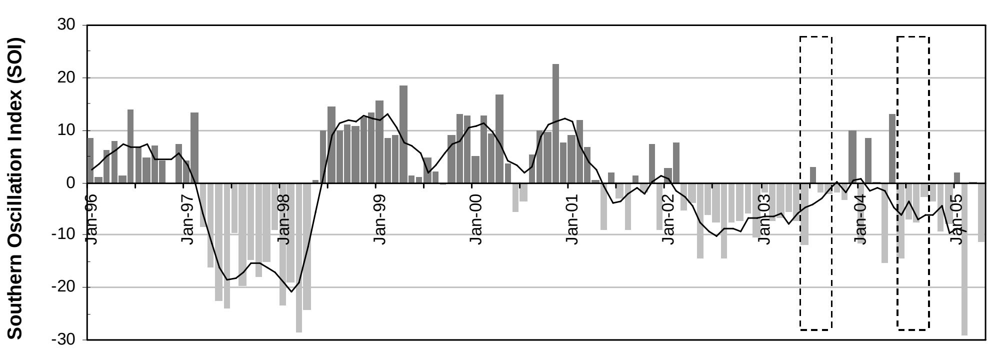

Figure 1-2. The monthly southern oscillation index (SOI) from January 1996 to April 2005. Negative values indicate El Niño conditions and positive values indicate La Niña conditions in the tropical Pacific Ocean. The black curve represents the 5-month running average SOI. The two boxes with dashed outlines indicate the two sampling periods that are the focus of this report. Data from the Australian Weather Bureau, http://www.bom.gov.au/climate/current/soi2.shtml (May 2005).

The Pacific Decadal Oscillation (PDO) may be more strongly related to conditions in the Pacific Northwest than the El Niño-Southern Oscillation (Hare and Mantua 2000). Recent speculation that a regime shift in 1990 or 1999 is reflected in the PDO record can be confirmed only when additional data becomes available (Rodionov 2004; Hare and Mantua 2000). This speculation, however, reflects the ambiguous PDO signal in the recent data record (Figure 1-3).

The magnitude of freshwater inputs to greater Puget Sound may directly affect *Z. marina* abundance through modification of water clarity and salinity. There may be additional indirect effects. Newton et al. (2003) have shown that persistent drought conditions can have profound effects on the Puget Sound marine system including perturbations to stratification in the water column, circulation as well as planktonic primary productivity.

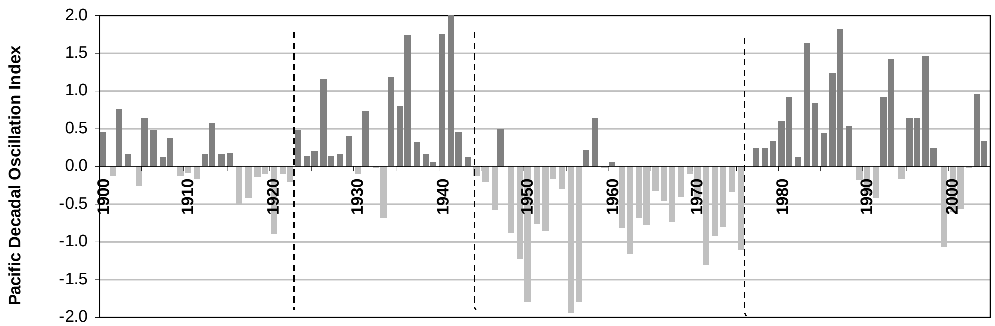

Figure 1-3. The annual Pacific Decadal Oscillation (PDO) from 1900 to 2004. The dashed lines indicate recognized regime shifts. Data from the University of Washington, http://jisao.washington.edu/pdo/PDO.latest (May 2005).

The discharge in the Fraser, Skagit and Puyallup rivers was below the long-term average in the 2003 sampling period but this followed above average flows in the preceding spring for the Skagit and Puyallup rivers. In the 2004 sampling period the discharge in all three rivers transitioned from below average to above. For the Fraser, the below average discharge in the 2004 sampling period was fairly severe. In contrast, the discharge in the Skokomish River was fairly close to the long-term mean for both the 2003 and 2004 SVMP sampling periods (Figure 1-4).

In summary, the climate indices and stream flow data do not indicate conditions markedly different from the long-term means, except perhaps for the anomalously low flows in the Fraser River in 2004. Therefore we would not anticipate an obvious climate-induced response in *Z. marina* abundance over the study area in this reporting period.

1.3 Developments in 2003-2004

This section briefly summarizes developments in several Puget Sound activities that are relevant to the SVMP and then summarizes key programmatic developments within the SVMP during 2003-2004.

The SVMP has developed linkages with a number of activities in the Puget Sound region. This helps us to increase the visibility and usage of our monitoring products and to influence strategic initiatives that are relevant to SVMP monitoring and more generally to *Z. marina* management issues.

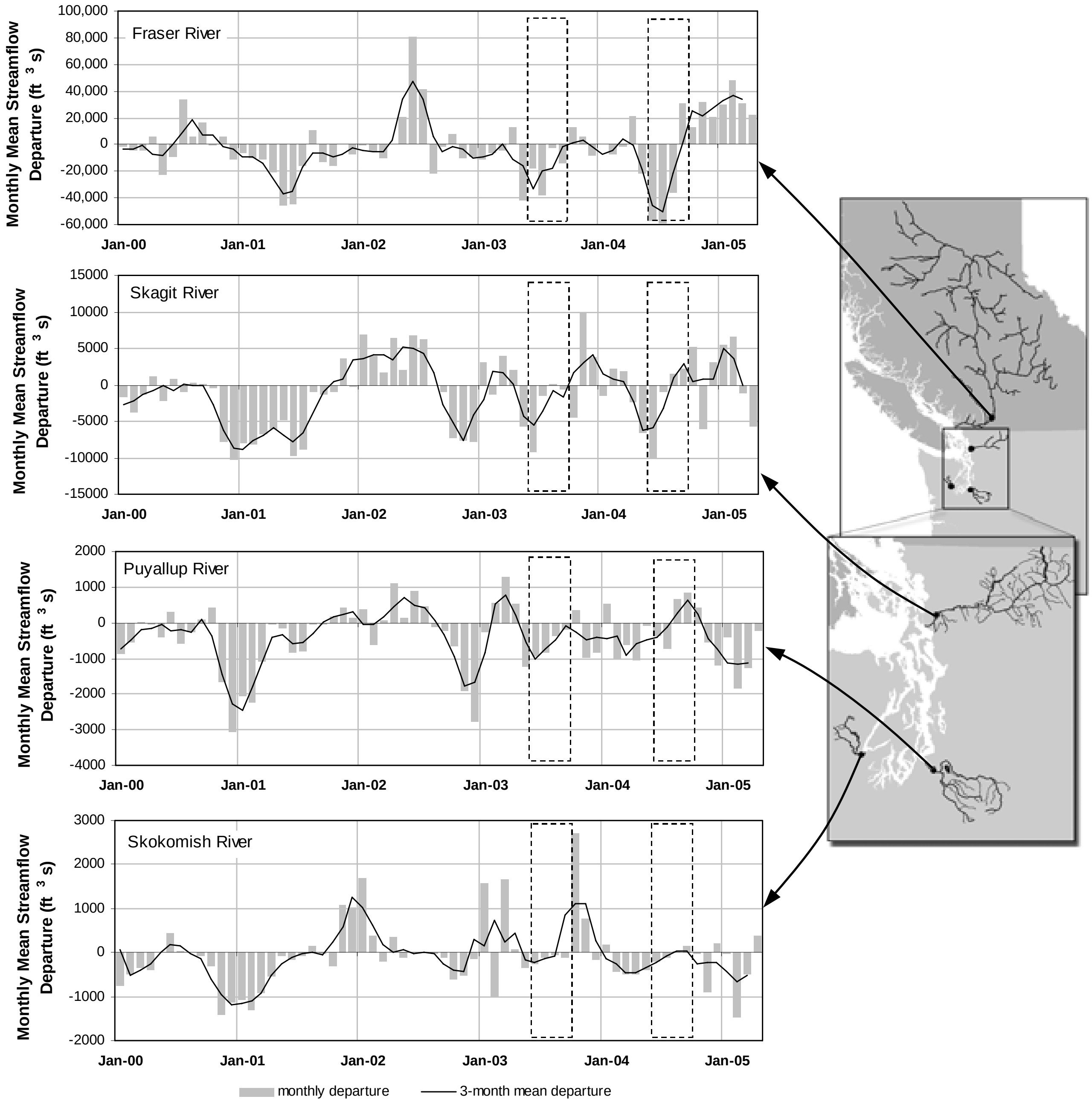

Figure 1-4. Mean monthly streamflow departures from long-term means at four major rivers: Fraser River at Hope (station 08ME005), Skagit River near Mt. Vernon (station 12000500), Skokomish River (station 12000500) and the Puyallup River at Puyallup (station 12005500). The boxes with dashed outlines indicate the two sampling periods that are the focus of this report. Based on data downloaded from the USGS at http://www.usgs.gov/nwis for the U.S. stations and Water Survey Canada at http:www.wsc.ec.gc.ca for the Canadian station, May 2005.

One of the most concerning recent patterns seen in *Z. marina* abundance within greater Puget Sound is the total loss or sharp decline in a number of embayments in the San Juan archipelago. Mounting evidence for these declines from SVMP data, herring spawn surveys by the Washington Department of Fish and Wildlife and other observations led to a workshop in 2003 to assess available information on the situation and identify potential actions (Wyllie-Echiverria et al. 2003). SVMP staff presented our monitoring results at this workshop and collaborated with the University of Washington on subsequent efforts to fully document the declines (Wyllie-Echeverria et al. 2005a, 2005b; Reeves et al. 2005). To further understand the causes of these declines and to explore restoration options, the SVMP is collaborating with the FRIENDS of the San Juans and the University of Washington on a project funded in 2004 by the state Salmon Recovery Funding Board.

Also during 2003-2004, the periodic low dissolved oxygen conditions in Hood Canal appeared to worsen and this received considerable scientific and political attention. The Select Committee on Hood Canal was formed in the state House of Representatives solely to address relevant issues affecting Hood Canal. SVMP staff presented preliminary SVMP results from this report to the committee in February, 2005. The overall effect of *Z. marina* on the Hood Canal oxygen budget is not well understood but it clearly plays a role directly through oxygen generation and indirectly through nutrient uptake and decomposition of *Z. marina* detritus.

In addition, there is evidence that low dissolved oxygen conditions in Hood Canal may stress *Z. marina* and ultimately lead to a decline in abundance. SVMP staff collaborated with the University of Washington to compile this evidence (Glaub et al. 2005).

In 2001, the state legislature created the Washington Comprehensive Monitoring Strategy (Substitute Senate Bill 5637) and directed state agencies to develop a broad strategic approach to state monitoring with regard to watershed health and salmon recovery. Commissioner Sutherland represented DNR on the Monitoring Oversight Committee created by this legislation and SVMP staff participated directly in the development of the Comprehensive Strategy report that was completed in December 2002. This report highlighted the SVMP as a key element both of existing nearshore monitoring and of proposed future monitoring options (Interagency Committee for Outdoor Recreation 2002a, pp.198-201). The associated Action Plan listed SVMP monitoring as an essential current monitoring activity (Interagency Committee for Outdoor Recreation 2002b, p.33).

In 2004, to complement the Comprehensive Monitoring Strategy, Governor Locke created the Governor's Forum on Monitoring Salmon Recovery and Watershed Health. DNR is represented in the Governor's Forum and SVMP staff participate in a Forum subcommittee focusing on nearshore marine issues.

Another development during this reporting period has been the work on the nearshore component of a Puget Sound salmon recovery plan. The final plan will ultimately be submitted to the federal services to meet legal obligations under the Endangered Species Act associated with the 1999 listing of Chinook, Hood Canal summer chum and bull trout within the SVMP study area. The Shared Strategy for Puget Sound is coordinating production of the overall recovery plan and the Puget Sound Action Team led the effort on the nearshore component. DNR and, in particular, SVMP staff served as reviewers during the drafting of the nearshore component.

In addition, there were several specific programmatic developments within the SVMP during 2003-2004. The key developments are discussed briefly in the following sections.

1.3.1 External Project Review

We conducted an external project review of the SVMP in 2003. The primary goal was to gain an external critique to help evaluate the overall effectiveness of the SVMP and to make recommendations for methodological and programmatic improvements. This review synthesized and articulated expert opinion from independent specialists. The general findings were that our approach, parameters measured, and rigorous statistical foundation were appropriate. The reviewers made a fundamental recommendation that we direct a portion of our effort to characterize the relationship between *Z. marina* status and trends and the key controlling factors or stressors. They also recommended that we explore ways to improve our ability to detect changes at a region and site scales. The reviewers also prioritized several specific methodological improvements. The final report of the project review contains further details (Sewell et al. in prep.).

1.3.2 Assessment of Sampling and Analysis Methods

We directed considerable effort in 2003-2004 to use data from the first three years of our monitoring to quantitatively assess the performance of our sampling design and analysis methods (Dowty 2005a). This effort led to several refinements to the study design to improve overall effectiveness. It also validated many assumptions made in the initial study design, which was completed before any sample data was available for testing. The final report also prioritized questions for further study. Subsequent work that addressed some of these priorities is described in this 2003-2004 monitoring report

1.3.3 Consistency of Video Post-Processing

We conducted a study with three video processors and test video selected to depict a range of *Z. marina* and macroalgae densities and water clarity conditions. We used the results to quantify consistency of the video post-processing, our fundamental method of data collection (Reeves et al. in prep.). We found a moderate level of overall discrepancies between processors (<10%) but found some evidence for systematic errors that are not considered in our analysis. We also found that consistency decreased sharply in sparse or highly patchy *Z. marina* areas. We will use these findings to refine our training for video processors.

1.3.4 Re-processing of 2002 Videography at Two Sites

In our previous monitoring report (Berry et al. 2003), we identified species discrimination between *Zostera japonica* and *Zostera marina* to be a methodological concern. To better understand this issue, we evaluated the abundance, distribution and physical appearance of *Z. japonica* at sites where it occurred using field data and videotape images. We re-analyzed the 2002 videography to improve our species identification and between year classification consistency. This report includes the revised estimates, which supersede the earlier results (Berry et al. 2003).

1.3.5 Water Quality Analysis

As part of the regular sampling procedures at each site for 2000 through 2003, water quality measurements were taken at each site at the time of sampling. These data had been archived and were first analyzed in 2004. We selected a subset of sites to analyze and to examine for spatial patterns and correlations between variables. The results of this effort are described in this monitoring report.

1.3.6 Intensive Site Study

In the 2005-2007 biennial state budget, finalized in the spring of 2005, the legislature directed funds to the SVMP to initiate intensive site studies. These funds were requested largely in response to the feedback received as part of the project review (section 1.3.1) with the objective of characterizing key stressors on *Z. marina* and the nature of the response to these stressors. This work will begin later in 2005.

2 Methods

This chapter emphasizes changes in methods made in this reporting period and only briefly summarizes methods that have been described previously (Berry et al. 2003).

2.1 Methodological Changes in 2003-2004

This section highlights four fundamental changes made to the monitoring design in 2003 or 2004. Additional minor changes are discussed later in sections 2.2 through 2.6.

2.1.1 Focus Area Sampling

In response to limitations in the existing regional scale analysis (Berry et al. 2003, pp.22-23) as well as recommendations that emerged during the project review (Sewell et al. in prep.), we requested additional resources to improve our results at the regional scale with more intensive sampling. The legislature approved a budget enhancement in the 2004 supplemental budget, which allowed for additional sampling starting in the 2004 field season.

We refer to this additional sampling as focus area sampling and have selected a design that involves intensive sampling in one region each sampling season. We use the term focus area rather than region to denote our option of focusing this effort on a subset of a given region, rather than the entire region. The rationale for this decision is two-fold: (a) some regions are too large to allow for robust region-wide estimates given the level of additional funding available; (b) within some regions, a sub-area may be a particular interest because of localized stressors or localized patterns of decline detected in the sound-wide sampling or in other independent observations.

One focus area will be sampled each field season and we will rotate through the five regions. This results in a five-year return period for a particular region. The objectives are to produce estimates of *Z. marina* status for the designated focus area as well as robust change estimates at five-year intervals.

The focus area sampling will likely rely on the use of fixed sites and a paired-site analysis, rather than a rotational design, but this element of the design can be finalized later with the benefit of a comparative power analysis based on the initial data.

2.1.2 Termination of Plant Characteristics Sampling

Berry et al. (2003, pp.48-50) showed that the level of effort required to obtain useful status and trend information for plant characteristics (shoot density, leaf width, leaf length) at each site was beyond the scope of the project at this time. Berry et al. (2003, p.50) recommended that this component of the original monitoring design be discontinued.

Following the 2002 field season, this component of data collection was eliminated.

2.1.3 Termination of Water Quality Sampling

In this reporting period we analyzed the water quality data that had been collected and archived from the 2000-2003 sampling seasons. The methods for this analysis are described in section 2.6.5, p.24. Based on the results of this analysis and more generally on the limitations of annual water quality data collected at one profile per site at different times within a three-month window (June – August), we decided to eliminate this component of data collection following the 2003 field season.

2.1.4 Changes to Flats Sampling Frame and Stratification

As mentioned earlier (section 1.3.2, p.9), Dowty (2005a) recommended refinements to the sound-wide sampling design. Changes to the flats sampling frame and stratification were recommended and first implemented in the 2004 sampling season. Four changes were made to the subdivision of large embayments into discrete sampling sites that resulted in a net decrease of one in the number of flat sites. This constituted a change to the flats sampling frame that was feasible because the sites involved had not yet been sampled. The purpose of this change was to make all subdivision of large embayments conform to systematic rules.

More importantly, Dowty (2005a) recommended changing the stratification of the flats sampling frame in order to improve precision in initial estimates of *Z. marina* status. This change involved removing three anomalous flats from the main flats stratum (flats11, flats12 and flats20) and placing them in a new stratum, which would be completely surveyed each year. For clarity, the residual main flats stratum was labeled the 'rotational' flats stratum and will still subject to rotational sampling. The new stratum was labeled the 'persistent' flats stratum and will be subject to a complete survey (of the three sites) each year. There was no change to the flat sites placed in the core stratum.

These changes were implemented in the 2004 sampling season.

2.2 Sound-Wide Sampling Design

This section summarizes the sampling design for the sound-wide sampling that is more fully described in Berry et al. (2003), and in Skalski (2003) therein, except for specific changes noted below.

2.2.1 Study Area

The study area coincides with our sound-wide scale. It includes all of greater Puget Sound, which includes the Straits of Juan de Fuca, southern Georgia Strait, the San Juan Archipelago, Saratoga/Whidbey basin, Hood Canal as well as Puget Sound proper. The extreme reaches of southern Puget Sound are excluded from the study area because *Z. marina* has not been observed there (Berry et al. 2003).

2.2.2 Stratification and Sampling Frames

Sound-Wide

All potential *Z. marina* habitat within the study area was delineated within the two categories of flats and fringe based on geomorphic criteria (see Berry et al. 2003 for additional details)

Sampling frames were created separately for the flat and fringe habitat and each site was assigned a unique code. The fringe sites were stratified into narrow fringe, wide fringe and core strata as described by Berry et al. (2003). In 2003, the flat sites were stratified into the flats and core strata as described by Berry et al. (2003) for the earlier sample years. However, in 2004, the flats stratification was changed as described in section 2.1.4 (p.12), resulting in rotational flats, persistent flats and core strata. The details of the frames and strata are summarized in Table 2-1.

geomorphic category	sampling frame	no. sites in frame	stratum	no. sites in stratum
fringe	fringe	2370	core	2
			narrow fringe	2018
			wide fringe	350
flats	original flats frame (2000-03)	71	core	4
			flats	67
	revised flats frame (2004 forward)	70	core	4
			persistent flats	3
			rotational flats	63

Table 2-1. Summary of sampling frames, strata and numbers of sites including the changes to the flats stratification in 2004.

Regional

The regional analysis uses a post-hoc regional stratification of the sound-wide data and therefore relies on the same underlying sampling frames. Simply dividing the sound-wide strata spatially using the SVMP regions (Figure 1-1) is problematic because of the resultant low sample size and in some cases incomplete representation of strata within a region. As described in Berry et al. (2003), the regional analysis relies on collapsing the sound-wide strata into only two regional flats and fringe strata in order to increase sample size within each stratum.

The 2004 data were treated similarly in that the rotational flats, persistent flats and core stratum flats sites were collapsed into one regional flats′ stratum. The regional fringe′ stratum in 2004 was identical to 2003 and earlier years.

For all fringe sites, except two in the core stratum, we use a prefix to identify the associated region. These prefixes are given in Table 2-2. For core sites and flat sites, the region is not indicated with a prefix. The regions associated with these sites are given in Table 2-3.

prefix	region
cps	Central Puget Sound
hdc	Hood Canal
nps	North Puget Sound
sjs	San Juan Islands – Straits of Juan de Fuca
swh	Saratoga-Whidbey Basin

Table 2-2. Prefixes for each SVMP region. These prefixes are used in site codes to identify the region for fringe sites.

site code	site name	region
core001	Padilla Bay	nps
core002	Picnic Cove	sjs
core003	Jamestown	sjs
core004	Lynch Cove	hdc
core005	Dumas Bay	cps
core006	Burley Spit	cps
flats08	Portage Bay North	nps
flats10	Nooksack Delta East	nps
flats11	Samish Bay North	nps
flats12	Samish Bay South	nps
flats18	Similk Bay	swh
flats19	Pull and Be Damned Point	swh
flats20	Skagit Bay North	swh
flats35	Nisqually Delta East	cps
flats37	Wing Point	cps
flats41	Dosewallips	hdc
flats43	Dabob Bay	hdc
flats62	Swifts Bay, Lopez Island	sjs
flats70	S. Fork Skagit River	swh

Table 2-3. The regions associated with core sites and flat sites sampled in 2003 and 2004.

2.2.3 Rotational Design and Site Selection

Site selection for each field season follows a rotational design in the narrow fringe, wide fringe, flats (2003) and rotational flats (2004) strata. For these strata, 80% of the randomly selected sites from the previous season are retained and 20% are replaced with new randomly selected sites (Berry et al. 2003). Dowty (2005a) explores the specific considerations in the selection of the rate of site rotation.

The core stratum and the 2004 persistent flats stratum are completely surveyed each year and are therefore not subject to sampling or rotation.

In general, for each field season the sample of sites within each stratum subject to rotation is determined in two steps. First, 20% of sites from the previous year that have been sampled for at least five years are randomly selected for removal (the five-year criterion was ignored, by necessity, in the first years of monitoring). Second, an equal number of sites are randomly selected from eligible sites in the stratum for addition to the sample. Eligible sites are those that (a) are not currently in the sample and (b) have not been previously sampled. The latter criteria for eligible sites will be dropped for each stratum once we have rotated through all sites in the stratum. As described in Berry et al. (2003), random selection from the eligible pool may be repeated if a given sample does not satisfy requirements for balanced representation of the regions.

The specific sites sampled in 2003 and 2004 are shown in Figure 2-1.

2.3 Focus Area Sampling Design: 2004 San Juan Co.-Cypress Is. Focus Area

We selected the San Juan – Straits region to initiate our new focus area sampling in 2004 (see section 2.1.1, p.11). Given the large size of this SVMP region and the local nature of observed declines (Wyllie-Echeverria et al. 2003), a subset of the region was delineated that included San Juan County and Cypress Island in Skagit County (Figure 2-2, p.19).

2.3.1 Stratification and Site Selection

The FRIENDS of the San Juans led an effort that surveyed San Juan County for *Z. marina* in 2003 and they generously made a preliminary summary of their results available to the SVMP (FRIENDS of the San Juans 2004). The 2003 data allowed us to devise a more discriminating stratification providing the potential to improve the precision in our focus area results.

The focus area was sampled using the following four strata:

1. flats-absent: *Z. marina* thought to be absent.
2. flats-other: all remaining flats.
3. fringe-absent: *Z. marina* thought to be absent.
4. fringe-other: *Z. marina* thought to be present or presence was unknown.

For the two fringe strata, no distinction was made between wide fringe and narrow fringe sites, i.e. they were combined into one group before being stratified into fringe-absent and fringe-other. The total population of wide fringe sites within the focus area represents only 4% of all fringe sites (19 of 502).

This decision to pool narrow and wide fringe was based on a consideration of the tradeoffs between diluting sample size in multiple strata vs. the possibility of losing precision by pooling disparate sites in the same stratum. It was decided not to divert effort to sample such a minor component of the overall fringe site population.

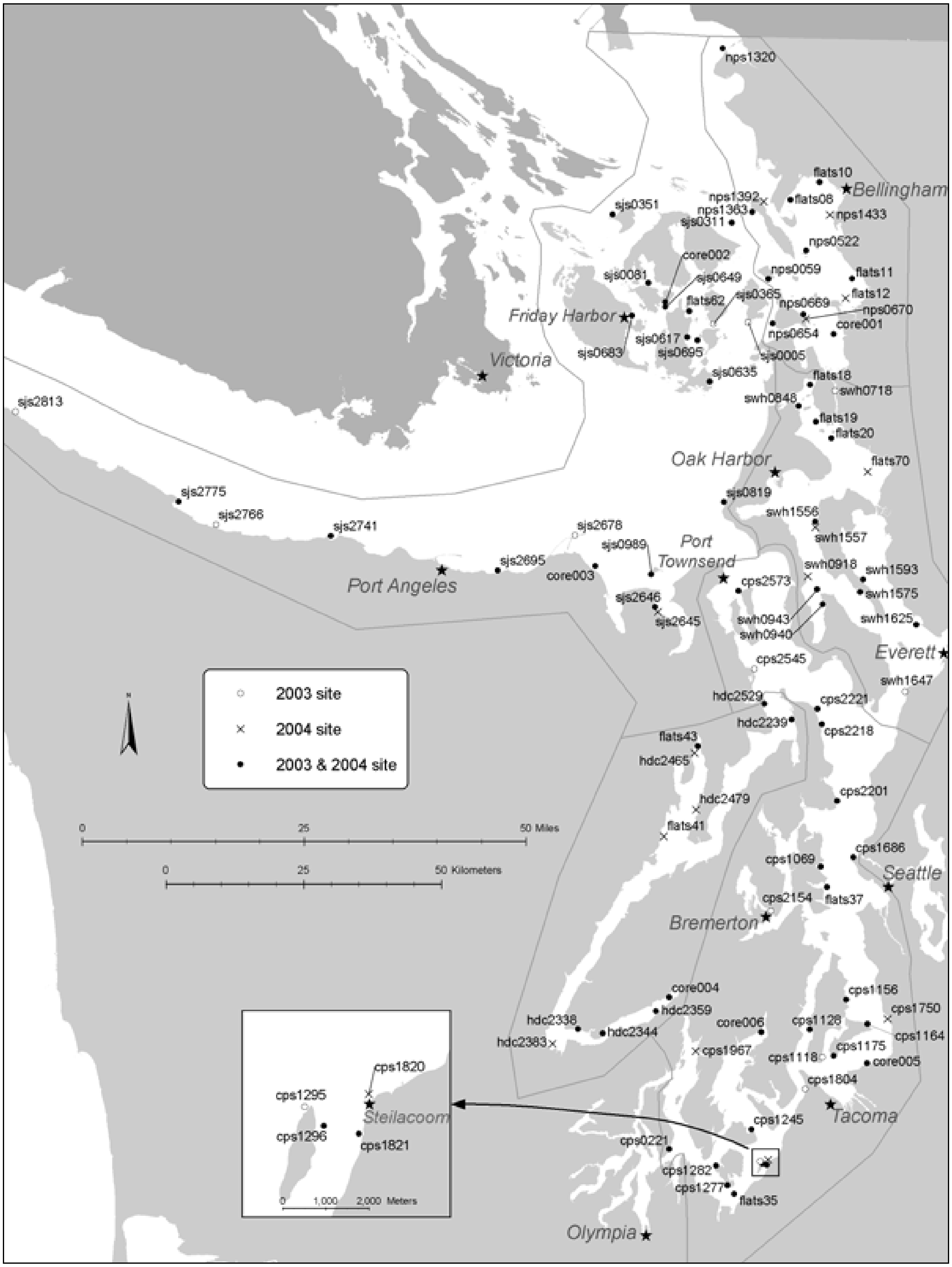

Figure 2-1. Sites sampled in 2003 and 2004 as part of the sound-wide study.

Details of the placement of sites within these strata are given below.

Flats-Absent Stratum

Recent independent observations indicate that *Z. marina* was no longer present at Westcott Bay, flats53, by 2004 (e.g. Wyllie-Echeverria et al. 2003). This site was then placed in its own stratum and is the only site in the flats-absent stratum. These independent observations were considered valid data for the purposes of the focus area analysis and therefore measurement of *Z. marina* at flats53 was deemed not necessary as part of this study.

Flats-Other Stratum

There are 20 sites in the SVMP flats sampling frame that fall within the boundary of the focus area. Since one of these (flats53) was placed in a separate stratum, there are 19 sites in the flats-other stratum.

Of these, two sites were already part of the 2004 sample for the ongoing sound-wide study (core002 and flats62). Since data from these sites would be available for the focus area analysis, these two sites were removed from the pool of sites eligible for random site selection. This left 17 sites eligible for random selection in this stratum.

Fringe-Absent Stratum

There are 502 total fringe sites within the focus area. Sites that belonged in the fringe-other stratum were identified (described below, 378 sites) and set aside. The remaining 124 sites were assigned to the fringe-absent stratum.

Fringe-Other Stratum

SVMP sites where *Z. marina* had been observed in the FRIENDS of the San Juans (FOSJ) dataset were placed in the fringe-other stratum. Sites where the SVMP had observed *Z. marina* in previous years were also added to the stratum (this information had been shared with FOSJ and these sites were excluded from their study). Finally, the 27 fringe sites on Cypress Island, which was outside the scope of the FOSJ study, were added to stratum. The *Z. marina* status of these latter sites was unknown.

This resulted in 378 sites in the fringe-other stratum which included sites where *Z. marina* was known to be present and sites with unknown status.

Site Selection

The allocation of effort between the strata was determined and the respective numbers of sites were randomly selected from each stratum pool of eligible sites. Low effort was allocated to the fringe-absent stratum (3 sites) since these were presumed not to have any *Z. marina*. The effort allocated to flats-other (8 sites) and fringe-other (17 sites) was roughly equivalent under the assumption that the effort to sample a flat site is twice what is required for a fringe site.

Since sites sampled as part of the sound-wide sampling were randomly selected, data from those that fell within the focus area boundary could be used in the focus area analysis (core002 was also included although it was not randomly selected). Seven fringe sites that were sampled as part of the sound-wide study fell within the focus area and each of these had been sampled in previous years. One of these did not previously have *Z. marina* and was therefore placed in the fringe-absent stratum (sjs0695). The other six previously had *Z. marina* and these were been placed in the fringe-other stratum.

Also, one site that we randomly selected to be sampled in the fringe-other stratum had also been selected as part of the sound-wide sampling. Data from this site (sjs0311) was used in calculating both sound-wide and focus area results.

A summary of the strata, the sampling effort and the use of data from the sound-wide sampling is shown in Table 2-4.

Figure 2-2 shows the locations of sites sampled in the focus area effort.

stratum	sites sampled in focus area effort	other sites (data used in analysis)	overall sampling rate (sites used / sites in stratum)
flats-absent	0	1	100% (1/1)
flats-other	8	2	53% (10/19)
fringe-absent	3	1	3% (4/124)
fringe-other	17	6	6% (23/378)

Table 2-4. Summary of total number of sites per focus area stratum and sample sizes. We supplemented data from the focus area study with data from additional sites that included one flat site known to have no *Z. marina* from independent observations (flats53), two flat sites with *Z. marina* present (core002 and flats62) that were sampled in the sound-wide study, one fringe site that has no *Z. marina* that was sampled in the sound-wide study (sjs0695) and six fringe sites with *Z. marina* present that were sampled in the sound-wide study.

2.4 King County Pilot Effort in Quartermaster Harbor

In 2004, the SVMP partnered with the King County Department of Natural Resources and Parks, Water and Land Resources Division to sample four sites within Quartermaster Harbor. This was a small pilot effort to introduce King County to the SVMP methodology and to assess the potential of a *Z. marina* environmental indicator for the county. Reeves (2005) provides additional detail on this effort. These sites were not randomly selected and the results were not included in the regional or sound-wide estimates. The locations of the three fringe sites and one flat site are shown in Figure 2-3.

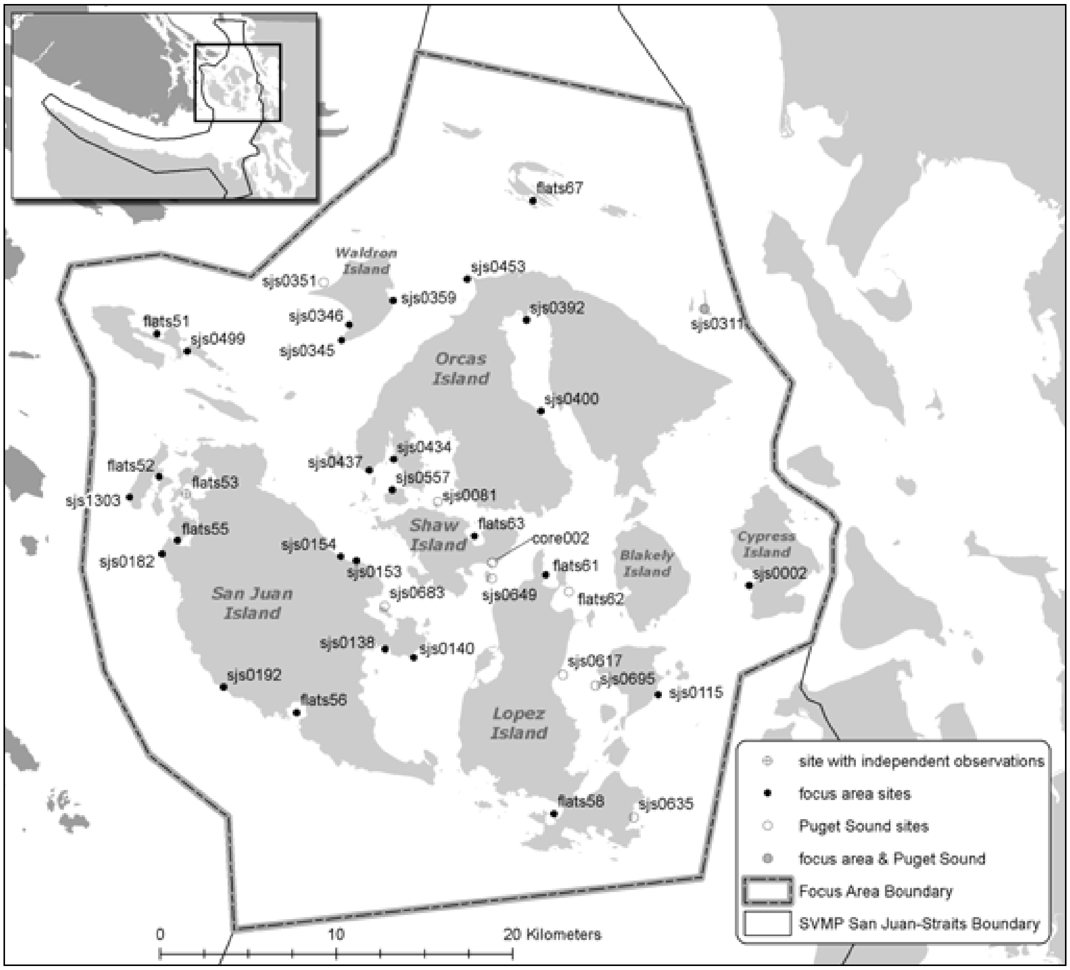

Figure 2-2. Sites sampled in the 2004 San Juan Co. – Cypress Is. focus area study. The inset map shows the extent of the main map relative to the SVMP San Juan – Straits region.

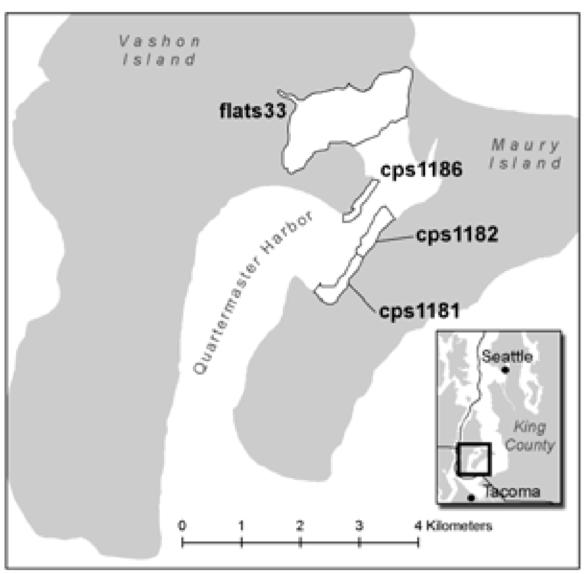

Figure 2-3. Sites sampled in Quartermaster Harbor as part of pilot effort with the King County Department of Natural Resources.

2.5 Site Sampling

For each site selected for measurement, underwater videography (Norris et al. 1997) was used to sample random transects in a modified line-intercept technique. We perform sampling between June and September. Further details on site sampling methods are given in Berry et al. (2003). A brief description of the general methods is given below followed by a description of changes implemented in 2003 and 2004. Unless otherwise noted, the instrumentation used and methodology follow Berry et al. (2003).

Site sampling is restricted to a sample area, referred to as the sampling polygon, that represents the area of *Z. marina* presence within the boundaries of a site. This sampling polygon is delineated before sampling begins based on reconnaissance and any available data from previous years. The random transects generally follow the depth gradient and extend beyond the shallow and deep edges of the sampling polygon.

The nominal resolution of the sampling is one square meter, i.e. every square meter sampled is categorized as having *Z. marina* present or absent based on the evidence of shoots rooted within the video image. Neither shoot density or percent cover is quantified.

Our general target is to sample 11 random transects at a site, but this number varies in practice depending on the precision of previous estimates sampled at this level of effort at the site and on available time that may be limited by tides and scheduling.

The fractional cover of *Z. marina* on the transects is used to calculate site *Z. marina* area. The maximum and minimum depths of *Z. marina* presence on the transects is used to estimate mean maximum and mean minimum depth of *Z. marina* at each site.

2.5.1 Methodological Changes

- In 2003 our contractor for field operations, Marine Resources Consultants, upgraded video equipment to improve image clarity. The previous SeaCam 2000 camera was replaced with the SuperSeaCam, which improved light sensitivity, by a factor of fifteen.
- In 2003 we enhanced our field preparation effort by producing a packet of information that included site-specific maps and summaries of previous data.
- In 2004, we introduced DVD as a medium for recording video. We started using 8mm tape as primary medium, DVD as secondary medium and VHS as tertiary medium.
- In 2004, we sampled several sites from a 17’ aluminum work skiff. These sites were either extremely shallow or very rocky. In previous years these sites would have been considered inaccessible and would not have been sampled. The data collection method at these sites varied from normal protocols. We used the BioSonics Inc. DT Series echosounder (Sabol et al. 2002) as the primary data collection instrument on the transects, with a drop-camera to verify species.

  Marine Resources Consultants processed the raw BioSonics data and provided *Z. marina* presence/absence results based on interpretation of the echogram in concert with the drop-camera observations. This method is based on the distinct signal produced by *Z. marina* in the BioSonics echogram (Sabol et al. 2002).

The sites listed in Table 2-5 were sampled with the skiff:

site code	site name
flats08	Portage Bay
flats51	Prevost Harbor
flats56	False Bay
flats67	Fossil Bay
nps0522	Eliza Island
sjs0140	Pear Point
sjs0192	Edwards Reef
sjs0359	South of Mail Bay
sjs0453	Point Doughty

Table 2-5. Sites sampled in 2004 with the BioSonics echosounder from a 17' skiff.

- In 2004, we increased sampling intensity at selected sites with the sole intention of improving the precision of estimates of mean maximum depth of *Z. marina*. We did this at sites where precision of previous data was sub-optimal but with potential for improvement with a modest increase in effort. Specifically, we flagged sites where the standard deviation of mean maximum depth was in the range s=0.7–0.8 m for additional effort. Sites where previous precision was very poor (s ≥ 9m) were not considered for increased effort because the level of additional effort needed would be prohibitive.

  We selected five random transects at sites designated for additional effort but sampled only the portion of the transects that spanned the deep edge boundary of the *Z. marina* bed (Figure 2-4). These transects did not span the entire sampling polygon and therefore did not contribute to estimates of site *Z. marina* area. Table 2-6 shows the sites where we increased sampling effort in 2004.

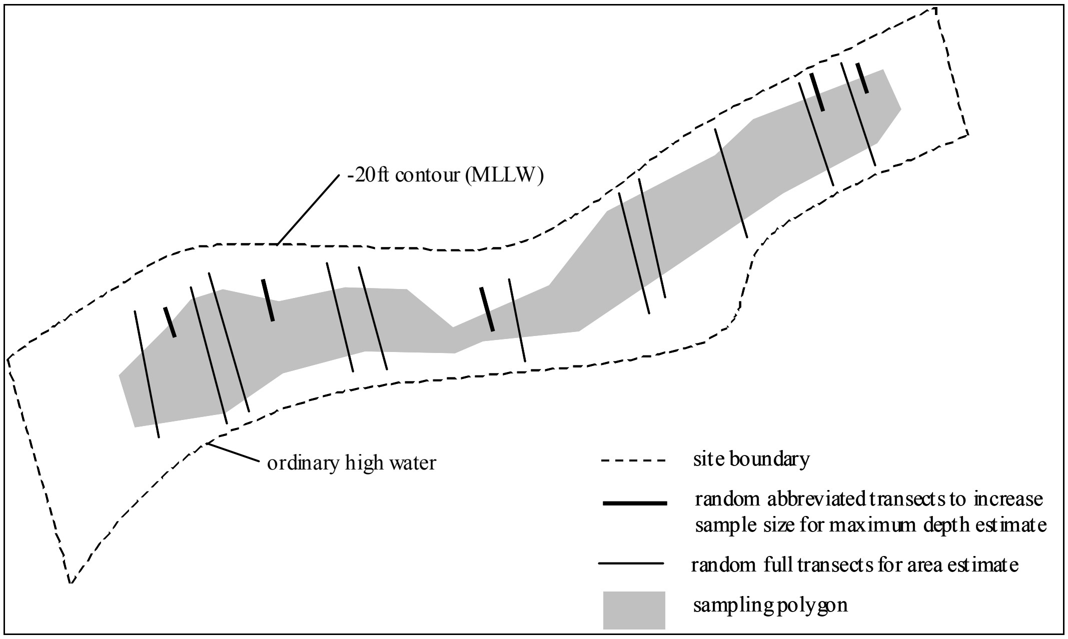

Figure 2-4. Example of the use of abbreviated random transects to improve the estimate of mean maximum depth of *Z. marina*.

site	mean maximum *Z. marina* depth observations in 2003 (m MLLW)	standard deviation (m)
cps1069	12	0.8
cps1164	13	0.7
cps1277	12	0.8
cps2201	11	0.7
hdc2239	11	0.8
hdc2338	19	0.7
nps0059	13	0.8
sjs0635	10	0.7
sjs2775	12	0.8
swh0943	11	0.7

Table 2-6. Sites targeted for increased sampling effort in 2004 to improve estimates of mean maximum depth of *Z. marina*, based on 2003 standard deviation estimates for this parameter.

2.6 Data Processing and Analysis

This section describes changes made to data processing and analysis procedures in 2003 and 2004. Berry et al. (2003) describe the fundamental procedures used.

2.6.1 Data Processing

We made several changes related to our video post-processing. A technician reviews all video from the random transects and classifies each second of video, according to *Z.*

marina presence or absence. Each second of video corresponds roughly to one meter of transect length depending on boat speed.

Starting in 2003, we performed all video processing with DNR technicians. In addition, these technicians participated in data collection on the boat. Previously, video processing had been contracted out. This change allowed the technicians to become familiar with the overall sampling procedures and limitations of the video. It also allowed them to interact closely with other DNR staff that performed field work and get assistance with interpretation of field notes and video collected by these other staff.

We have improved the quality of the video classification just by nature of the improved video camera used starting in 2003 and the improved quality of the video on 8mm tape and DVD (relative to VHS) that we started using in 2004.

In 2003 we also evaluated the training we provided to the technicians for classifying video and developed recommendations that were implemented in 2004. We also developed more explicit criteria for determining *Z. marina* presence in video in an attempt to make the processing more systematic. Wright (2004) describes both the training recommendations and the classification criteria.

2.6.2 *Z. marina* Depth Analysis

There was no change to the analysis procedures for depth parameters but for the estimation of mean maximum depth of *Z. marina*, additional data was available for selected sites in 2004 as noted earlier (Table 2-6). We tested mean minimum and maximum *Z. marina* bed depths at sites sampled in consecutive years for significant change using a *t*-test and two levels of significance (Dowty 2005, Appendix C).

2.6.3 *Z. marina* Area Analysis

There were no changes to the analysis for *Z. marina* area as part of the sound-wide study.

Since the focus area study was new in 2004, and a new stratification was used, the analysis deviated from that used previously in the Puget Sound study. Nevertheless, the fundamental approach to extrapolation within flats and fringe strata and the aggregating of strata still followed procedures described in Skalski (2003).

The parameters used for extrapolation within the fringe strata, i.e. total shoreline length within each stratum, had to be developed specifically for the focus area study. This is complicated by the presence of orphans. Orphans are sub-1000m segments that were unavoidable artifacts formed in the creation of the fringe sampling frame. These are a small percentage of the total stratum shoreline length but have a measurable effect on estimates. In the Puget Sound analysis, orphans contribute to the extrapolation of the narrow or wide fringe stratum depending on the habitat width in each orphan. In the focus area study, where stratification was based on previous observations of *Z. marina* presence, the appropriate stratum could not be easily ascertained. For simplicity, all orphans were assigned to the fringe-other extrapolation parameter. The extrapolation values are shown in Table 2-7.

stratum	number of sites	total fringe length (includes orphans) (m)
fringe-absent	124	124,000
fringe-other	378	397,975
total (all fringe)	502	521,975

Table 2-7. Extrapolation parameters (total fringe length) used in the focus area analysis.

As mentioned earlier (section 2.3.1, p.17), sites sampled as part of the Puget Sound study that fell within the focus area boundary were included in the focus area analysis to increase sample size. All sites included in the focus area analysis area listed in Appendix L.

2.6.4 *Z. marina* Change Analysis

At the sound-wide scale, we used a Monte Carlo analysis to produce more reliable estimates of precision for the year-to-year change results. These estimates of precision, including error bars, replace those based on the original SVMP estimators described by Skalski (2003, p.24). Details of the Monte Carlo analysis are described in a separate report (Dowty 2005b).

The Monte Carlo simulations showed that actual confidence intervals at the sound-wide scale can be more than two times larger than intervals estimated with the sound-wide estimator (Dowty 2005b). We have not yet completed Monte Carlo simulations for the estimates of regional change in *Z. marina* area and therefore continue to apply the original sound-wide SVMP estimators (Skalski 2003, p.24) to the regional scale. For this reason, as well as the generally low sample sizes used for regional estimates, the regional confidence intervals presented in this results section are not as reliable as those presented elsewhere in this report and should be interpreted with caution.

Two different methods were used to assess change in *Z. marina* area at the site level, but these methods were not all applied to the same sites. For all sites sampled in two consecutive years, either 2002-03 or 2003-04, we calculated the relative change in area and tested for significance as we did previously (Berry et al. 2003). At sites sampled for five consecutive years, we performed a five-year trend analysis. The technique was identical to that designed for application at the sound-wide scale (Skalski 2003, p.26).

We did not execute change analysis as part of the San Juan County-Cypress Island focus area study in 2004 because 2004 was only the first year of data collection for this study. However, we did initiate a multi-parameter assessment of site level-change and sites within the focus area were included in this analysis.

2.6.5 2000-2003 Water Quality Analysis

We calculated attenuation coefficients (K_d) for a subset of archived water quality data collected between 2000 and 2003 (Berry et al. 2003). We also examined spatial and temporal trends in surface and bottom temperature and tested for correlations between maximum *Z. marina* depth and the calculated light attenuation coefficients. For this analysis we chose two fringe and two flats sites for each region (Table 2-8), calculated K_d for vertical transects sampled within 2 hours of solar noon (Zimmerman et al. 1991; Carruthers et al. 2001) and compared these values to the maximum depth of *Z. marina* growth at each site (Zimmerman et al. 1991). We divided our San Juan-Straits region into two sub-regions for this analysis.

region	flat	fringe
Central Puget Sound (cps)	flats28, flats35	cps1118, core005, core006
Hood Canal (hdc)	flats43, core004	hdc2529, hdc2338
North Puget Sound (nps)	core001, flats10	nps1363, nps0059
San Juan–Straits (sjs) San Juan Is. sub-region	core002, flats62	sjs0081, sjs0351
San Juan–Straits (sjs) Strait of Juan de Fuca sub-region	core003	sjs2814, sjs2646
Saratoga-Whidbey (swh)	flats28, flats18	swh1593, swh1556

Table 2-8. Sites selected for water quality data analysis, by region and stratum.

3 Results

3.1 Field Effort Summary

Table 3-1 summarizes our overall sampling effort over the first five years of SVMP sampling. In 2003, we sampled 76 sites throughout the study area. In 2004 we had a sharp rise in the number of sites (110) because of the addition of the focus area study.

The average number of random transects per site in 2003 was 15 and ranged from 4 (sjs0649, Canoe Island) to 30 (flats62, Swifts Bay). In 2004, the average number of random transects per site was 14 and ranged from 4 (cps1820, Gordon Point and sjs0649, Canoe Island) to 25 (flats18, Similk Bay). Previously we surveyed an average of 12 random transects per site in 2000 and 2002, and an average of 13 transects in 2001.

In 2003 we conducted all sampling in just two months, July and August, due to scheduling constraints. Once site was an exception, sjs0989-Protection Island, which was sampled on September 26, 2003 after coordinating with the US Fish & Wildlife Service to avoid disturbing nesting rhinoceros auklets. In 2004, sampling extended from June 21 to September 30.

year	field season months	number of sites visited	number sampled	sites not sampled due to obstructions	sites without eelgrass	number of sampling days
2000	July – October	66	61	5	13	46
2001	July – October	77	74	3	15	54
2002	June - September	76	73	3	14	54
2003	July and August	76	76	0	12	50
2004	June – September	110	110	0	12	72

Table 3-1. Summary of sampling effort for 2000-2004.

3.2 Status of *Z. marina*

This section presents results on the status of *Z. marina* area at the sound-wide scale and within the focus area. At the regional scale we summarize the depth limits of *Z. marina* but we do not report separate *Z. marina* area estimates because of limited sample size within the regional strata. The estimates of area at individual sites are listed in Appendix A and in Appendix B for the 2003 and 2004 results of the Puget Sound study respectively and in Appendix C for the 2004 focus area results. Area results for the Quartermaster Harbor sites are listed in Appendix I. Site-level depth results are presented in Appendix F (2003),Appendix G (2004), Appendix H (focus area) and Appendix I (Quartermaster Harbor).

3.2.1 Puget Sound *Z. marina* Area

We estimate that the total *Z. marina* area in the Puget Sound study area is approximately 20,000 ha (49,000 acres). More specifically, our most recent estimate based on 2004 data is 21,140 ± 3,010 ha (52,240 ± 7,740 acres). We consider this our most reliable estimate as it is based on the revised stratification introduced in 2004. The sound-wide status results are discussed more comprehensively in Appendix M.

We estimate that the total *Z. marina* area in the study area is split roughly equally between the flats and fringe geomorphic categories (Figure 3-1). The distribution along the shoreline is highly aggregated in a few large sites. Figure 3-2 shows that just a few sites hold a large proportion of the *Z. marina* area within the sites sampled and within the study area as a whole. Padilla Bay, core001, and Samish Bay, flats11 and 12, contain by far the largest concentrations of *Z. marina*, together representing more than a quarter (27%) of *Z. marina* in the study area.

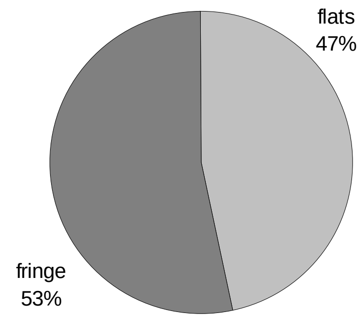

Figure 3-1. Distribution of *Z. marina* area among the two geomorphic categories used by the SVMP. Based on 2004 results.

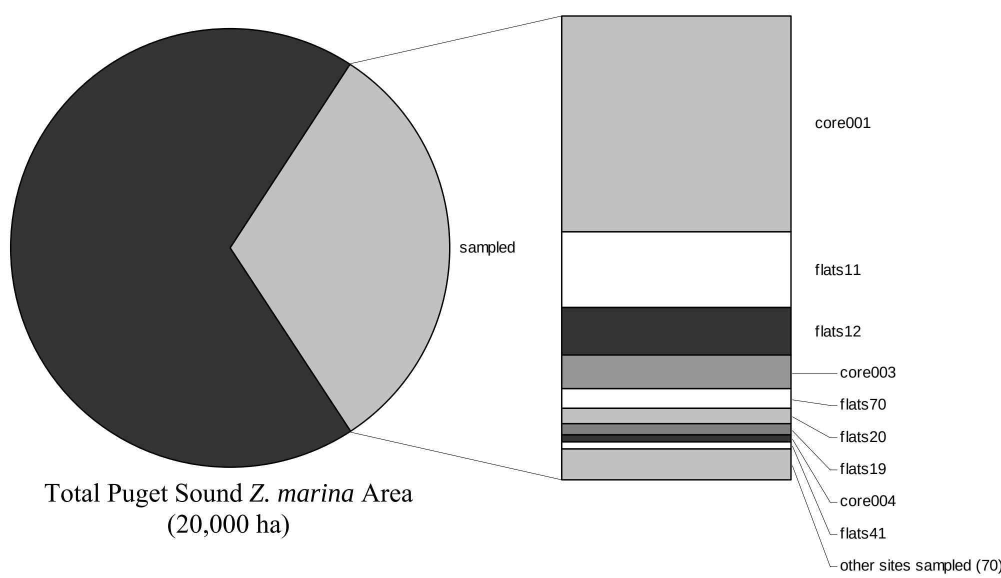

Figure 3-2. Pie chart illustrating that we annually sample roughly 37% of the *Z. marina* area estimated to be in greater Puget Sound study area. The bar chart shows the distribution of sampled *Z. marina* area among sampled sites. Core001, Padilla Bay, contains approximately 17% of the total *Z. marina* area in the study area. Based on 2004 site results from the Puget Sound study only and a total of 20,000 ha in the study area.

In 2003, the average *Z. marina* fraction at a site was 0.53 and ranged from 0.12 (sjs0819, N of Partridge Pt.) to 0.92 (sjs0351 NW Waldron Island). The average *Z. marina* fraction in 2004 was 0.52 and ranged from 0.02 (cps1820, Gordon Pt.) to 0.89 (swh0943, Hackney Island). From 2000 to 2002 the *Z. marina* fraction was highest at sjs0351, NW Waldron Island (0.90) and lowest at sjs0049, Crescent Bay (0.0049).

The average Coefficient of Variation (CV) for all sample sites in 2003 was 0.11 and ranged from 0.01 (sjs0351, NW Waldron Island) to 0.39 (swh0718 (Swinomish Channel). In 2004, the average CV was 0.11 and ranged from 0.02 (sjs0351, NW Waldron Island) to 0.28 (sjs0819, N of Partridge Point). In 2000, 2001 and 2002, the average annual site CV's were 0.19, 0.16 and 0.12 respectively.

3.2.2 Focus Area *Z. marina* Area

The overall status results for the San Juan Co.-Cypress Is. focus area are shown in Table 3-2 and Figure 3-3(a). Figure 3-3(b) shows the breakdown of this estimate among the flats and fringe categories.

***Z. marina* Area**	1,500 ha
Variance	208,689 ha^2
CV	0.30
80% Confidence Interval	± 586 ha
95% Confidence Interval	± 896 ha

Table 3-2. 2004 San Juan-Cypress Island status results.

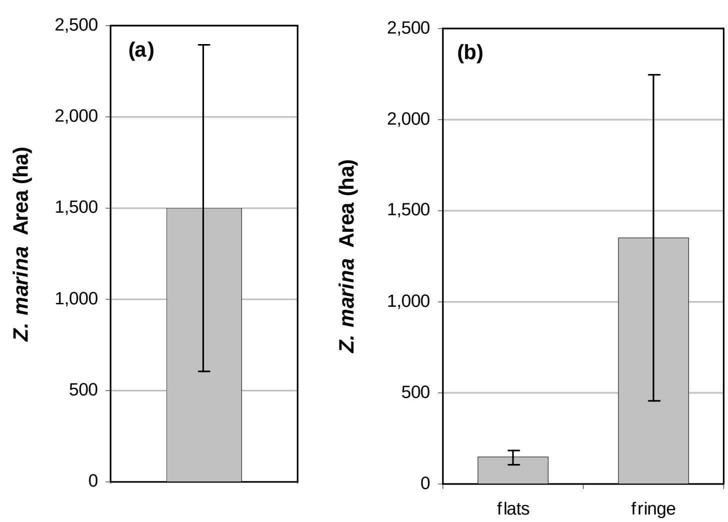

Figure 3-3. 2004 San Juan-Cypress Island (a) overall status and (b) status within the flats and fringe categories. Error bars are 95% confidence intervals.

The focus area status estimate of 1,500 ha (3,710 acres) represents 7.5% of the total sound-wide status based on an approximate value of 20,000 ha for sound-wide status.

The 95% confidence interval is quite broad, ranging from 606 ha to 2,396 ha. Both the *Z. marina* area estimate and the variance estimate are dominated by the fringe-other stratum, which is reflected in the fringe category in Figure 3-3(b).

3.2.3 Regional *Z. marina* Depth

Minimum and maximum *Z. marina* depths, both extreme single observations and site means, are summarized in Figure 3-4 and Table 3-3 by region for all sites sampled from 2000 to 2004. While spatial patterns in bed depth continue to be evident among regions each sample year, depth ranges continue to grow larger as more data are collected. This increasing dispersion supports our premise that the depth parameter is better tracked at the site level, not at the region or sound wide levels.

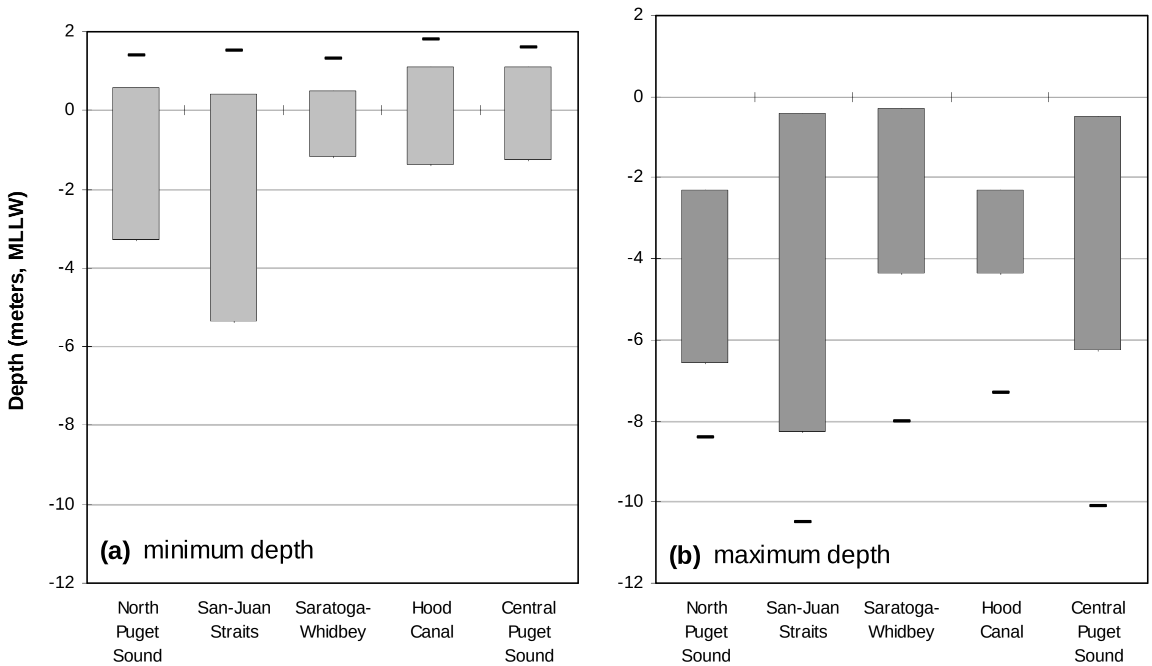

Figure 3-4. Site-level minimum and maximum *Z. marina* depth results summarized by region. The bars indicate the range of mean site (a) minimum depth and (b) maximum depth for all sites within the region. The horizontal markers indicate the extreme (a) minimum and (b) maximum single-transect observation for all transects from all sites sampled within the region. These graphs summarize all data from 2000-2004.

Despite the high variability in depth results, there are several discernable differences between regions.

1. The San Juan – Straits region has the deepest *Z. marina* beds followed by North Puget Sound and Central Puget Sound.
2. The deep limit of *Z. marina* in Hood Canal and Saratoga-Whidbey is similar and notably shallower than in the other regions.
3. The overall shallow limit of *Z. marina* is more consistent across regions than the deep limit although there is still significant site-level variability, particularly in the San Juan – Straits region.

4. Hood Canal is unique in that it has the narrowest range of site mean maximum depth and it is also the only region where the ranges in mean minimum and maximum depth do not overlap. This indicates a relatively consistent depth range in this region and a well-defined depth band that is consistently encompassed by all *Z. marina* beds in the region.
5. The San Juan – Straits region displays the highest variability in ranges of site mean minimum and maximum depths and the greatest overlap in these two ranges. This indicates not only a wide range in depth limits overall, but that some *Z. marina* beds are restricted to relatively shallow depths and other beds are restricted to greater depths with no shared depth range.

Region	Minimum Depth (m)		Maximum Depth (m)	
	Absolute	Range in Site Means	Absolute	Range in Site Means
North Puget Sound	+1.4	+0.6 to **-3.3**	**-8.4**	**-2.3** to -6.6
San Juan/Straits	+1.5	+0.4 to **-5.4**	**-10.5**	-0.4 to **-8.3**
Saratoga/Whidbey	+1.3	+0.5 to **-1.2**	-8.0	-0.3 to -4.4
Hood Canal	+1.8	+1.1 to -1.4	**-7.3**	-2.3 to **-4.4**
Central Puget Sound	+1.6	+1.1 to -1.3	**-10.1**	-0.5 to **-6.3**

Table 3-3. Range of maximum and minimum *Z. marina* depth (MLLW) for all strata by region in 2000-2004 (modifications per 2003-2004 data are bolded).

3.3 Change in *Z. marina*

3.3.1 Sound-Wide Change in *Z. marina* Area

Figure 3-5 depicts the year-to-year change in *Z. marina* area at the sound-wide scale over 2000-2004 with 95% confidence intervals based on Monte Carlo analysis. The values are given in Table 3-4. In 2003-04, we estimate that Z. marina area in Puget Sound increased by 7%. This is our first statistically significant change estimate (i.e. the error bar does not span 0% and bring the sign of change into question).

An alternate measure of sound-wide change is simply to tally the number of observations of increases and decreases in site-level *Z. marina*. By this measure, all locations have equal weighting. Figure 3-6 shows the numbers of sites with increases and decreases over the 2002-03 and 2003-04 intervals. While there are differences in the numbers of sites with increases and decreases in both intervals, these differences are small. The majority of the observed site-level changes are not statistically significant.

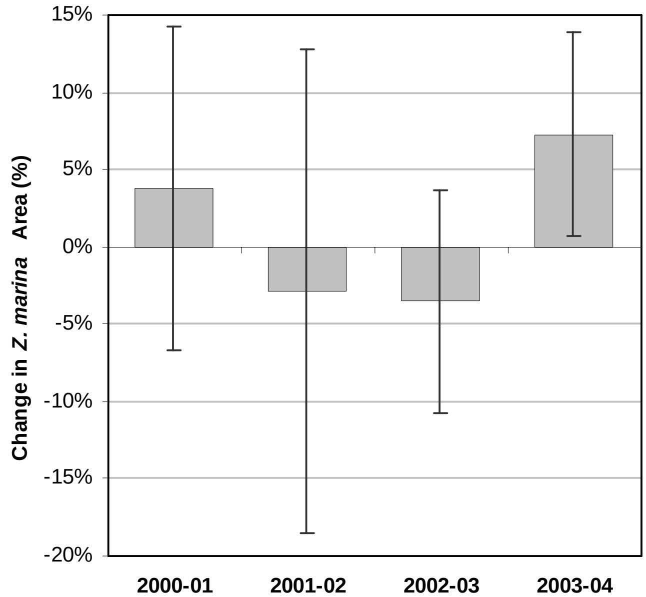

Figure 3-5. Overall sound-wide year-to-year change in *Z. marina* area, 2000-2004. Error bars represent 95% confidence intervals derived from Monte Carlo analysis.

	2000-01	2001-02	2002-03	2003-04
Relative Change	3.8%	-2.9%	-3.5%	7.3%
95% CI	±10.4%	±15.7%	±7.2%	±6.6%

Table 3-4. Estimates of sound-wide year-to-year change and 95% confidence intervals for 2000-2004. Confidence intervals were derived from Monte Carlo analysis. These data are plotted in Figure 3-5.

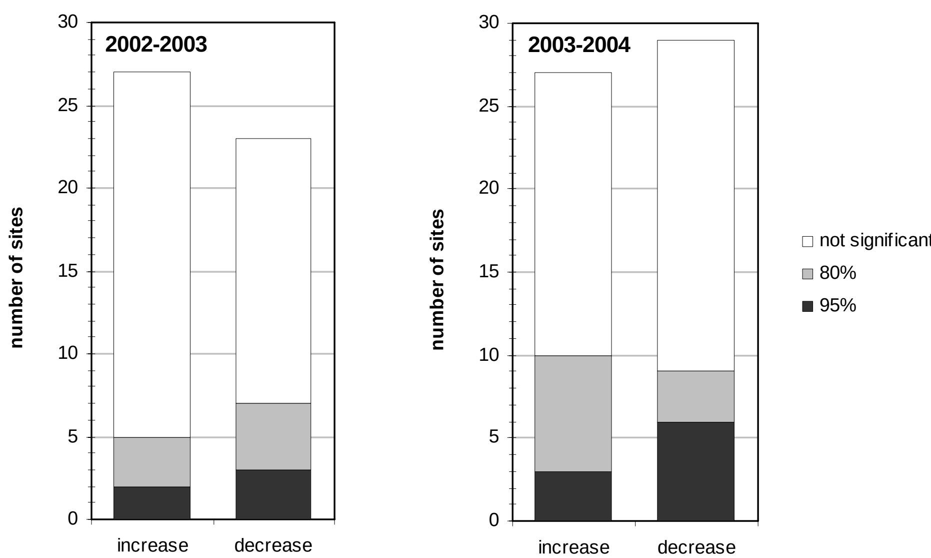

Figure 3-6. Numbers of sites sampled with observed increases and decreases in *Z. marina* area over the 2002-03 and 2003-04 intervals. Shading is used to distinguish sites with statistically significant change at α =0.05 (95%), additional sites with significant change at α =0.2 (80%) and sites whose change was not significant.

3.3.2 Regional Change in *Z. marina* Area

We present the year-to-year change results within regions (see Figure 1-1, p.5) with confidence intervals estimated simply by using the estimator developed for the sound-wide scale (Skalski 2003) at the regional scale. This follows the approach of Berry et al. (2003) and contrasts with the more reliable Monte Carlo procedures used in the previous section for estimating confidence interval at the sound-wide scale (section 3.3.1).

Figure 3-7 shows the year-to-year change in regional *Z. marina* area for 2000-2004, grouped by region. The results are tabulated in Table 3-5 with both 80% and 95% confidence intervals.

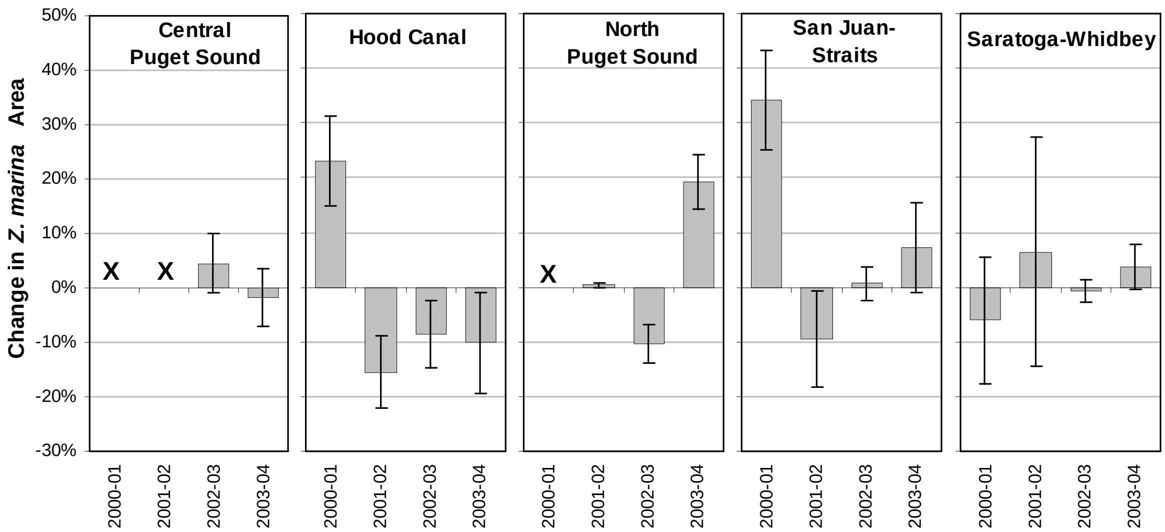

Figure 3-7. Year-to-year change in *Z. marina* area within regions for 2000-2004, grouped by region. Error bars indicate estimates of 95% confidence intervals based on the original SVMP procedures rather than Monte Carlo analysis. X's indicate insufficient data to produce an estimate.

These results are summarized by region below.

Central Puget Sound. An insufficient number of paired sites in 2000-2002 resulted in no estimates for these years. The 2002-03 and 2003-04 estimates are of opposite sign and not significant. No changes detected.

Hood Canal. A large increase in 2000-01 (+23%) was followed by three consecutive declines. This is the only case of persistent regional change. The confidence intervals shown are consistent with statistical significance at α=0.5.

North Puget Sound. There was no estimate for 2000-01. The three subsequent results are variable – no change, followed by a decline and then an increase in *Z. marina* area. There is no evidence for a persistent trend, but the signal may represent actual short-term variability.

San Juan-Straits. The change estimate from the 2000-01 interval is a strong increase that is statistically significant. The subsequent results are variable and not significant.

Saratoga-Whidbey. The results are variable and not significant. No changes detected.

		Central Puget Sound	Hood Canal	North Puget Sound	San Juan - Straits	Saratoga - Whidbey
Change	2000-01	no data	23.0%	no data	34.1%	-6.1%
	2001-02	no data	-15.5%	0.4%	-9.6%	6.5%
	2002-03	4.5%	-8.6%	-10.3%	0.6%	-0.8%
	2003-04	-1.8%	-10.2%	19.2%	7.2%	3.6%
80% CI	2000-01	no data	5.38%	no data	5.91%	7.51%
	2001-02	no data	4.23%	0.24%	5.72%	13.75%
	2002-03	3.61%	4.10%	2.30%	2.01%	1.30%
	2003-04	3.44%	6.05%	3.31%	5.38%	2.70%
95% CI	2000-01	no data	8.23%	no data	9.04%	11.48%
	2001-02	no data	6.47%	0.37%	8.75%	21.02%
	2002-03	5.52%	6.26%	3.52%	3.07%	1.99%
	2003-04	5.25%	9.25%	5.06%	8.22%	4.14%
sample size (flats / fringe)	2000-01	1 / 18	2 / 8	1 / 3	6 / 14	3 / 5
	2001-02	1 /16	2 / 5	2 / 3	4 / 15	3 / 8
	2002-03	2 / 18	2 / 4	3 / 5	3 / 15	2 / 8
	2003-04	2 / 18	2 / 5	4 / 6	3 / 14	3 / 7

Table 3-5. Year-to-year change in regional *Z. marina* area, confidence intervals (half widths) and stratum sample sizes for 2000-2004. Confidence intervals were estimated using original SVMP procedures rather than Monte Carlo analysis.

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

Year-to-Year Change in *Z. marina* Area

In this section we focus on the year-to-year relative change results for site-level *Z. marina* area that are statistically significant. The complete year-to-year *Z. marina* area change results at the site level are presented in Appendix D for 2002-03 and Appendix E for 2003-04.

Figure 3-8 shows the locations of all sites tested for change in *Z. marina* area between 2002 and 2003 and identifies those with statistically significant change when tested at α=0.2 (80% confidence) and at α=0.05 (95% confidence). There were 62 paired sites that were sampled in both 2002 and 2003 but 12 of these had no *Z. marina* leaving 50 sites that were tested for change in this interval. There were 5 sites with significant change when tested at 95% confidence (2 increases, 3 decreases) and an additional 7 sites (12 sites total) with significant change when tested at 80% confidence (5 total increases, 7 total decreases). There is no obvious spatial pattern to the sites with significant relative change.

Figure 3-9 shows the magnitude of estimated relative change in *Z. marina* area for the sites with significant change between 2002 and 2003. Site sjs0819, North of Partridge Point, has the greatest relative decrease (-53%; significant with 95% confidence) and flats35, Nisqually Delta East, has the greatest relative increase (+55%; significant with 80% confidence).

Figure 3-10 shows the locations of sites tested for change in *Z. marina* area between 2003 and 2004. There were 64 paired sites that were sampled in both 2003 and 2004 but 8 of these had no *Z. marina* leaving 56 sites that were tested for change in this interval. There were 9 sites with significant change when tested at 95% confidence (3 increases, 6 decreases) and an additional 10 sites (19 sites total) with significant change when tested at 80% confidence (10 total increases, 9 total decreases). The site locations suggest the possibility of some spatial coherence to site-level changes. The estimates of change for the four sites in the Strait of Juan de Fuca with significant change are all increases in *Z. marina* area. The estimates for the four sites in the North Puget Sound region with significant change are all increases. The estimates for the two sites in the San Juan Archipelago with significant change are both decreases. The estimates for the three sites in the Central Puget Sound region with significant change are all increases. The estimates for three of the four sites in Hood Canal with significant change are decreases but the estimate for the fourth site (hdc2338) is an increase and it is in close proximity to one of the sites with a decrease.

Figure 3-11 shows the magnitude of estimated relative change in *Z. marina* area for the sites with significant change between 2003 and 2004. Site sjs2775, Pysht River, has the greatest relative increase (+73%; significant at 95% confidence). There are several sites with similar levels of relative decrease in the -20 to -30% range.

A comparison of the estimated changes in 2002-03 and 2003-04 reveals that only two sites had significant change estimates (hdc2239 and sjs0081) in both intervals. Only hdc2239, located north of Port Gamble, exhibited consistent change with estimated declines of -18.2% (2002-03) and -19.6% (2003-04).

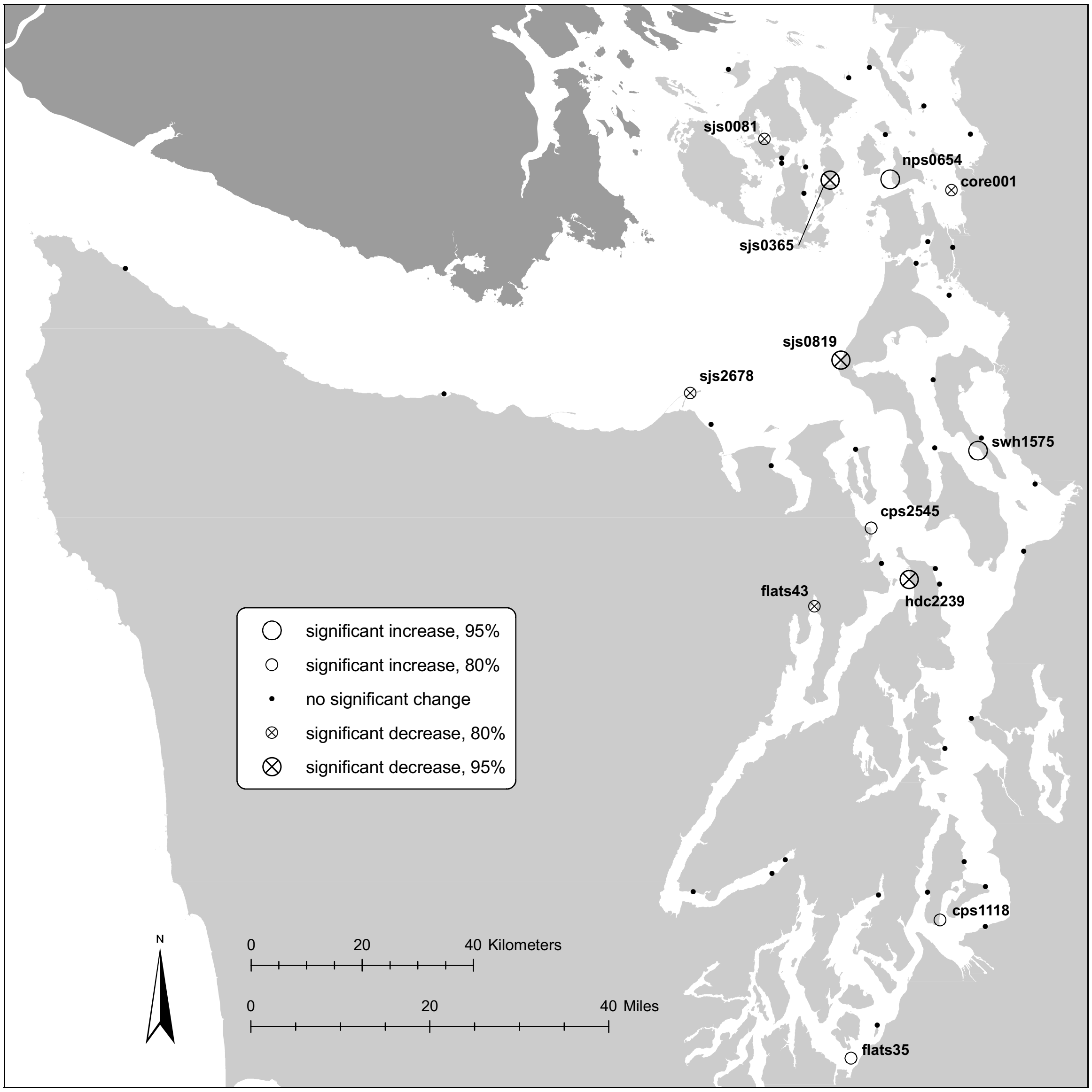

Figure 3-8. Sites with significant relative change in *Z. marina* area between 2002 and 2003 when tested at α=0.2 (80%) and α=0.05 (95%). Sites that were tested but exhibited no significant change are also shown.

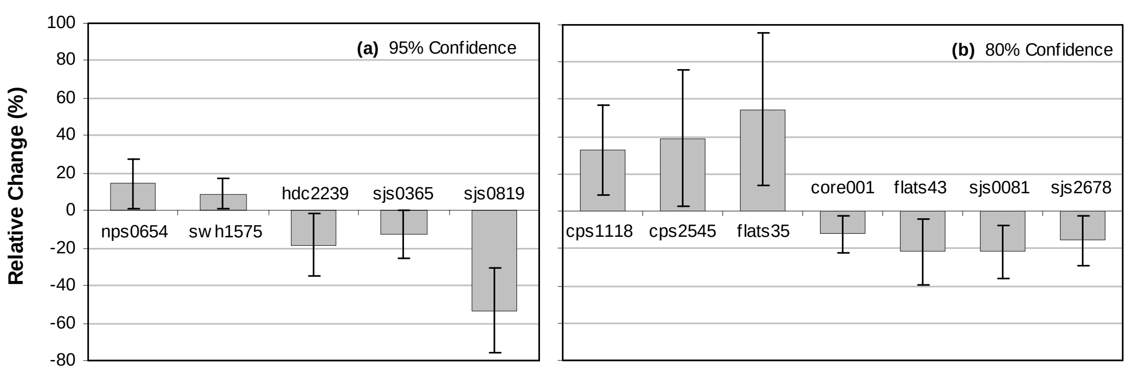

Figure 3-9. Magnitude of estimated change in *Z. marina* area for sites with significant change at 95% and 80% confidence (error bars are associated 95% or 80% confidence intervals respectively).

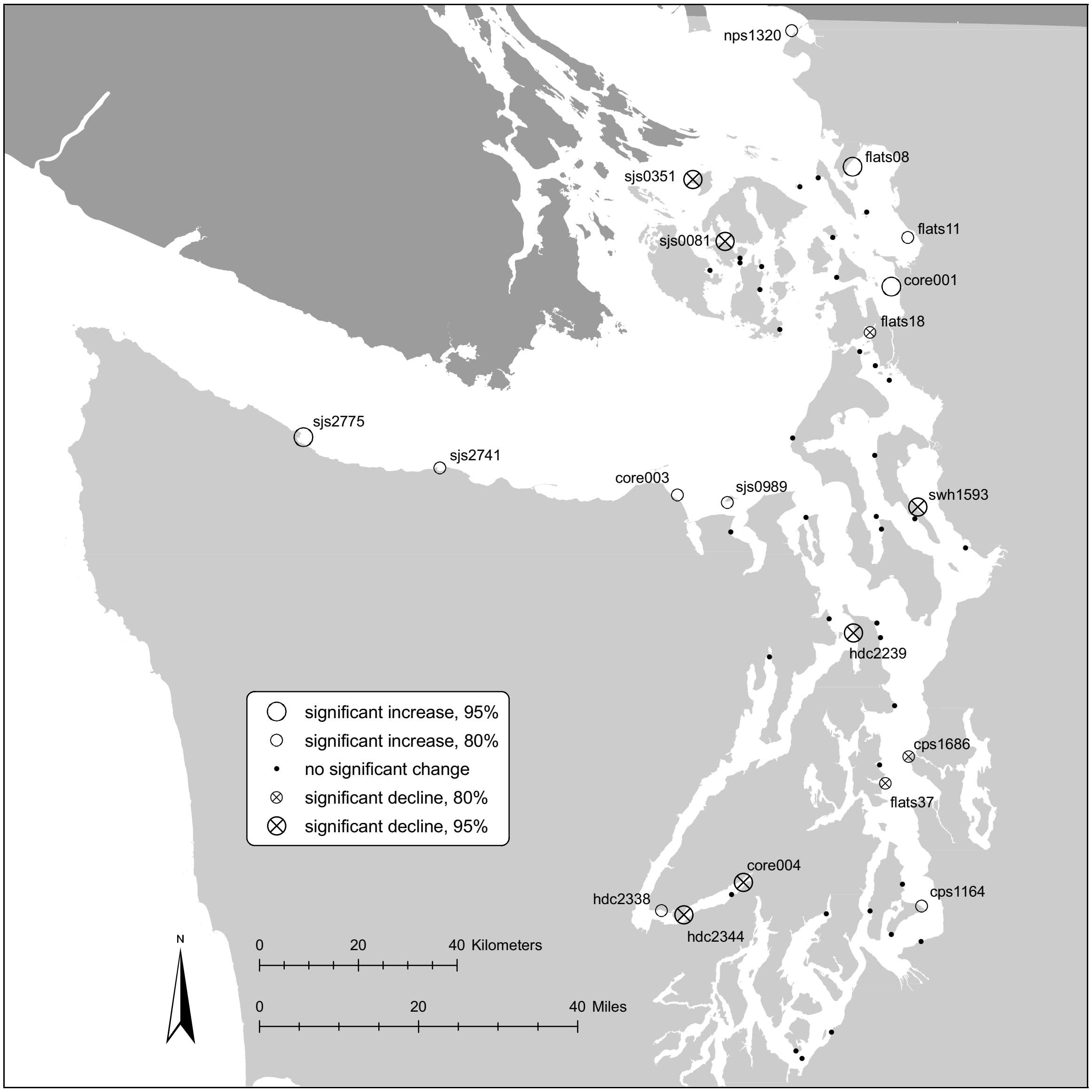

Figure 3-10. Sites with significant relative change in *Z. marina* area between 2003 and 2004 when tested at α=0.2 (80%) and α =0.05 (95%). Sites that were tested but exhibited no significant change are also shown.

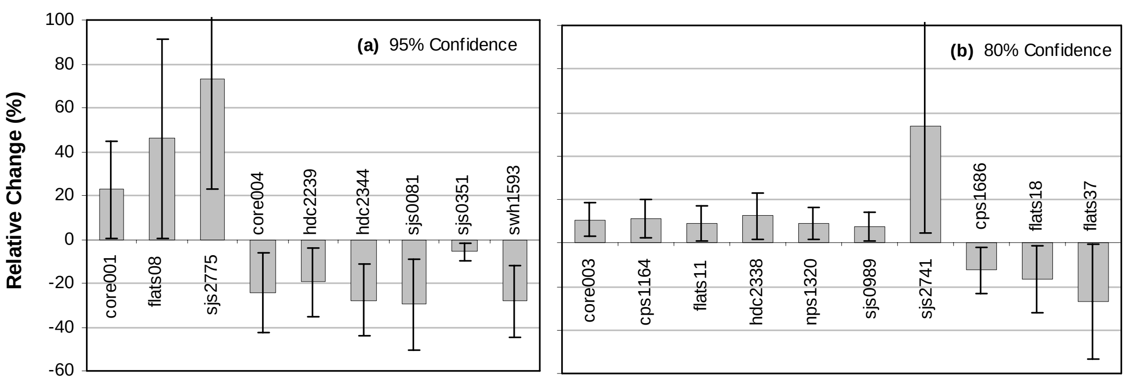

Figure 3-11. Magnitude of estimated change in *Z. marina* area for sites with significant change at 95% and 80% confidence (error bars are associated 95% or 80% confidence intervals respectively).

Five-Year Trends in *Z. marina* Area

Since the SVMP began in 2000, we have sampled a total of 22 sites for five consecutive years. Each of these sites was tested for 5-year trends in *Z. marina* area. Out of the 22 sites, 5 sites had significant trends at the 95% level of confidence (3 decreases, 2 increases). An additional 11 sites (16 sites total) had significant trends at the 80% level of confidence (13 total decreases, 3 total increases).

Figure 3-12 shows the locations of the 22 sites tested for 5-year trends and identifies those with significant trends. Table 3-6 includes the estimates of annual rates of change for those sites with significant trends. Appendix J contains graphs of the 2000-2004 data points and the estimated trends for each of the 22 sites tested.

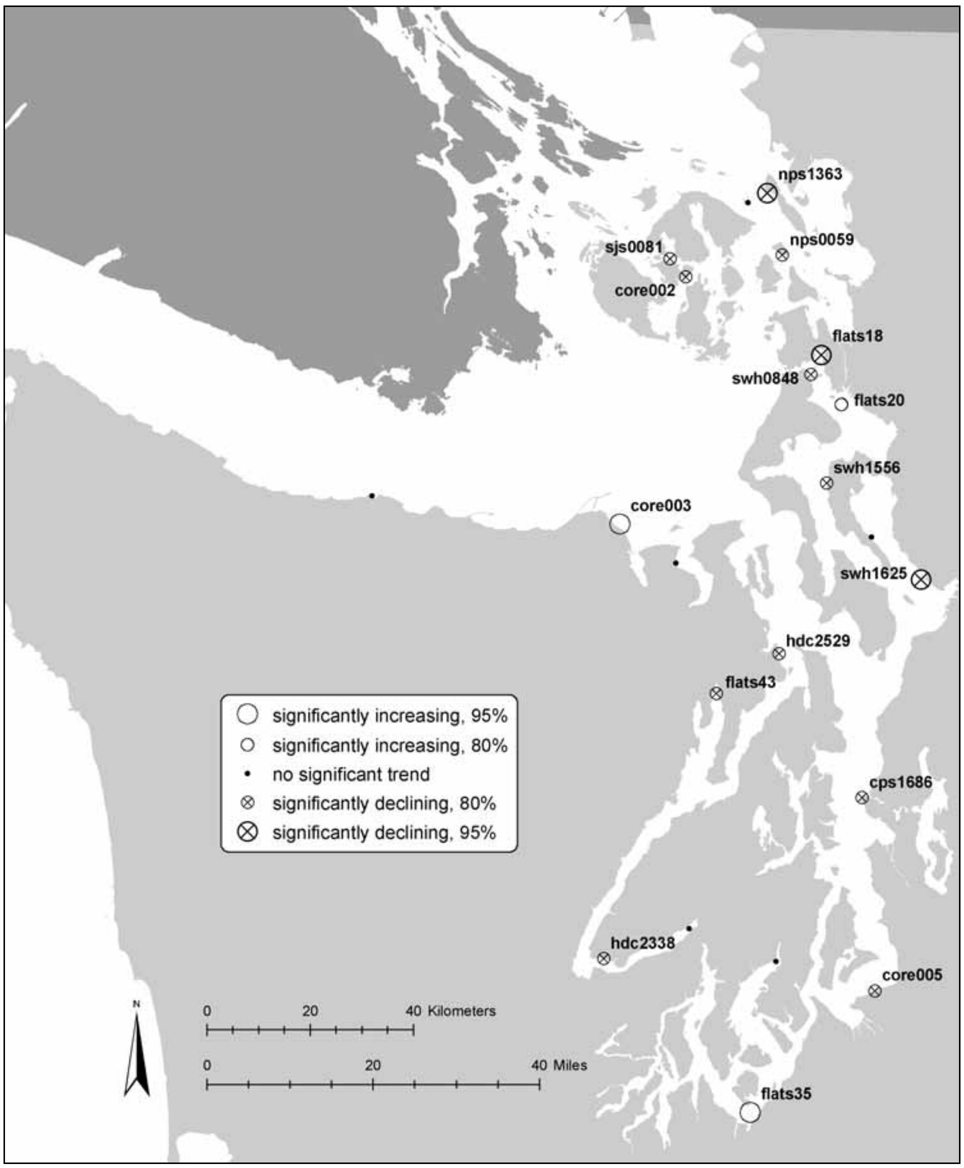

Figure 3-12. Sites with significant five-year trends in *Z. marina* area over 2000-2004 when tested at α=0.2 (80%) and α =0.05 (95%). Sites that were tested but exhibited no significant trend are also shown.

On an absolute areal basis, two sites have far greater estimates of rate of change than the other sites and both of these are increasing trends. These two sites are core003 (+38.2 ha/year) and flats20 (+14.9 ha/year). On a relative basis, the greatest estimated rate of change is an increase trend at flats35 (+43.1 %/year) and decreasing trends at swh1625 (-17.6 %/year) and core005 (-19.1 %/year).

direction of trend	site code	site name	5-year trend test results		
			confidence of test result	estimated trend (ha/year)	equivalent annual relative change (% / year)
increasing area	core003	Jamestown	95%	+38.2	+10.2
	flats35	Nisqually Delta E.	95%	+3.9	+43.1
	flats20	Skagit Bay N.	80%	+14.9	+7.6
decreasing area	flats18	Similk Bay	95%	-2.4	-5.5
	nps1363	Village Pt. (Lummi Island)	95%	-0.2	-9.2
	swh1625	S. of Tulalip Bay	95%	-0.1	-17.6
	core002	Picnic Cove	80%	-0.3	-6.6
	core005	Dumas Bay	80%	-0.5	-19.1
	cps1686	Fort Lawton	80%	-0.2	-2.8
	flats43	Dabob Bay	80%	-0.8	-5.7
	hdc2338	Across from Union	80%	-0.1	-5.8
	hdc2529	S. of Tala Point	80%	-0.4	-7.0
	nps0059	Sinclair Island S.	80%	-0.04	-5.1
	sjs0081	Broken Pt. (Shaw Island)	80%	-0.1	-8.7
	swh0848	Ala Spit	80%	-0.1	-0.5
	swh1556	NW Camano Island	80%	-0.1	-0.9
no trend	core004	Lynch Cove	no trend	no trend	no trend
	core006	Burley Spit			
	sjs0311	Clark Island			
	sjs2646	Discovery Bay			
	sjs2741	West of Crescent Bay			
	swh1593	Cornell (Camano Island)			

Table 3-6. Results of tests for five-year trend in site-level *Z. marina* area at two levels of significance. The estimated trend is based on the regression slope and the percentage change values are relative to the estimated *Z. marina* area at each site in 2000.

3.3.4 Site Level Change in *Z. marina* Depth

Mean maximum depth

We present all sites with significant change in mean maximum *Z. marina* bed depth between 2002 and 2003 in Figure 3-13 and Table 3-7. Sites with significant change between 2003 and 2004 are presented in Figure 3-14 and Table 3-8.

Between 2002 and 2003, there were 4 sites with significant changes in mean maximum depth when tested at 95% confidence (3 expanding, 1 receding) and an additional 8 sites (12 sites total) when tested at 80% confidence (5 total expanding, 7 total receding).

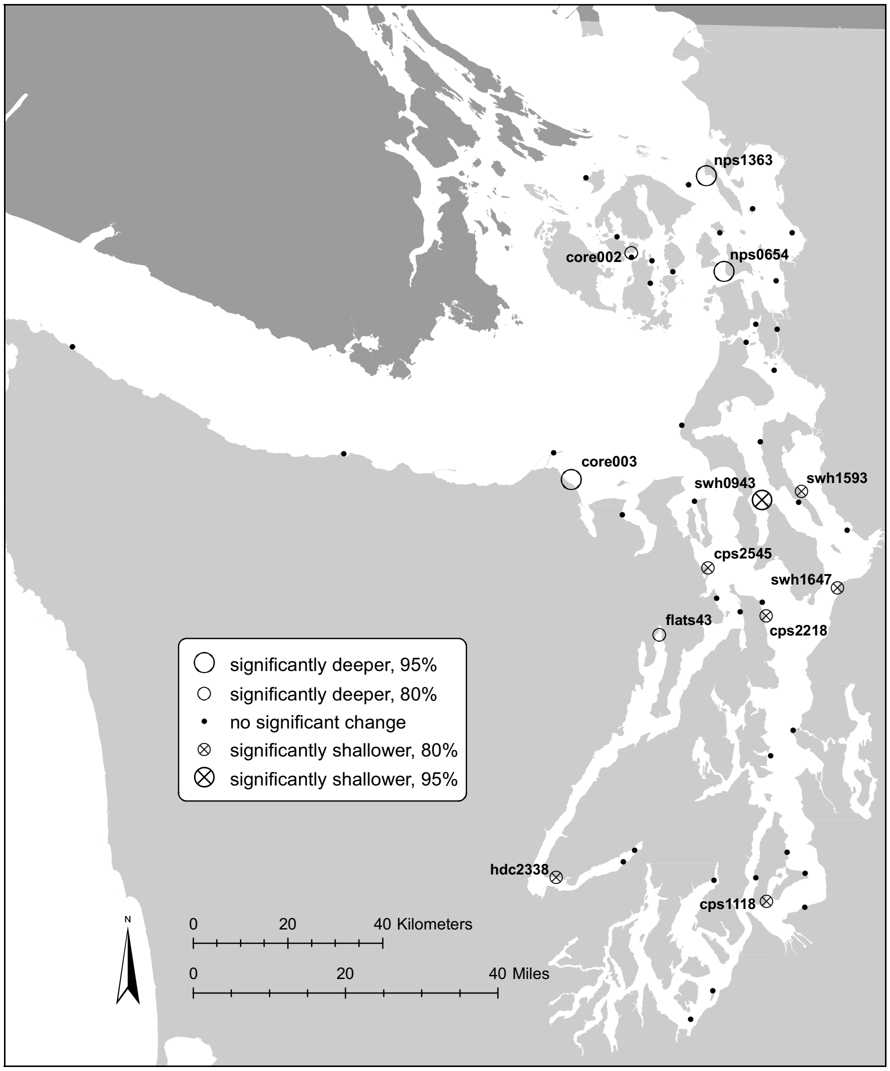

Figure 3-13. Sites with significant change in mean maximum *Z. marina* depth between 2002 and 2003 when tested at α=0.2 (80%) and α =0.05 (95%). Sites that were tested but exhibited no significant change area also shown.

direction of change	site	confidence of test for change	mean maximum depth (m)		
			change	2002	2003
deeper (expanding)	core003	95%	-0.9	-5.2	-6.1
	nps0654	95%	-1.4	-3.8	-5.2
	nps1363	95%	-1.5	-3.7	-5.2
	core002	80%	-0.3	-4.9	-5.2
	flats43	80%	-0.7	-3.5	-4.2
shallower (receding)	swh0943	95%	0.7	-4.6	-3.9
	cps1118	80%	0.6	-2.4	-1.8
	cps2218	80%	1.5	-3.2	-1.7
	cps2545	80%	0.6	-4.1	-3.5
	hdc2338	80%	0.5	-3.7	-3.2
	swh1593	80%	0.3	-1.9	-1.6
	swh1647	80%	0.8	-5.1	-4.3

Table 3-7. Significant changes in mean maximum *Z. marina* depth between 2002 and 2003 when testing at two different levels of significance.

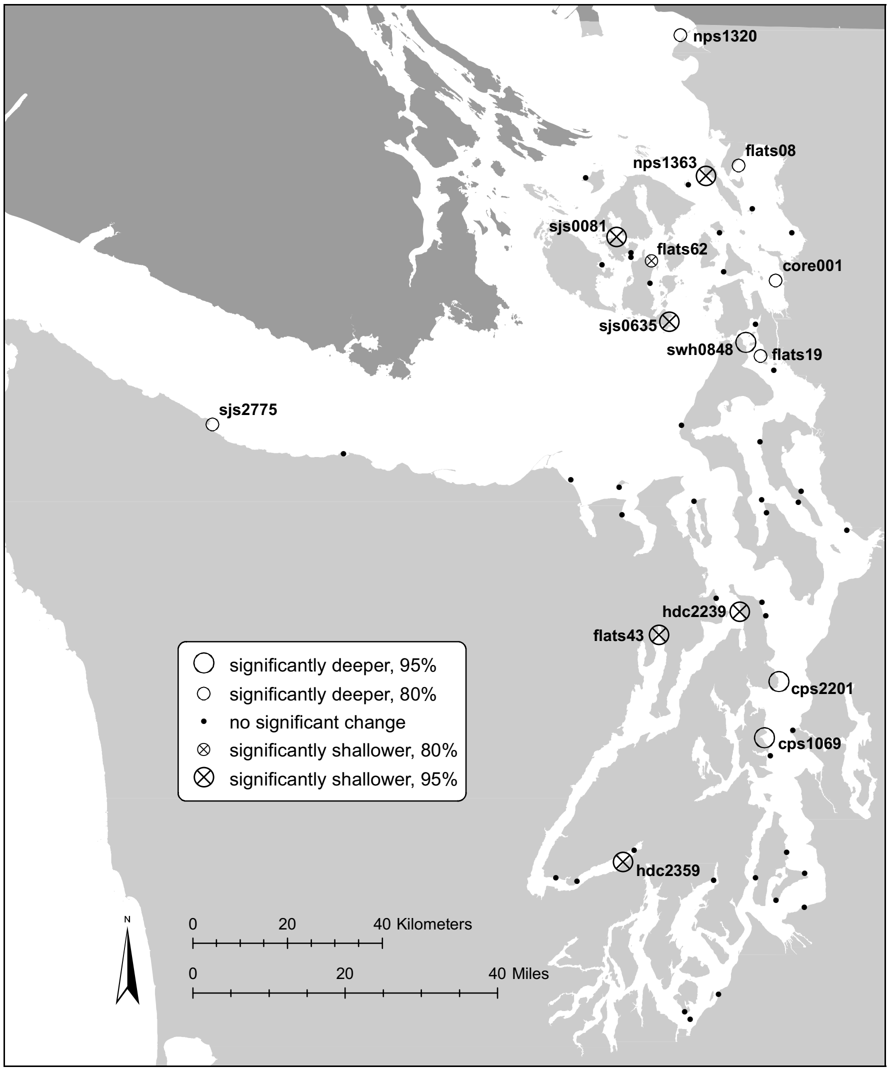

Figure 3-14. Sites with significant change in mean maximum *Z. marina* depth between 2003 and 2004 when tested at α=0.2 (80%) and α=0.05 (95%). Sites that were tested but exhibited no significant change area also shown.

direction of change	site	confidence of test for change	mean maximum depth (m)		
			change	2003	2004
deeper (expanding)	cps1069	95%	-0.7	-3.6	-4.3
	cps2201	95%	-1.2	-5.1	-6.3
	swh0848	95%	-0.5	-2.3	-2.8
	core001	80%	-0.4	-3.3	-3.7
	flats08	80%	-0.3	-2.3	-2.6
	flats19	80%	-0.4	-1.0	-1.4
	nps1320	80%	-0.2	-3.5	-3.7
	sjs2775	80%	-0.6	-6.0	-6.6
shallower (receding)	flats43	95%	0.8	-4.2	-3.4
	hdc2239	95%	0.7	-4.4	-3.7
	hdc2359	95%	0.5	-3.9	-3.4
	nps1363	95%	0.6	-5.2	-4.6
	sjs0081	95%	1.6	-5.5	-3.9
	sjs0635	95%	1.0	-6.3	-5.3
	flats62	80%	0.6	-2.9	-2.3

Table 3-8. Significant changes in mean maximum *Z. marina* depth between 2003 and 2004 when testing at two different levels of significance.

All sites with significant changes that were outside (toward the ocean) of Admiralty Inlet had expanding deep margins. Those on the inland side of Admiralty Inlet except one, flats43-Dabob Bay in Hood Canal, had receding deep margins.

Between 2003 and 2004, there were 9 sites with significant changes in mean maximum depth when tested at 95% confidence (3 expanding, 6 receding) and an additional 6 sites (15 sites total) when tested at 80% confidence (8 total expanding, 7 total receding).

The spatial pattern of sites with significant changes differed in 2003-04 relative to 2002-03. In particular, the four sites in the San Juan Islands with significant changes all had receding deep margins and the two sites in central Puget Sound had expanding deep margins. Both patterns are opposite the 2002-03 patterns in these areas. The three sites with significant changes in Hood Canal in 2003-04 all had receding deep margins.

The success of the effort to increase precision of mean maximum depth measurements through the use of abbreviated transects was equivocal. Of the ten sites identified for additional effort (Table 2-6, p.22), the field schedule allowed for increased sampling at eight of these. Of these sites, precision improved at four and declined at three.

Mean Minimum Depth

We present all sites with significant change in mean minimum *Z. marina* bed depth between 2002 and 2003 in Figure 3-15 and Table 3-9. Sites with significant change between 2003 and 2004 are presented in Figure 3-16 and Table 3-10.

Between 2002 and 2003, there were 4 sites with significant changes in mean minimum depth when tested at 95% confidence (1 expanding, 3 receding) and an additional 7 sites (11 sites total) when tested at 80% confidence (6 total expanding, 5 total receding). There is no apparent spatial organization to these sites. Sites with significantly expanding shallow margins are in relatively close proximity to sites with receding shallow margins.

Between 2003 and 2004, there were 3 sites with significant changes in mean minimum depth when tested at 95% confidence (all 3 receding) and an additional 6 sites (9 sites total) when tested at 80% confidence (4 total expanding, 5 total receding). Three of these sites with receding shallow margins are clustered in the Saratoga-Whidbey basin.

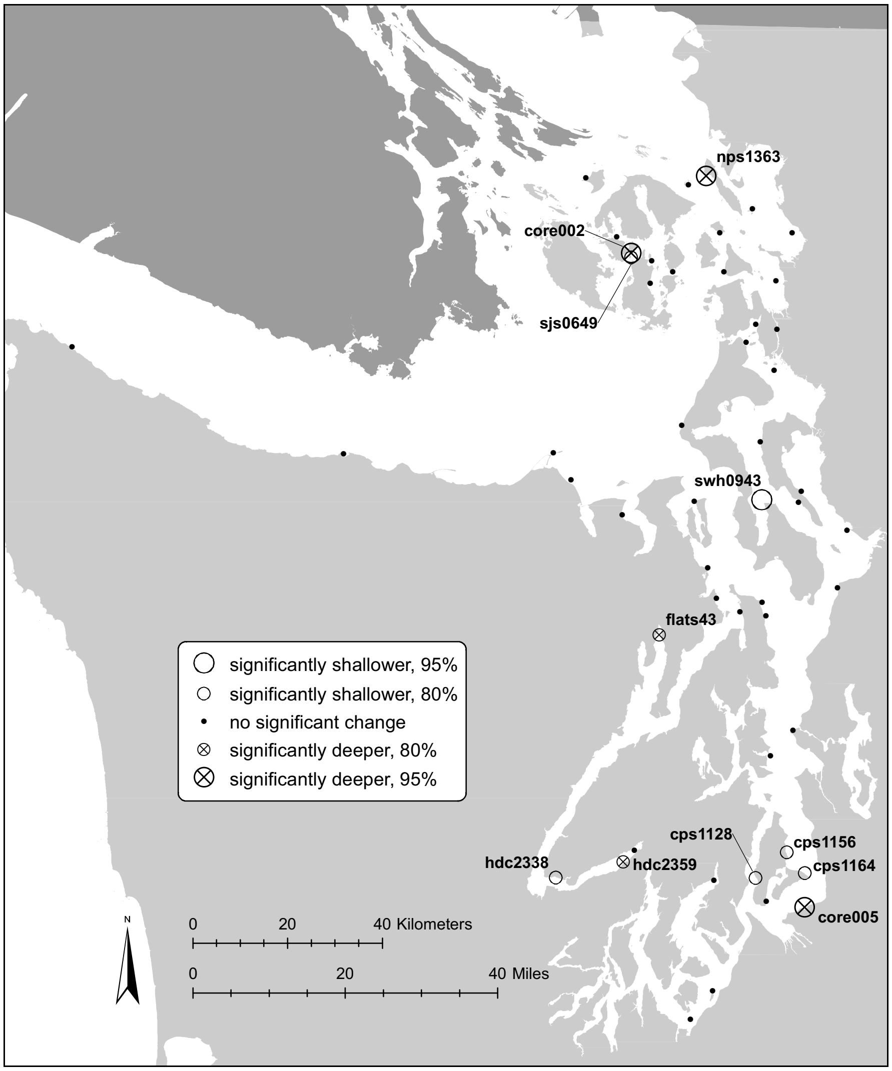

Figure 3-15. Sites with significant change in mean minimum *Z. marina* depth between 2002 and 2003 when tested at α=0.2 (80%) and α =0.05 (95%). Sites that were tested but exhibited no significant change area also shown.

direction of change	site	confidence of test for change	mean minimum depth (m)		
			change	2002	2003
shallower (expanding)	swh0943	95%	0.7	-1.2	-0.5
	cps1128	80%	0.8	-0.8	0.0
	cps1156	80%	0.5	-0.1	0.4
	cps1164	80%	0.4	-1.0	-0.6
	hdc2338	80%	0.3	-1.5	-1.2
	sjs0649	80%	1.4	-4.8	-3.4
deeper (receding)	core002	95%	-1.3	-1.0	-2.3
	core005	95%	-0.8	-0.1	-0.9
	nps1363	95%	-0.8	-2.5	-3.3
	flats43	80%	-0.3	-0.2	-0.5
	hdc2359	80%	-0.4	-0.2	-0.6

Table 3-9. Significant changes in mean minimum *Z. marina* depth between 2002 and 2003 when testing at two different levels of significance.

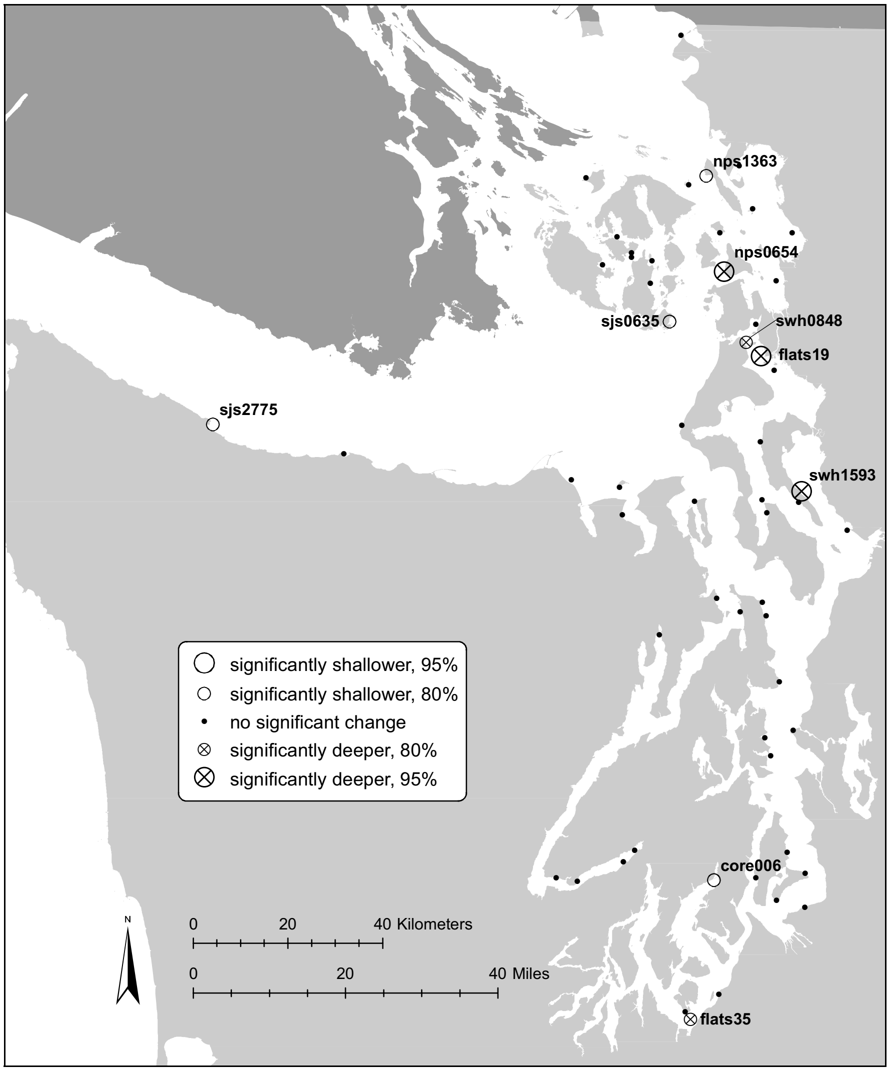

Figure 3-16. Sites with significant change in mean minimum *Z. marina* depth between 2003 and 2004 when tested at α=0.2 (80%) and α =0.05 (95%). Sites that were tested but exhibited no significant change area also shown.

direction of change	site	confidence of test for change	mean maximum depth (m)		
			change	2003	2004
shallower (expanding)	core006	80%	0.2	-1.1	-0.9
	nps1363	80%	0.4	-3.3	-2.9
	sjs0635	80%	0.3	-4.8	-4.5
	sjs2775	80%	0.8	-3.4	-2.6
deeper (receding)	flats19	95%	-0.6	0.4	-0.2
	nps0654	95%	-0.6	-1.3	-1.9
	swh1593	95%	-0.5	0.0	-0.5
	flats35	80%	-0.3	0.3	0.0
	swh0848	80%	-0.5	-0.2	-0.7

Table 3-10. Significant changes in mean minimum *Z. marina* depth between 2003 and 2004 when testing at two different levels of significance.

3.4 Observations of *Z. japonica* and *Phyllospadix spp.*

In 2004 we began to keep systematic records of sites where we observed seagrass species other than *Z. marina*. The most common congener is *Z. japonica* but we have also observed *Phyllospadix* spp., surfgrass, in the video images. There are three species of *Phyllospadix* growing in Puget Sound waters (*P. torreyi*, *P. scouleri* and *P. serrulatus*) however identification to the species level in the video image is difficult and consequently has not been done. Figure 3-17 shows the locations these species were observed in 2004.

In 2004 we observed *Z. japonica* at 18 sites primarily in three clusters located in central Puget Sound (Quartermaster Harbor and vicinity), north Puget Sound (Padilla and Samish Bays) and Hood Canal. *Z. japonica* was not observed in the Strait of Juan de Fuca and Admiralty Inlet, the Saratoga-Whidbey basin nor south of the Tacoma Narrows. It was only observed at one site in the San Juan Islands (East Sound). *Phyllospadix spp.* was observed at three sites bordering the eastern Strait of Juan de Fuca.

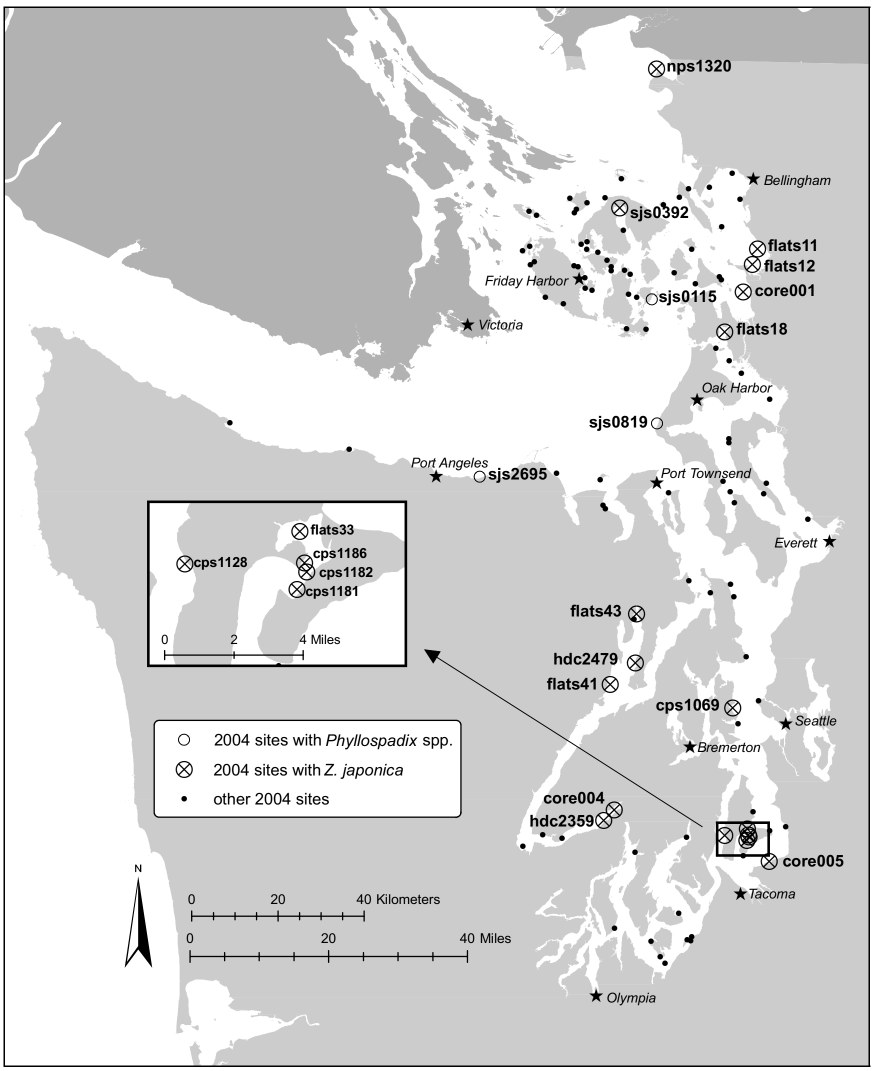

Figure 3-17. 2004 sites where seagrass species *Z. japonica* and *Phyllospadix spp.* were observed.

3.5 Spatial Patterns in Water Quality Parameters

The mean regional surface and bottom temperatures from selected sites, at outer edge of *Z. marina* beds, ranged from 9.0 to 17.9 Celsius during 2000 through 2003. Mean surface and bottom temperatures were warmest in the Hood Canal region, 17.7 ºC and 16.3 ºC respectively and coldest in the Strait of Juan de Fuca, 11.1 ºC and 10.3 ºC respectively (Table 3-11). Overall, the warmest surface and bottom temperatures were observed during the 2003 monitoring season and coldest temperatures during the 2001 season, however many sites were sampled in different months each year.

Region	Surface Temperature (ºC)					Bottom Temperature (ºC)				
	2000	2001	2002	2003	Mean	2000	2001	2002	2003	Mean
Central Puget Sound	15.9	13.1	14.6	16.3	14.9	14.2	13.2	13.7	14.7	13.9
Hood Canal	16.8	15.9	19.0	20.0	17.7	15.5	14.4	17.4	18.4	16.3
North Puget Sound	13.1	13.4	12.8	13.7	14.1	11.3	12.6	11.9	12.1	12.3
San Juan – Straits										
San Juan Islands	12.0	12.4	12.6	12.2	12.3	11.4	11.4	10.8	11.9	11.4
Straits	10.8	10.2	10.6	11.8	11.1	9.9	9.0	10.0	11.4	10.3
Saratoga – Whidbey	14.7	15.0	16.0	17.9	15.8	13.6	14.1	14.2	12.4	13.6

Table 3-11. Summary of mean surface and bottom temperatures from selected sites broken down by region.

As expected the water temperature decreased with depth and increased with longitude. Salinities ranged from 33.4 ppt in the Strait of Juan de Fuca, to 24.2 ppt in the Saratoga – Whidbey region.

The values of the extinction coefficients, K_d ,for 2000 through 2003, ranged from 0.2 at sjs0351-Waldron Is. and sjs2813-Rasmussen Creek at the clearest sites, to 0.9 at flats18-Similk Bay, the most turbid site. Summarized by region, the mean K_d value was largest in the Saratoga – Whidbey region, 0.62, and smallest in the Strait of Juan de Fuca, 0.28 (Table 3-12).

Region	K_d				Mean K_d
	2000	2001	2002	2003	
Central Puget Sound	N/A	0.49	0.45	0.31	0.39
Hood Canal	0.51	0.42	0.39	0.46	0.41
North Puget Sound	0.45	1.24	0.31	0.50	0.51
San Juan – Straits					
San Juan Islands	N/A	0.32	0.39	0.42	0.41
Strait of Juan deFuca	0.20	0.34	0.30	0.26	0.28
Saratoga – Whidbey	0.63	0.70	0.90	0.57	0.62

Table 3-12. Summary of calculated mean K_d values by region.

We used linear regression to test the relationship between maximum *Z. marina* bed depth to K_d values. Maximum depth of *Z. marina* was negatively correlated to K_d throughout the study area.

Although the relationship is not strong, R^2 = 0.27, it was significant at p=0.01 (Figure 3-18).

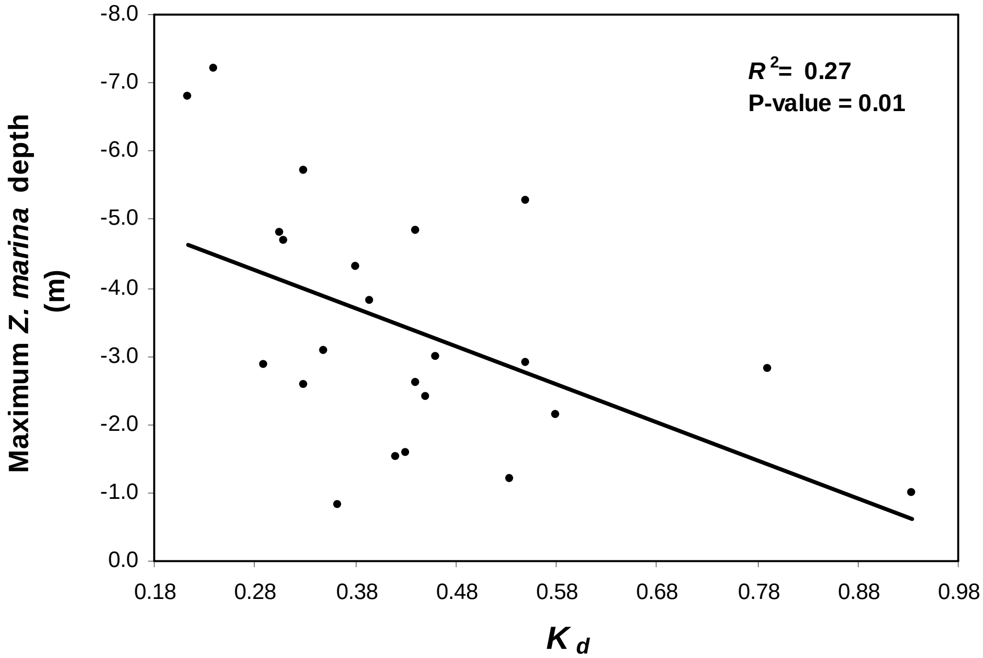

Figure 3-18. Mean maximum *Z. marina* depth and calculated mean K_d values.

4 Discussion

We now have two additional years of monitoring data since we released our first report (Berry et al. 2003), and a five-year data record overall. In this chapter we present our current overall interpretation of the SVMP data record and summarize what we see as our immediate priorities, both in terms of adapting the project to meet management needs most effectively and in terms of refining our current methodology to improve results from the existing monitoring program.

4.1 How is *Z. marina* Faring in Greater Puget Sound?

One of the primary motivations for a long-term natural resource monitoring program is to provide an early warning of resource decline. This is particularly important in systems that may have thresholds beyond which stressors rapidly push the system to what could be considered system collapse.

There is precedent for collapse in marine systems and in particular for widespread loss in nearshore aquatic vegetation in urbanizing estuaries (De Jonge and De Jonge 1992; Short and Burdick 1996; Short and Wyllie-Echeverria 1996; Orth and Moore 1983). Once massive decline has occurred, restoration on the scale of a large estuary is complex, very expensive and demands a long-term effort.

Given these considerations, the most urgent question for the SVMP is whether our limited dataset provides any evidence of declining trends and on what scale. Of course, as we compile more data we are increasingly better equipped to answer this question. Specifically, once we compile a sufficient data record we will be able to utilize trend analysis techniques (Skalski 2003). Until that time, we rely primarily on observations of change between two consecutive years using our paired-site analysis at the sound-wide, regional and individual site scales as described in the following sections.

4.1.1 <u>Sound-Wide</u>

At the sound-wide scale we do not have evidence of decline at a level that is measurable by our year-to-year analysis. In fact, the only significant change we have detected was an increase in sound-wide *Z. marina* area in the 2003-04 interval. However, we must consider two important points when interpreting this conclusion. First, there are limits to our ability to detect change with the paired-site analysis. We estimate that we can determine relative change in Puget Sound *Z. marina* area to within roughly ±10% (Table 3-4, p.31). This leaves the possibility open that important trends are present that are beneath our detection limit with the paired-site analysis.

Second, our data record currently gives us a five year window (four change intervals). Ecological signals are noisy and in some cases important signals may be present but only become apparent as the data record is extended. For example, as noted earlier the recent Pacific Decadal Oscillation signal may reflect a regime shift in the ocean system but this will not be known conclusively until much more data are available (p.6). We must recognize the possibility that Puget Sound *Z. marina* may be in a period of change that has a longer time scale than five years and will only become apparent as more data are compiled.

Notwithstanding these two considerations, our current sound-wide results clearly do not provide evidence of consistent decline in *Z. marina* area across the study area as a whole. While this is a good measure of the change of the total *Z. marina* resource within the study area, it is less appropriate as a measure of how all the locations within the study area are faring with respect to change in *Z. marina*. This is due to the very aggregated spatial distribution of *Z. marina* in the study area (Figure 3-2, p.27), which heavily weights the sound-wide change results in Figure 3-5 to reflect conditions at just a few sites.

The overall tally of changes in site-level *Z. marina* area is a useful alternate measure of sound-wide change that weights all locations equally. The results (Figure 3-6) indicate that there are near equal numbers of sites with increases and decreases in *Z. marina* area (the chance of observing exactly 0.0% change at a site is extremely small). This is consistent with the absence of a sound-wide trend and supports the finding from the paired-site results.

Our current sound-wide results clearly do not provide evidence of consistent change in *Z. marina* area across the study area as a whole. However, as we assess the data at smaller spatial scales, the results become more complex and more compelling.

4.1.2 Regional

Within the five regions that make up the study area, *Z. marina* area is more variable than at the sound-wide, or study area, scale. There is some evidence for change within the regions but in general it takes the form of short-term oscillations and not a persistent trend. This in itself is an important result because short-term variability, most likely natural variability, had not previously been documented in Puget Sound at the scale of the regions. This information has significant management implications. For example, any attempt to associate change in *Z. marina* area with a particular causal factor, such as some permitted in-water activity, must consider natural variability and be able to isolate this factor. Likewise, any specific targets in a *Z. marina* remediation effort must consider the background variability over short time horizons in order to formulate appropriate project performance measures.

Hood Canal is the important exception at the regional scale. The persistent decline observed over three years (2001-2004) in Hood Canal provides perhaps the single most important SVMP result to date. The three consecutive estimates of declines follow a 2000-01 estimate of an increase but the net effect is a cumulative decline of nearly -15% in *Z. marina* area (Figure 4-1).

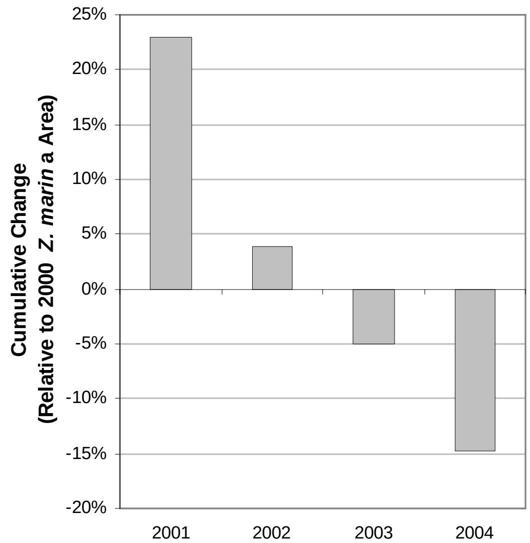

Figure 4-1. The cumulative decline in Hood Canal *Z. marina* area relative to 2000 conditions that is suggested by the year-to-year change estimates (presented in Figure 3-7, p.32). Determining the statistical reliability of these cumulative change estimates is problematic but the uncertainty increases considerably relative to the original paired-site results.

This result is particularly relevant given the current scientific and political focus on Hood Canal associated with low dissolved oxygen in Hood Canal waters. Previous work has shown that low dissolved conditions can have a deleterious effect on *Z. marina* (Holmer and Bondgaard 2001; Lapointe et al. 1994; Glaub et al. 2005). This work raises the possibility of a linkage between low dissolved oxygen conditions and the persistent declines in *Z. marina* we have found in Hood Canal. This potential linkage deserves further investigation.

The importance of this linkage is magnified when we consider that *Z. marina* does not simply react passively to dissolved oxygen conditions. It plays a direct role in the aquatic oxygen budget, both through oxygen generation and demand but indirectly through its effects on the nutrient budget. These issues are not well understood and have not been assessed in the Hood Canal system. SVMP staff presented these issues and the data presented in this report to the state legislature, through the Select Committee on Hood Canal, in direct fulfillment of the PSAMP statutory direction (p.3).

As with the sound-wide results, there are important limitations to consider when interpreting the regional results. The problem with low sample size in the regional strata has been discussed previously (Berry et al. 2003). Several regional *Z. marina* change results could not be calculated due to an insufficient number of samples (Figure 3-7, p.32). This was one of the main motivations for initiating the focus area study in 2004.

Even when regional results could be computed, however, reliability of the estimates is a concern because of the low sample sizes. We have seen that the procedure used to estimate confidence intervals was not reliable when used at the sound-wide scale (Dowty

2005b). In this report we replaced the procedure used previously to estimates confidence intervals at the sound-wide scale with Monte Carlo estimates, but the Monte Carlo analysis has not yet been completed at the regional scale.

For this reason, the confidence interval estimates at the regional scale should be treated with caution. This may draw into question the significance of the individual declines in Hood Canal, but when the three consecutive declines are considered together this pattern is highly unlikely to occur by chance. Therefore the significance of the overall pattern is greater than that of the individual declines and increases the likelihood that this represents a real decline in Hood Canal *Z. marina* area.

4.1.3 Site-Level

Site-level analysis differs from the regional and sound-wide scales in a couple of important aspects. Since site-level analysis involves the repeated application of statistical tests to a large number of sites, it is important to consider the expected number of false positives for the particular α level used in testing. Also, since there are several parameters estimated at the site-level (area, maximum and minimum depth, patchiness), it is possible to look at multiple parameters for corroborating evidence of change.

Estimates of Change and Expected False Positives

For the 2002-03 interval, we tested 50 paired sites for change in *Z. marina* area. We would expect 2-3 sites to be identified as having significant change when testing at α=0.05 (95% confidence) and 10 sites to be identified when testing at α=0.2 (80% confidence) simply due to the effects of chance in producing false positive results. We would expect similar numbers for the 2003-04 interval when 56 sites were tested (2-3 false positives expected when testing at α=0.05 and 11-12 expected at α=0.2).

Clearly we must be cautious when interpreting a single positive change result from a particular site without any corroborating information. This includes interpreting in isolation the site results of Figure 3-8 through Figure 3-11. However, the actual number of sites with statistically significant change in *Z. marina* area is greater than expected by chance alone for both intervals and both levels of significance. Where chance alone would lead us to expect 2-3 and 10 sites with significant change in 2002-03, we observed 5 and 12 sites when testing at α=0.05 and α=0.2 respectively. For 2003-04, where chance alone would lead us to expect 2-3 and 11-12 sites, we observed 9 and 19 sites with significant change when testing at α=0.05 and α=0.2 respectively. This suggests that real changes in *Z. marina* area have taken place that are localized and measurable at the site-level.

The results from our first five-year trend analyses at the site-level are more striking. The large number of sites with significant trends (16 of 22 sites) when testing at α=0.2 was much higher than the expected number due to chance alone (4-5 sites) and was dominated by declining trends (13 sites). These results provide very strong evidence that there are not only real site-level changes in *Z. marina* but that they are persistent trends not just short-term variability. Unfortunately, many of these sites (except the core sites) are now eligible to rotate out of the sample so there is no assurance that we will be able to further track these sites as part of our current sampling design.

When we extend this analysis to the change results for mean maximum and mean minimum depth, we find that the numbers of sites with significant change is relatively close to the numbers expected due to chance alone.

The need to consider false positive results is an unavoidable consequence of the repeated application of statistical tests. Even so, the numbers of sites we are seeing with significant change indicate that we are capturing real localized changes in our results. This is particularly true with the 5-year trend results. Nevertheless, the numbers of expected false positives is not negligible and this complicates the interpretation of results for any individual site. Fortunately we can take a more comprehensive look at the various site-level results to increase our ability to reliably identify individual sites undergoing change.

Multi-Parameter Assessment

We can improve our ability to detect change at individual sites by evaluating multiple parameters in concert. We have estimates of changes in site *Z. marina* area, mean maximum depth, mean minimum depth and five-year trends, although we do not have estimates for all these parameters for all sites. We also calculate a patchiness index at each site (Berry et al. 2003) but the relationship between changes in patchiness and *Z. marina* decline or expansion is complex and we will not use these results here.

In addition to considering multiple parameters, we can consider results from two change intervals (2002-03 and 2003-04) to look for corroborating evidence of change. In these two intervals, only one site had consistent, statistically significant change in *Z. marina* area. This was hdc2239 in the northern area of Hood Canal. This consistency provides assurance that *Z. marina* at this site is declining and that this is a reliable result. Site hdc2239 entered the sample in 2002 and is scheduled to be sampled in 2005 and 2006 before becoming eligible to rotate out. We will watch these future results closely to see if the trend continues at this site.

Two sites had significant changes in mean maximum depth in both intervals but the results were not consistent. In each case an expansion at the deep margin in 2002-03 was followed by a retreat in 2003-04. These two sites were nps1363 – Village Pt. on Lummi Island, and flats43 – Dabob Bay in Hood Canal.

Only one site had significant changes in mean minimum depth in both intervals and these also were not consistent. At nps1363 a receding shallow margin in 2002-03 was followed by an expansion in 2003-04.

When we examined all three of these parameters together in both change intervals and included the five-year trend results, we increased the potential of the analysis but we also increased the complexity. This was not a systematic assessment since we did not have complete results for all sites. This was simply an opportunistic effort to utilize all available data. Also, there were no obvious rules about how to weight the parameters when they conflict.

We took the following approach. We first considered all results, whether significant or not. We focused on identifying sites experiencing declines as these are our greatest concern and they have the greatest management relevance. We considered changes in *Z. marina* area, mean maximum and mean minimum depth in both time intervals as six parameters in one category and the five-year trends in a separate category. We generally considered four or more of the six parameters indicating decline to be strong evidence. Similarly, we considered a significant five-year declining trend to be strong evidence. Convergence in the evidence was clearly considered strong evidence of decline. When the evidence was conflicting or equivocal we considered a number of secondary factors. These included the level of statistical significance associated with the results, the temporal pattern of the data points used in the five-year trend analysis (Appendix J), and the completeness of the data (number of values available for consideration). All data were initially summarized in a format to facilitate this multi-parameter assessment (Appendix K). We also considered the existence of independent observations where the evidence was compelling.

We identified fourteen sites through the multi-parameter assessment that have strong or very strong evidence of declining *Z. marina*. We have put these in two categories based on the strength of the evidence in the available data. All of these sites were sampled in 2003 and 2004 except Westcott Bay, flats53, which was last sampled in 2001 but was included because of overwhelming independent information (Wyllie-Echeverria et al. 2003). The location of these sites is shown in Figure 4-2. Table 4-1 lists the sites and their regions and also indicates which sites remain in the 2005 sample. All but one of the five sites in the category with stronger evidence will be sampled in 2005. Four of the sites in the other category randomly rotated out of the sample and are not scheduled to be sampled in 2005: cps1686, flats62, nps1363 and swh1556.

category	site code	site name	region	remains in sample in 2005?
very strong evidence of decline	flats18	Similk Bay	Saratoga – Whidbey	yes
	flats53	Westcott Bay	San Juan – Straits	no
	hdc2239	Hood Canal NE	Hood Canal	yes
	sjs0081	Broken Point (Shaw Is.)	San Juan – Straits	yes
	swh1625	S. of Tulalip Bay	Saratoga – Whidbey	yes
strong evidence of decline	core006	Burley Spit	Central Puget Sound	yes
	cps1686	Fort Lawton	Central Puget Sound	no
	flats37	Wing Point	Central Puget Sound	yes
	flats43	Dabob Bay	Hood Canal	yes
	flats62	Swifts Bay	San Juan – Straits	no
	hdc2359	Lynch Cove Fringe	Hood Canal	yes
	nps0654	Yellow Reef (Guemes Is.)	North Puget Sound	yes
	nps1363	Village Point (Lummi Is.)	North Puget Sound	no
	swh1556	NW Camano Island	Saratoga – Whidbey	no

Table 4-1. Sites identified by multi-parameter assessment as having strong evidence of *Z. marina* decline. The last column indicates which sites will be sampled in 2005 and which have rotated out of the sample (flats53 rotated out following the 2001 sampling).

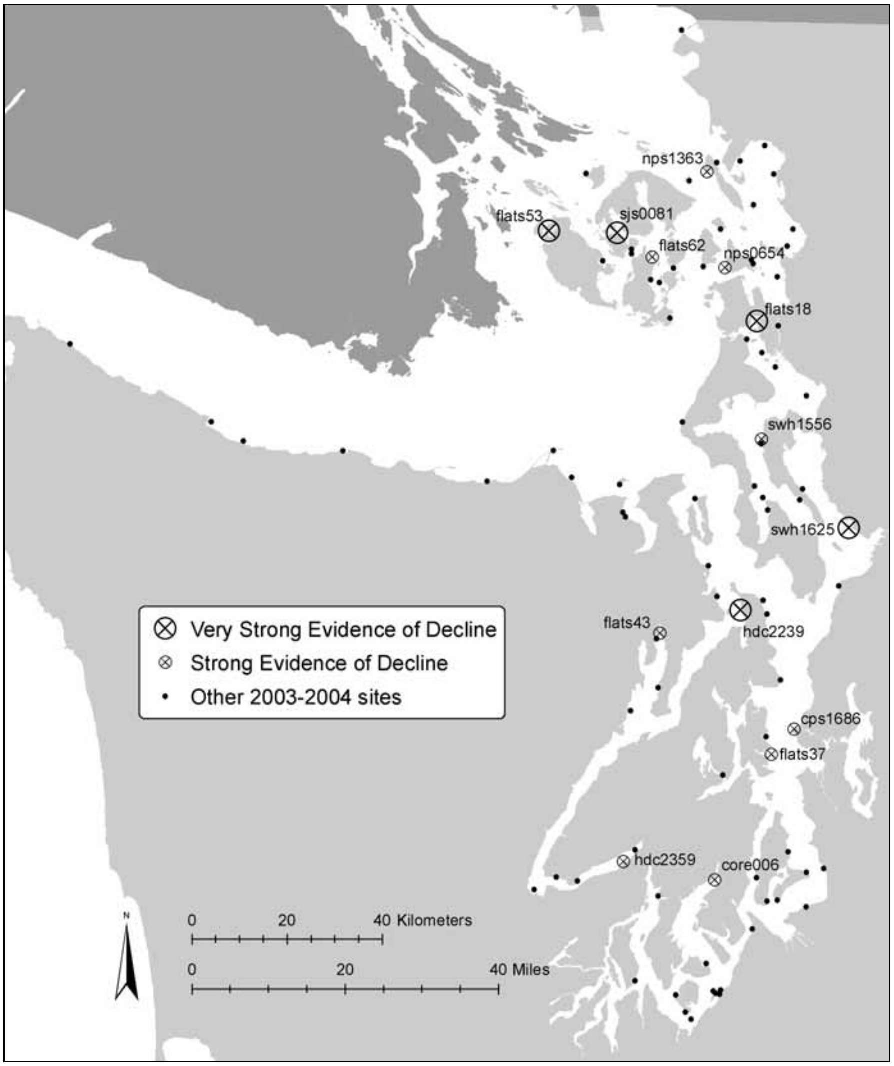

Figure 4-2. Sites with strong evidence of decline as identified by the multi-parameter assessment. Sites were placed in one of two categories depending on the strength of the evidence in the available data.

There is a clear need for continued monitoring of these sites with declining *Z. marina*. This continued monitoring may differ from SVMP methodology and will likely rely on partnerships with other agencies and local entities. There is also a need to explore the relative ecological value of declining sites in terms of their importance as herring spawning areas, nursery areas for Dungeness Crab, feeding grounds for great blue heron and sites important for black brant migration.

<u>*Z. japonica*</u>

Z. japonica is an introduced species that tends to have a shorter growth form and different leaf morphology than *Z. marina*. It is not clear how it differs from *Z. marina* in terms of the ecological services it provides, but its distribution has been shown to be locally very dynamic (Bulthuis and Shull 2003). It tends to colonize shallower areas in the upper intertidal. We have observed *Z. japonica* only where *Z. marina* is also present. In some cases we have observed the two species in different depth ranges with open areas separating the beds. In other cases there is a zone of intermixing of the two species that can be quite extensive. We will continue to record our observations of *Z. japonica* within and across sites.

Association with Water Quality Parameters

These temperature and salinity results generally fell within optimum ranges for *Z. marina* vegetative growth in Puget Sound (Phillips, 1974) and support our conclusion that areas of greater oceanic influence tended to have deeper absolute and mean maximum *Z. marina* bed depths. Water quality parameters varied broadly within regions and within years. The weak correlations (i.e. $R^2 < 0.50$) between water quality parameters and maximum *Z. marina* depth indicate other physical parameters and disturbance vectors, such as amount and characteristics of substrate, wave action and tidal amplitude, also limit the depth to which *Z. marina* can grow.

These data allow us to quantify the wide range of parameters for summer conditions at the edge of the *Z. marina* beds throughout the study area. For any parameter, the data exhibited a gradient of conditions generally from north to south.

The K_d measurements were weakly correlated with depth, which supports the suggestion that water quality is not a singular controlling factor for *Z. marina* depth. It should also be noted that these measurements encompassed a much broader range than other embayments such as San Francisco Bay and Chesapeake Bay.

Our snapshot water quality data represents conditions only on a given day. Between years, we did not control for sampling day within the three-month field season. Seagrasses are long-term integrators responding to “average” conditions. Since annual sampling does not necessarily reflect average conditions, we would not expect the data to be strongly correlated with *Z. marina* area.

The recommendation from the SVMP project staff was to discontinue the water quality sampling at this level, i.e. one vertical transect per site per year. Therefore, we should consider implementing continuous monitoring at a subset of core sites in the future. Long-term continuous measurements of these sorts of parameters are expensive, but they are critical to separating anthropogenic impacts from natural stochasticity.

4.2 Areas of Concern

We have two major areas of concern regarding *Z. marina* decline in the greater Puget Sound that are at a broader scale than the localized declines identified in Figure 4-2. These areas of concern are in Hood Canal and the shallow embayments of the San Juan Islands.

In the case of Hood Canal, our results strongly suggest the presence of a three-year declining trend (Figure 3-7, p.32). Because of concern over these declines and the broader concern associated with low dissolved oxygen, we selected Hood Canal as our 2005 focus area. Results from this effort will give us an overall status estimate for *Z. marina* area in Hood Canal and provide a baseline for estimating change when our rotating focus area sampling returns to the area in 2010. It is important to look for corroborating evidence that confirms the trend we have reported and to identify causal factors. If there is a linkage with the increasing frequency and duration of hypoxia events, this relationship needs to be documented and brought to managers and decisionmakers who will be balancing costs and benefits of management options in Hood Canal.

The *Z. marina* declines in the embayments of the San Juan Islands are a continuing concern. Following a workshop on this issue in 2003 (Wyllie-Echeverria et al. 2003) we have applied our data in collaborative efforts to better document these declines (Wyllie-Echeverria et al. 2005a, 2005b; Reeves et al. 2005). This analysis has shown that five embayments in particular have experienced strong declines (Figure 4-3). Two of these (Westcott Bay and Blind Bay) have been documented as herring spawning sites, which emphasizes the potential importance of these declines as effects propagate through the nearshore and broader marine system. Only one of the five sites identified (Westcott Bay, flats53) emerged as a site with strong or very strong evidence of concern in the multi-parameter analysis across Puget Sound (Table 4-1 and Figure 4-2). One reason for this is that the analysis of the San Juan embayments used archived aerial photography to consider a longer time period than spanned by the SVMP dataset. Also, the results revealed a pattern of decline at the heads of embayments, typically confined to only a portion of the corresponding SVMP site area. Hence, the declines that were clear at the head of the embayments were less apparent at the overall site-scale.

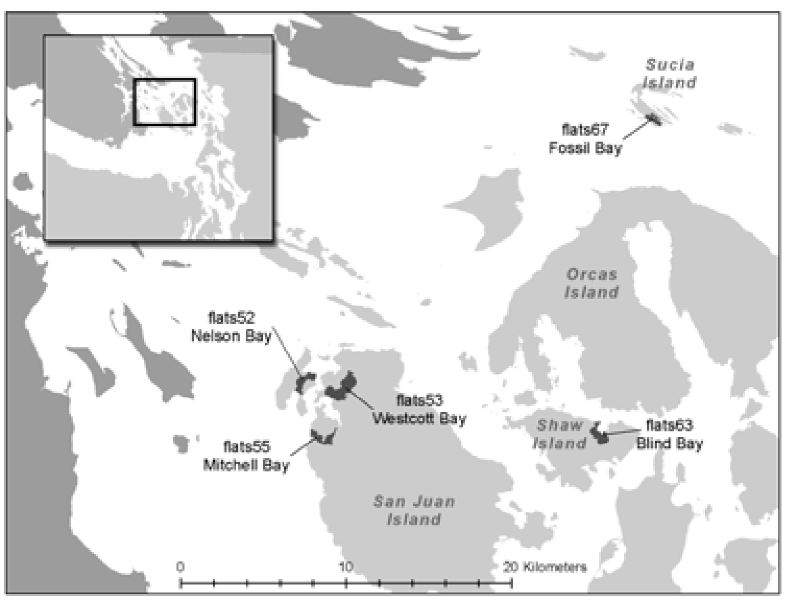

Figure 4-3. Five embayments in the San Juan Islands where strong declines in *Z. marina* have been documented.

We are continuing our collaborative work to better define the scope of these declines at the heads of San Juan embayments and to identify causal factors. We have not seen persistent declines overall in the San Juan – Straits region (Figure 3-7, p.32) but the area where these declines have been observed is only a small part of this region so this is not unexpected. Since each of the five identified embayments is influenced by the discharge of the Fraser River, one possible causal factor is the intensity and timing of sediment plumes from this river. Zimmerman et al. have demonstrated the importance of turbidity in determining *Z. marina* viability (Zimmerman 2003; Zimmerman et al. 2001) and Partridge et al. (2005) report compelling evidence of large-scale sediment events associated with the Fraser River. In the latter study, the Washington Department of Ecology presented an eleven-year record of sediment grain size composition at a site north of the San Juan Archipelago, which revealed a sharp spike in silt in 1997. Such an event could plausibly affect *Z. marina* within the time frame of the declines observed in San Juan embayments. Algal blooms are another plausible explanation that need further evaluation. In our SVMP field sampling, we have occasionally observed vigorous algal blooms that were confined to the heads of San Juan Island embayments, with strong gradients of water clarity improving toward the central area of the embayment.

We know that change at the site level can be dramatic. The total loss of *Z. marina* within 3-4 years at Westcott Bay (flats53), one of the five identified embayments in the San Juan Islands, is an clear example. At the site-level we would ideally like to be able to develop an early warning capability to identify sites that may experience sharp losses in the future, but others suggest than once decline is detected it is difficult to reverse (Hemminga and Duarte 2000).

An important benefit to producing results at multiple scales is that we can better characterize the scope of detected declines. By considering site, region and sound-wide scales together we can determine that most of the site-level declines we have identified (Figure 4-2) are localized and not indicative of broad patterns that would be detected at higher scales. This is borne out by the lack of consistent trend in most regions and in the study area as a whole. Hood Canal is the exception. Our results suggest that there is a broader pattern within this basin that deserves further attention.

4.3 How is the Monitoring Design Performing?

Our previous work has shown that given our current data record we anticipate meeting our target detection capability (Dowty 2005a). Our target is to achieve the ability to detect a 20% decline in *Z. marina* area throughout Puget Sound in a 10-year data record (Berry et al. 2003). In this respect, our monitoring design is performing as planned.

In practice, though, the project is evaluated on the suite of parameters we estimate at different time scales and a range of spatial scales and on our ability to maximize available resources. In this reporting period we have acted aggressively to improve the project overall by streamlining our activities, increasing our precision for a given unit of effort and by improving the reliability of our estimates. Specific examples include the improved precision associated with our revised stratification; the development and implementation of our rotating focus area study in response to weaknesses seen in our regional results; the elimination of monitoring components – water quality and plant characteristics sampling – that were not sufficiently productive; and the implementation of Monte Carlo studies to improve the reliability of our estimates.

When assessing project performance, it is important to recognize two major challenges facing the project. First, the project is designed to monitor a single seagrass species so *Z. marina* must be distinguished from confounding vegetation such as green algae and *Z. japonica*. Second, the bathymetry and water clarity in greater Puget Sound are such that *Z. marina* grows beyond the depth range accessible by remote sensing methods commonly used elsewhere for nearshore vegetation surveys.

4.3.1 Assessment of Focus Area Estimates

The precision of the focus area status estimates was lower than expected (Figure 3-3, p.28). The results indicated that one particular stratum (fringe-other) was responsible for the low precision. Within the fringe-other stratum, uncertainty was dominated by sampling error rather than measurement error (Table 4-2).

sampling error (ha^2)	286,5537
measurement error (ha^2)	46

Table 4-2. Sampling and measurement error within the fringe-other stratum.

The high sampling error suggests that the distribution of sites in this stratum may contain outliers that have a similar effect as has previously been demonstrated in the sound-wide flats stratum (Dowty 2005a). This is indeed the case as shown in Figure 4-4.

The sites sjs0351 (NW Waldron Is.) and sjs0115 (White Cliff on Decatur Island) are extreme outliers relative to the rest of the sample. The site sjs0351 is a wide fringe site in the sound-wide study and sjs0115 is a narrow fringe. This indicates there was a cost, in terms of precision, to combining wide and narrow fringe sites for the focus area study. However, even if sjs0351 is withheld from the estimate, the effect of sjs0115 alone leads to a similar level of precision.

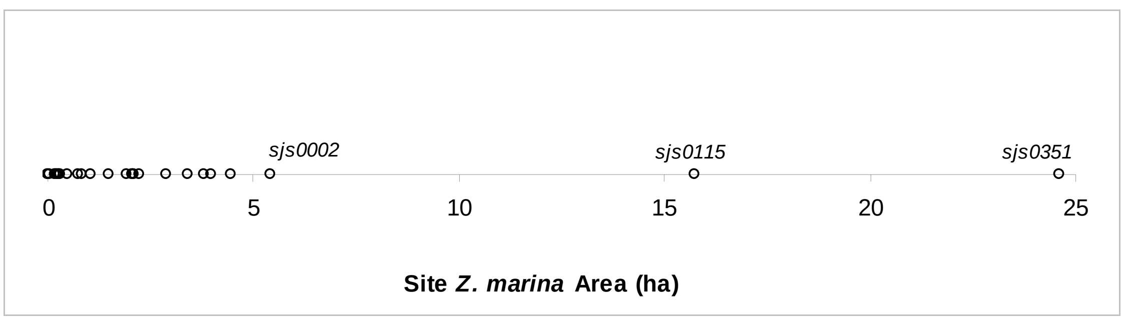

Figure 4-4. Distribution of *Z. marina* area for fringe sites in the fringe-other stratum (*Z. marina* present or status unknown).

These results emphasize the need for a comparative assessment of precision in change estimates based on (1) paired-site analysis and (2) change in status estimates. This assessment should include the effect of highly skewed distributions.

We have not yet finalized an approach to site rotation in the focus areas. Future statistical work that is currently planned may help provide guidance. The main options need to be further developed but in short are:

1. No rotation. This will optimize the change estimates using paired site analysis. It would also optimize change analysis using the status estimates but this would likely be an inferior test relative to the paired site test.
2. 20% rotation. This follows the sound-wide design and lowers the possibility of missing localized change not in the vicinity of a fixed set of random sites. It would also allow for the possibility of applying the retrospective adjustment calculation.

4.4 Current Priorities

It is critical for the SVMP to be responsive to changing management priorities for Puget Sound. It is also important for the SVMP to continually examine operations for opportunities to improve the reliability of results and overall project efficiency.

In response to these needs, we have identified several priorities to guide our current efforts.

1. Complete 2005 focus area sampling in Hood Canal and examine results for corroborating evidence of decline in *Z. marina*. Initiate process studies and pursue partnerships and external funding to identify causal relationships between *Z. marina* decline and environmental stressors.
2. Increase effort in current collaboration with the University of Washington and the FRIENDS of the San Juans to identify factors causing *Z. marina* decline in shallow embayments of the San Juan Islands.
3. Develop plan to build partnerships to ensure sites with strong evidence of declining *Z. marina* continue to be monitored when these sites rotate out of the SVMP sample.
4. Complete Monte Carlo estimates of precision in the regional change estimates to improve reliability.
5. Further develop multi-parameter assessment of change at sites with significant declines in the 5-year trend analyses.
6. Improve web data dissemination including site-level data.
7. Complete Monte Carlo assessment of the reliability of the retrospective adjustment procedure and investigate benefits of restricting application to a subset of the strata.
8. Complete comparative analysis of options for site rotation and change analysis in the focus areas.

5 Summary

In this report we have presented new 2003-2004 results from our monitoring of *Z. marina* in Puget Sound. This extends our overall data record to five years, 2000-2004. In 2004, we added a major component to our sampling – an ongoing focus area study that will rotate through the five regions of our study area on a five year schedule. We initiated the focus area study in an area that includes the San Juan Islands and Cypress Island since this area has previously been identified as an area of concern (Wyllie-Echeverria et al. 2003). The focus area sampling will allow us to produce robust results at the scale of individual regions within the study area.

In this 2003-04 period we also made several adjustments to our sampling and analysis methods based on recommendations from our first report (Berry et al. 2003) as well as those from a detailed statistical study that we completed (Dowty 2005). Some important changes included enhanced sampling for maximum depth of *Z. marina*, a change to our stratification to improve precision and the elimination of water quality and plant characteristics sampling.

The following points summarize the main findings from this report.

1. Results from the Hood Canal region suggest that *Z. marina* area has declined there for three consecutive years.
2. The other four regions either have not changed measurably in *Z. marina* area or have displayed what is most likely natural variability with no consistent trend.
3. While there is no overall trend in the region that includes the San Juan Islands, we have observed a pattern of sharp declines in several shallow embayments in this area that include herring spawning sites.
4. A multi-parameter assessment of site-level results identified 14 sites with strong evidence of declining *Z. marina*. These sites are dispersed among all the five regions of the study area but none were identified in the Strait of Juan de Fuca portion of the San Juan – Straits region.
5. In greater Puget Sound overall *Z. marina* area is stable. We found no evidence of a decline in total *Z. marina* area or evidence that a significant number of locations in the study area are experiencing *Z. marina* decline. On the contrary, in 2003-04 we had our first observation of significant sound-wide change and it was an increase of 7%.
6. Our most recent estimates of the overall amount of *Z. marina* in greater Puget Sound are consistent with our previous estimates of approximately 20,000 hectares (49,000 acres).

7. We estimate that the San Juan Islands and Cypress Island together account for approximately 7.5% of the total amount of *Z. marina* in the Puget Sound study area.
8. Our results continue to show that the distribution of *Z. marina* in Puget Sound is highly aggregated with more than a quarter of the total (27%) located in Padilla and Samish Bays.

Based on these findings, the entire Hood Canal region is an area of concern for *Z. marina* decline. Given the current interest in identifying and alleviating the factors contributing to low dissolved oxygen conditions, it is important not only to examine the factors causing *Z. marina* decline but also to characterize the role of *Z. marina* in the Hood Canal oxygen budget.

Shallow embayments of the San Juan Islands are a second area of concern for *Z. marina* decline. This area was identified through a collaborative effort that utilized SVMP data in conjunction with other data sources. We continue our collaborative work to document declines in this area and to identify causal factors.

In addition, the 14 sites with strong evidence of *Z. marina* declines represent localized areas of concern. In 2005 we will continue to monitor most of these sites but for the few that have rotated out of the sample it is important to develop a mechanism to ensure some level of continued monitoring.

The contrasting results across spatial scales indicate that the observed declines are not sufficiently widespread to cause overall declines in Puget Sound *Z. marina*. They also indicate that in general declines are of a localized nature except in the case of Hood Canal and the specific case of shallow embayments in an area of the San Juan Islands.

Given these findings and opportunities we see to improve specific aspects of our monitoring, we have identified several priorities to guide our current efforts.

1. Complete 2005 focus area sampling in Hood Canal and examine results for corroborating evidence of decline in *Z. marina*. Develop process studies and pursue partnerships to identify causal factors.
2. Increase effort in current collaboration with the University of Washington and the FRIENDS of the San Juans to identify factors causing *Z. marina* decline in shallow embayments of the San Juan Islands.
3. Develop plan to build partnerships to ensure sites with strong evidence of declining *Z. marina* continue to be monitored when these sites rotate out of the SVMP sample.
4. Complete Monte Carlo estimates of precision in the regional change estimates to improve reliability.
5. Further develop multi-parameter assessment of change at sites with significant declines in the 5-year trend analyses.
6. Improve web data dissemination including site-level data.

7. Complete Monte Carlo assessment of the reliability of the retrospective adjustment procedure and investigate benefits of restricting application to a subset of the strata.

8. Complete comparative analysis of options for site rotation and change analysis in the focus areas.

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Appendix A *Z. marina* Area Estimates at 2003 SVMP Sample Sites

Site	Location	Approximate Latitude (degrees)	Approximate Longitude (degrees)	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) 80% Lower Limit	80% Upper Limit
Core											
Core001	Padilla Bay	48.52086	-122.50592	13,14-July	10	0.6494	2,818.28	42,551.420	0.07	2,554.24	3,082.32
Core002	Picnic Cove	48.56229	-122.92167	4-Jul	25	0.6499	2.98	0.036	0.06	2.74	3.22
Core003	Jamestown	48.13078	-123.07213	12,13-Aug	10	0.5953	489.91	407.399	0.04	464.07	515.74
Core004	Lynch Cove	47.43036	-122.86130	29,30-July	12	0.7264	167.07	86.931	0.06	155.13	179.00
Core005	Dumas Bay	47.33286	-122.37606	3-Aug	20	0.1576	0.67	0.037	0.29	0.42	0.92
Core006	Burley Spit	47.37774	-122.63707	9-Aug	15	0.4815	6.17	0.371	0.10	5.39	6.95
Flats											
Flats08	Portage Bay S.	48.73727	-122.62043	9,10-July	15	0.4997	41.79	36.319	0.14	34.08	49.51
Flats10	Nooksack Delta E.	48.76776	-122.55054	8-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A
Flats11	Samish Bay N.	48.55837	-122.52759	12-Jul	8	0.7469	1,104.11	1,758.532	0.04	1,050.44	1,157.79
Flats18	Similk Bay	48.43667	-122.56061	17-Jul	20	0.4726	38.98	22.077	0.12	32.98	45.01
Flats19	Pull and Be Damned	48.37637	-122.54388	16,17,18-Jul	21	0.3449	152.35	324.882	0.12	129.28	175.42
Flats20	Skagit Bay N.	48.38564	-122.57115	20-Jul	21	0.3271	221.86	473.461	0.10	194.01	249.71
Flats35	Nisqually Delta E.	47.11264	-122.69174	7-Aug	15	0.3933	24.31	8.800	0.12	20.51	28.11
Flats37	Wing Point	47.61775	-122.48772	31-Jul	14	0.4376	17.61	9.416	0.17	13.69	21.54
Flats43	Dabob Bay	47.83891	-122.81747	26-Jul	20	0.5300	11.11	2.394	0.14	9.13	13.09
Flats62	Swifts Bay	48.55140	-122.86195	3-Jul	30	0.4934	10.99	0.842	0.08	9.82	12.17
Narrow Fringe											
cps0221	SE Harstene Island	47.18247	-122.84974	8-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1069	Murden Cove (Bainbridge Island)	47.65080	-122.50460	1-Aug	13	0.4350	9.11	1.208	0.12	7.70	10.51
cps1118	Neill Point (Vashon Island)	47.34018	-122.48922	2-Aug	15	0.5065	3.05	0.054	0.08	2.76	3.35
cps1128	Paradise Cove (Vashon Island)	47.38423	-122.52060	4-Aug	18	0.4844	2.81	0.050	0.08	2.52	3.09
cps1156	Klahanic Beach (Vashon Island)	47.43463	-122.43504	4-Aug	14	0.6546	6.15	0.223	0.08	5.55	6.76
cps1164	N. of Pt. Robinson (Maury Island)	47.39574	-122.38260	3-Aug	14	0.6767	5.84	0.088	0.05	5.46	6.22
cps1175	Piner Point (Maury Island)	47.34251	-122.46132	2-Aug	14	0.5692	4.23	0.032	0.04	4.00	4.46
cps1245	Gertrude Island (by McNeil)	47.21872	-122.65472	6-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1277	Thompson Cove (Anderson Island)	47.12628	-122.70791	8-Aug	15	0.2547	0.97	0.067	0.27	0.64	1.31
cps1282	NE. Anderson Island	47.15803	-122.73662	8-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1295	NW Ketron Island	47.16711	-122.63191	6-Aug	15	0.5522	0.29	0.001	0.12	0.25	0.34
cps1296	NE Ketron Island	47.16328	-122.62795	5-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1686	Fort Lawton	47.66715	-122.42635	10-Aug	10	0.6521	7.65	0.265	0.07	6.99	8.31
cps1804	Salmon Beach (S of Pt. Defiance)	47.28700	-122.52856	5-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1821	Cormorant Passage	47.16177	-122.61504	5-Aug	15	0.2753	0.91	0.035	0.21	0.67	1.16
cps2154	N. Bremerton	47.57681	-122.62183	1-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
cps2201	South of President Point	47.75883	-122.46804	31-Jul	14	0.6381	8.37	0.149	0.05	7.88	8.87
cps2545	Olele Point	47.97090	-122.67849	25-Jul	16	0.6209	0.57	0.002	0.08	0.51	0.63
cps2573	Ft. Flagler	48.09745	-122.72160	11-Aug	15	0.4152	4.22	1.224	0.26	2.80	5.64
hdc2338	Across from Union	47.37391	-123.07831	28-Jul	20	0.6221	1.47	0.008	0.06	1.35	1.58
hdc2344	Great Peninsula	47.36785	-123.01834	28-Jul	20	0.6652	2.04	0.010	0.05	1.91	2.17
hdc2359	Lynch Cove Fringe	47.40760	-122.89194	27-Jul	11	0.7014	10.23	0.269	0.05	9.57	10.90
hdc2529	S. of Tala Point	47.91407	-122.65129	25-Jul	11	0.4844	4.97	0.377	0.12	4.19	5.76
nps0059	Sinclair Island	48.60780	-122.67027	10-Jul	14	0.4545	0.68	0.007	0.12	0.58	0.79
nps0522	Eliza Island NE	48.65539	-122.57840	10-Jul	13	0.5813	3.48	0.101	0.09	3.07	3.89
nps0669	Guemes Island	48.55147	-122.58155	15-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A

Appendix A *Z. marina* Area Estimates at 2003 SVMP Sample Sites

Site	Location	Approximate Latitude (degrees)	Approximate Longitude (degrees)	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)	
										80% Lower Limit	80% Upper Limit
nps1363	Village Pt. (Lummi Island)	48.71571	-122.71381	8-Jul	21	0.4683	1.12	0.016	0.11	0.96	1.28
sjs0081	Broken Point (Shaw Island)	48.59528	-122.96486	5-Jul	20	0.5920	1.48	0.040	0.13	1.23	1.74
sjs0311	Clark Island	48.69796	-122.76405	7-Jul	15	0.6418	1.72	0.037	0.11	1.47	1.97
sjs0365	Thatcher Pass	48.53190	-122.80193	2-Jul	14	0.7210	1.60	0.010	0.06	1.48	1.73
sjs0617	Lopez Sound Road	48.50891	-122.86472	2-Jul	15	0.2498	1.92	0.111	0.17	1.49	2.34
sjs0635	Watmough Bay (Lopez Island)	48.42688	-122.80167	1-Jul	13	0.6514	3.24	0.080	0.09	2.88	3.61
sjs0649	Canoe Island (Shaw Island)	48.55695	-122.92123	4-Jul	4	0.4285	0.03	0.000	0.19	0.02	0.04
sjs0683	Brown Island N.	48.54114	-123.00301	4-Jul	23	0.5397	0.93	0.016	0.13	0.77	1.09
sjs0695	Trump Island (near Decatur Island)	48.50396	-122.83958	1-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs0819	N of Partridge Point	48.24140	-122.76352	13-Aug	11	0.1240	0.29	0.004	0.21	0.21	0.37
sjs0989	Protection Island SW	48.12010	-122.93553	26-Sep	11	0.8245	7.28	0.058	0.03	6.98	7.59
sjs2646	Discovery Bay	48.06700	-122.92414	12-Aug	11	0.6832	1.35	0.005	0.05	1.26	1.44
sjs2813	Rasmusson Creek	48.33870	-124.49399	18-Aug	15	0.4029	2.45	0.065	0.10	2.13	2.78
swh0718	Swinomish Channel	48.42820	-122.49960	15-Jul	8	0.4027	0.14	0.003	0.39	0.07	0.21
swh0940	Holmes Harbor E. (Whidbey Island)	48.07925	-122.51623	21-Jul	15	0.7764	7.33	0.079	0.04	6.97	7.69
swh1556	NW Camano Island	48.21356	-122.53895	22-Jul	19	0.7870	5.94	0.051	0.04	5.65	6.23
swh1593	Camano Island, Cornell	48.12136	-122.41851	23-Jul	16	0.4218	3.96	0.055	0.06	3.65	4.26
swh1625	So of Tulalip Bay	48.04926	-122.28672	23-Jul	18	0.1258	0.22	0.005	0.33	0.12	0.31
swh1647	Mukilteo	47.93962	-122.31035	10-Aug	10	0.6428	6.20	0.109	0.05	5.78	6.62
Wide Fringe											
cps2218	Pilot Pt.	47.88290	-122.51054	24-Jul	14	0.2028	4.32	0.478	0.16	3.43	5.20
cps2221	Point no Point	47.90831	-122.52171	24-Jul	11	0.3573	9.66	0.224	0.05	9.05	10.26
hdc2239	Hood Canal NE	47.88957	-122.58418	25-Jul	11	0.4235	8.74	0.457	0.08	7.87	9.60
nps0654	Yellow Reef (Guemes Island)	48.53537	-122.65604	14-Jul	11	0.8264	9.43	0.113	0.04	9.00	9.86
nps1320	Semiamo Spit	48.98181	-122.79820	6-Jul	15	0.6008	13.93	0.301	0.04	13.23	14.63
sjs0005	Cypress Island S.	48.53615	-122.71677	2-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs0351	NW Waldron Island	48.70554	-123.05815	5-Jul	11	0.9236	26.07	0.073	0.01	25.73	26.42
sjs2678	Dungeness Spit Lighthouse Res.	48.18048	-123.12492	14-Aug	16	0.4727	11.67	1.473	0.10	10.12	13.23
sjs2695	W. Green Point	48.11803	-123.31007	14-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs2741	West of Crescent Bay	48.16444	-123.71955	17-Aug	15	0.3448	11.85	6.069	0.10	8.70	15.00
sjs2766	E of Deep Creek	48.17797	-124.00035	19-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs2775	Pysht River	48.20922	-124.09449	19-Aug	15	0.2911	3.30	0.143	0.11	2.81	3.78
swh0848	Ala Spit	48.40135	-122.58722	16-Jul	11	0.6962	24.72	6.689	0.10	21.41	28.03
swh0943	Hackney Island (Whidbey)	48.10306	-122.53057	21-Jul	11	0.8735	17.47	0.087	0.02	17.09	17.85
swh1575	Camp Dianna, Camano Island	48.10025	-122.42591	22-Jul	11	0.8004	17.01	0.416	0.04	16.19	17.84

Appendix B *Z. marina* Area Estimates at 2004 SVMP Sample Sites

Site	Location	Approximate Latitude (degrees)	Approximate Longitude (degrees)	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) 80% Lower Limit	80% Upper Limit
Core											
Core001	Padilla Bay	48.52086	-122.50592	19-Jul	11	0.7862	3,458.98	39,006.578	0.06	3,206.18	3,711.79
Core002	Picnic Cove	48.56229	-122.92167	30-Jun	12	0.7196	3.30	0.065	0.08	2.97	3.62
Core003	Jamestown	48.13078	-123.07213	9-Sep	11	0.6487	542.86	300.778	0.03	520.66	565.06
Core004	Lynch Cove	47.43036	-122.86130	26-Aug	13	0.5505	126.60	193.629	0.11	108.79	144.41
Core005	Dumas Bay	47.33286	-122.37606	20-Sep	11	0.2838	1.22	0.091	0.25	0.83	1.61
Core006	Burley Spit	47.37774	-122.63707	27-Sep	15	0.3813	4.98	0.656	0.16	3.95	6.02
Persistent Flats											
Flats11	Samish Bay N.	48.55837	-122.52759	13-Jul	8	0.8114	1,202.85	2,446.663	0.04	1,139.53	1,266.16
Flats12	Samish Bay S.	48.57917	-122.48041	15-Jul	9	0.6603	746.37	3,538.475	0.08	670.23	822.51
Flats20	Skagit Bay N.	48.38564	-122.57115	10-Aug	20	0.3472	235.51	452.897	0.09	208.27	262.75
Rotational Flats											
Flats08	Portage Bay S.	48.73727	-122.62043	12-Jul	14	0.7087	60.96	16.249	0.07	55.80	66.12
Flats10	Nooksack Delta E.	48.76776	-122.55054	3-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
Flats18	Similk Bay	48.43667	-122.56061	20-Aug	25	0.4072	32.47	7.448	0.08	28.98	35.97
Flats19	Pull and Be Damned	48.37637	-122.54388	11-Aug	23	0.3764	175.10	198.357	0.08	157.08	193.13
Flats35	Nisqually Delta E.	47.11264	-122.69174	23-Sep	15	0.3417	24.76	18.548	0.17	19.25	30.28
Flats37	Wing Point	47.61775	-122.48772	15-Sep	15	0.3056	12.88	7.983	0.22	9.27	16.50
Flats41	Dosewallips	47.69311	-122.88664	30-Aug	12	0.8178	106.66	21.798	0.04	100.69	112.64
Flats43	Dabob Bay	47.83891	-122.81747	27-Aug	20	0.4971	10.88	2.222	0.14	8.97	12.78
Flats62	Swifts Bay	48.55140	-122.86195	28-Jun	23	0.4163	9.45	1.992	0.15	7.64	11.26
Flats70	South Fork Skagit River	48.29729	-122.41593	13-Aug	10	0.4463	319.76	1,073.067	0.10	277.83	361.69
Narrow Fringe											
cps0221	SE Harstene Island	47.18247	-122.84974	28-Sep	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1069	Murden Cove (Bainbridge Island)	47.65080	-122.50460	14-Sep	14	0.4423	10.29	0.811	0.09	9.13	11.44
cps1128	Paradise Cove (Vashon Island)	47.38423	-122.52060	17-Sep	18	0.5160	3.07	0.060	0.08	2.75	3.38
cps1156	Klahanic Beach (Vashon Island)	47.43463	-122.43504	16-Sep	14	0.6535	6.46	0.141	0.06	5.98	6.94
cps1164	N. of Pt. Robinson (Maury Island)	47.39574	-122.38260	16-Sep	20	0.7122	6.50	0.044	0.03	6.23	6.76
cps1175	Piner Point (Maury Island)	47.34251	-122.46132	17-Sep	18	0.5502	4.12	0.028	0.04	3.90	4.33
cps1245	Gertrude Island (by McNeil)	47.21872	-122.65472	27-Sep	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1277	Thompson Cove (Anderson Island)	47.12628	-122.70791	23-Sep	15	0.3169	1.49	0.111	0.22	1.06	1.92
cps1282	NE. Anderson Island	47.15803	-122.73662	27-Sep	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1296	NE Ketron Island	47.16328	-122.62795	24-Sep	N/A	N/A	0	N/A	N/A	N/A	N/A
cps1686	Fort Lawton	47.66715	-122.42635	13-Sep	11	0.5389	6.69	0.191	0.07	6.13	7.25
cps1750	Des Moines Beach	47.40448	-122.33522	20-Sep	11	0.5114	4.65	0.068	0.06	4.32	4.98
cps1820	Gordon Point	47.16997	-122.61359	24-Sep	4	0.0243	0.002	0.000	1.00	0.00	0.00
cps1821	Cormorant Passage	47.16177	-122.61504	24-Sep	18	0.2559	0.91	0.037	0.21	0.66	1.15
cps1967	Vaughn Bay (Case Inlet)	47.34373	-122.79453	28-Sep	11	0.6447	3.27	0.060	0.07	2.96	3.59
cps2201	South of President Point	47.75883	-122.46804	13-Sep	14	0.5294	8.07	0.236	0.06	7.45	8.69
cps2218	Pilot Pt.	47.88290	-122.51054	10-Sep	14	0.1800	3.88	0.090	0.08	3.50	4.26
cps2573	Ft. Flagler	48.09745	-122.72160	2-Sep	20	0.4616	4.71	0.697	0.18	3.64	5.78
hdc2338	Across from Union	47.37391	-123.07831	25-Aug	24	0.6110	1.65	0.004	0.04	1.57	1.73
hdc2344	Great Peninsula	47.36785	-123.01834	24-Aug	20	0.4708	1.47	0.023	0.10	1.28	1.67
hdc2359	Lynch Cove Fringe	47.40760	-122.89194	25-Aug	11	0.6896	10.06	0.132	0.04	9.60	10.52

Appendix B *Z. marina* Area Estimates at 2004 SVMP Sample Sites

Site	Location	Approximate Latitude (degrees)	Approximate Longitude (degrees)	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)	
										80% Lower Limit	80% Upper Limit
hdc2465	SE of Dabob Bay	47.83015	-122.81914	27-Aug	14	0.6736	6.88	0.211	0.07	6.29	7.46
hdc2479	Toanados Peninsula, West Side	47.73832	-122.81109	31-Aug	11	0.6221	7.87	0.145	0.05	7.38	8.35
hdc2529	S. of Tala Point	47.91407	-122.65129	23-Aug	15	0.5296	5.58	0.203	0.08	5.00	6.15
nps0059	Sinclair Island	48.60780	-122.67027	5-Aug	16	0.4644	0.65	0.002	0.07	0.59	0.72
nps0522	Eliza Island NE	48.65539	-122.57840	9-Jul	10	0.4061	2.99	0.201	0.15	2.42	3.57
nps0670	Boat Harbor (Guemes Island)	48.54435	-122.57668	20-Jul	10	0.4684	0.13	0.000	0.12	0.11	0.15
nps0669	Guemes Island	48.55147	-122.58155	2-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A
nps1363	Village Pt. (Lummi Island)	48.71571	-122.71381	4-Aug	23	0.4339	1.07	0.008	0.08	0.96	1.19
nps1392	Lummi Point (Lummi Island)	48.73358	-122.68769	3-Aug	16	0.6758	14.92	0.980	0.07	13.66	16.19
sjs0081	Broken Point (Shaw Island)	48.59528	-122.96486	21-Jul	21	0.4080	1.04	0.005	0.07	0.95	1.14
sjs0311	Clark Island	48.69796	-122.76405	5-Aug	15	0.7017	1.93	0.041	0.10	1.67	2.19
sjs0617	Lopez Sound Road	48.50891	-122.86472	30-Jul	17	0.2713	2.10	0.083	0.14	1.73	2.47
sjs0635	Watmough Bay (Lopez Island)	48.42688	-122.80167	23-Jul	16	0.5659	2.88	0.074	0.09	2.53	3.23
sjs0649	Canoe Island (Shaw Island)	48.55695	-122.92123	30-Jun	4	0.3070	0.02	0.000	0.26	0.01	0.03
sjs0683	Brown Island N.	48.54114	-123.00301	29-Jun	20	0.4751	0.85	0.018	0.16	0.67	1.02
sjs0695	Trump Island (near Decatur Island)	48.50396	-122.83958	19-Aug	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs0819	N of Partridge Point	48.24140	-122.76352	3-Sep	15	0.1372	0.33	0.009	0.28	0.21	0.45
sjs0989	Protection Island SW	48.12010	-122.93553	30-Sep	15	0.8320	7.83	0.076	0.04	7.47	8.18
sjs2645	Gardiner, Discovery Bay	48.05943	-122.91812	2-Sep	12	0.4833	0.53	0.006	0.14	0.43	0.62
sjs2646	Discovery Bay	48.06700	-122.92414	2-Sep	11	0.7103	1.45	0.007	0.06	1.34	1.55
swh0940	Holmes Harbor E. (Whidbey Island)	48.07925	-122.51623	23-Jul	11	0.7171	7.04	0.167	0.06	6.52	7.57
swh1556	NW Camano Island	48.21356	-122.53895	24-Jun	15	0.7283	5.59	0.099	0.06	5.19	5.99
swh1557	Rockaway Beach	48.20463	-122.53993	24-Jun	15	0.5111	3.05	0.227	0.16	2.44	3.66
swh1593	Camano Island, Cornell	48.12136	-122.41851	21-Jun	12	0.3028	2.84	0.081	0.10	2.48	3.21
swh1625	So of Tulalip Bay	48.04926	-122.28672	22-Jun	14	0.0946	0.18	0.002	0.28	0.11	0.24
Wide Fringe											
cps2221	Point no Point	47.90831	-122.52171	1-Sep	11	0.3275	8.90	0.347	0.07	8.15	9.65
hdc2239	Hood Canal NE	47.88957	-122.58418	31-Aug	15	0.3405	7.02	0.188	0.06	6.47	7.58
hdc2383	Anna's Bay	47.34856	-123.13948	24-Aug	15	0.2401	3.78	0.097	0.08	3.38	4.18
nps0654	Yellow Reef (Guemes Island)	48.53537	-122.65604	2-Jul	11	0.8109	9.27	0.256	0.05	8.62	9.92
nps1320	Semiamo Spit	48.98181	-122.79820	16-Aug	11	0.5512	15.15	0.301	0.04	14.44	15.85
nps1433	Post Point, Fairhaven	48.71454	-122.52422	3-Aug	16	0.7277	3.06	0.042	0.07	2.80	3.32
sjs0351	NW Waldron Island	48.70554	-123.05815	20-Jul	11	0.8711	24.59	0.230	0.02	23.98	25.20
sjs2695	W. Green Point	48.11803	-123.31007	8-Sep	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs2741	West of Crescent Bay	48.16444	-123.71955	8-Sep	14	0.5318	18.25	6.432	0.14	15.00	21.50
sjs2775	Pysht River	48.20922	-124.09449	7-Sep	15	0.4304	5.71	0.282	0.09	5.03	6.39
swh0848	Ala Spit	48.40135	-122.58722	25-Jun	19	0.7030	25.02	0.990	0.04	23.75	26.30
swh0918	Pratts Bluff (Whidbey Island)	48.12393	-122.55524	23-Jun	11	0.6968	13.87	0.437	0.05	13.03	14.72
swh0943	Hackney Island (Whidbey)	48.10306	-122.53057	23-Jun	17	0.8858	17.94	0.238	0.03	17.31	18.56
swh1575	Camp Dianna, Camano Island	48.10025	-122.42591	22-Jun	11	0.7401	16.38	0.822	0.06	15.22	17.54

Appendix C *Z. marina* Area Estimates at 2004 Focus Area Sample Sites

Site	Location	Approximate Latitude (degrees)	Approximate Longitude (degrees)	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)	
										80% Lower Limit	80% Upper Limit
Flats											
Flats51 (03)	Provost Harbor (Stuart Island)	48.67612	-123.18630	15-Aug	8	0.7156	12.98	0.925	0.07	11.75	14.21
Flats51	Provost Harbor (Stuart Island)	48.67612	-123.18630	6-Jul	18	0.6200	11.25	0.719	0.08	10.16	12.33
Flats52	Nelson Bay	48.60311	-123.18091	28-Jul	12	0.7883	14.87	0.780	0.06	13.74	16.00
Flats52 (03)	Nelson Bay	48.60311	-123.18091	24-Jun	8	0.5995	11.31	5.527	0.21	8.30	14.32
Flats55	Mitchell Bay	48.57096	-123.16532	27-Jul	14	0.3446	3.48	0.337	0.17	2.74	4.22
Flats55 (03)	Mitchell Bay	48.57096	-123.16532	28-May	7	0.4646	4.69	0.463	0.15	3.82	5.56
Flats56	False Bay (San Juan Island)	48.48505	-123.06935	8-Jul	11	0.2845	6.87	1.065	0.15	5.55	8.19
Flats56 (03)	False Bay (San Juan Island)	48.48505	-123.06935	17-Aug	13	0.2250	5.43	0.816	0.17	4.28	6.59
Flats58	Barlow Bay	48.43755	-122.86943	29-Jul	12	0.7117	7.37	0.187	0.06	6.82	7.93
Flats58 (03)	Barlow Bay	48.43755	-122.86943	13-Jun	11	0.7003	7.26	0.372	0.08	6.47	8.04
Flats61	Shoal Bay	48.55947	-122.88125	30-Jun	23	0.6403	6.34	0.154	0.06	5.84	6.85
Flats61 (03)	Shoal Bay	48.55947	-122.88125	30-May	18	0.6437	6.38	0.296	0.09	5.68	7.07
Flats63	Blind Bay	48.57824	-122.93717	18-Aug	28	0.3383	5.49	1.287	0.21	4.03	6.94
Flats63 (03)	Blind Bay	48.57824	-122.93717	21-Aug	35	0.2649	4.30	1.249	0.26	2.87	5.73
Flats67	Fossil Bay (Sucia Island)	48.75037	-122.90005	7-Jul	14	0.3396	4.73	0.910	0.20	3.51	5.95
Flats67 (03)	Fossil Bay (Sucia Island)	48.75037	-122.90005	7-May	12	0.4147	5.77	0.629	0.14	4.76	6.79
Narrow Fringe											
sjs0002	S. Strawberry Bay (Cypress Island)	48.55703	-122.72486	19-Aug	11	0.6445	5.40	0.111	0.06	4.97	5.83
sjs0115	White Cliff (Decatur Island)	48.49985	-122.79226	1-Jul	15	0.7194	15.75	0.576	0.05	14.78	16.72
sjs0138	North side of North Bay	48.51887	-123.00297	18-Aug	14	0.3271	1.47	0.172	0.28	0.94	2.00
sjs0140	Pear Point (San Juan Island)	48.51500	-122.98077	5-Jul	9	0.6789	2.25	0.017	0.06	2.08	2.41
sjs0153	San Juan Channel, Terrace Dr.	48.56352	-123.02702	29-Jun	7	0.0000	0.00	N/A	N/A	N/A	N/A
sjs0154	San Juan Channel, N. of Terrace Dr.	48.56546	-123.03953	29-Jun	12	0.5220	0.20	0.000	0.08	0.18	0.21
sjs0182	Smugglers Cove (San Juan Island)	48.56383	-123.17653	8-Jul	11	0.6789	0.26	0.000	0.06	0.24	0.29
sjs0192	S of Edwards Reef (San Juan Island)	48.49678	-123.12611	8-Jul	11	0.4065	0.50	0.012	0.22	0.36	0.64
sjs0311	Clark Island	48.69796	-122.76405	5-Aug	15	0.7017	1.93	0.041	0.10	1.67	2.19
sjs0345	Point Disney (Waldron Island)	48.67610	-123.04406	21-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs0346	Waldron Dock (Waldron Island)	48.68388	-123.03857	21-Jul	11	0.6682	3.43	0.071	0.08	3.09	3.77
sjs0359	S of Mail Bay (Waldron Island)	48.69721	-123.00518	7-Jul	11	0.3905	0.23	0.002	0.22	0.17	0.30
sjs0392	E. Sound County Park (Orcas Island)	48.68924	-122.90210	22-Jul	13	0.9858	0.30	0.001	0.09	0.27	0.33
sjs0400	Across from Rosaria (Orcas Island)	48.64293	-122.88879	22-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A
sjs0434	Deer Harbor (Orcas Island)	48.61598	-123.00120	22-Jul	13	0.6532	4.00	0.116	0.09	3.56	4.44
sjs0437	Steep Point (Orcas Island)	48.61010	-123.01934	29-Jul	10	0.7619	0.72	0.002	0.06	0.67	0.78
sjs0453	Racoon Point (Orcas Island)	48.70927	-122.94870	7-Jul	9	0.7060	3.82	0.094	0.08	3.43	4.22
sjs0499	NW John's Island	48.66783	-123.16268	26-Jul	12	0.7578	2.06	0.041	0.10	1.80	2.32
sjs0557	North side of Crane Island	48.60043	-123.00126	26-Jul	12	0.6491	4.46	0.198	0.10	3.89	5.03
sjs1303	NW of Kellet Bluff (Henery Island)	48.59217	-123.20312	27-Jul	N/A	N/A	0	N/A	N/A	N/A	N/A

Appendix D — Relative change in *Z. marina* area for sites sampled in 2002 and 2003

Site	2002 *Z. marina* Area (ha)	2002 Variance	2003 *Z. marina* Area (ha)	2003 Variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
core001	3,215.84	23,272.124	2,818.28	42,551.420	-12.4	58.43	7.64	9.80	14.98	80% (decrease)
core002	2.94	0.015	3.02	0.035	2.7	57.72	7.60	9.74	14.89	ns
core003	476.81	1,122.600	489.91	407.399	2.7	70.05	8.37	10.73	16.40	ns
core004	165.44	170.625	167.07	86.931	1.0	95.33	9.76	12.52	19.14	ns
core005	1.00	0.065	0.67	0.037	-32.5	676.29	26.01	33.34	50.97	ns
core006	7.06	1.317	6.17	0.371	-12.7	275.77	16.61	21.29	32.55	ns
cps1118	2.30	0.078	3.05	0.054	32.7	358.50	18.93	24.27	37.11	80% (increase)
cps1128	25,864	2,153,508	28,084	4,973,483	8.6	112.30	10.60	13.59	20.77	ns
cps1156	6.02	0.214	6.15	0.223	2.2	123.23	11.10	14.23	21.76	ns
cps1164	5.57	0.119	5.84	0.088	4.9	70.76	8.41	10.78	16.49	ns
cps1295	0.28	0.001	0.29	0.001	3.7	281.71	16.78	21.52	32.90	ns
cps1686	7.15	0.231	7.65	0.265	6.9	103.46	10.17	13.04	19.94	ns
cps2218	3.88	0.312	4.32	0.478	11.1	572.6	23.93	30.68	46.90	ns
cps2221	95,153	43,215,571	96,567	22,372,787	1.5	73.9	8.59	11.02	16.85	ns
cps2545	0.41	0.006	0.57	0.002	39.2	802.54	28.33	36.32	55.53	80% (increase)
cps2573	3.49	0.515	4.22	1.224	20.9	1,622.23	40.28	51.64	78.94	ns
flats11	1,158.85	2,836.730	1,104.11	1,758.532	-4.7	32.27	5.68	7.28	11.13	ns
flats18	42.29	10.115	39.00	22.077	-7.8	171.52	13.10	16.79	25.67	ns
flats20	227.94	836.046	221.86	473.461	-2.7	243.55	15.61	20.01	30.59	ns
flats35	15.72	6.926	24.31	8.800	54.7	1,027.30	32.05	41.09	62.82	80% (increase)
flats37	14.76	11.273	17.61	9.416	19.3	1,168.60	34.18	43.82	67.00	ns
flats43	14.21	2.471	11.11	2.394	-21.8	193.46	13.91	17.83	27.26	80% (decrease)
flats62	11.68	2.291	10.99	0.842	-5.9	210.69	14.52	18.61	28.45	ns
hdc2239	10.68	0.495	8.74	0.457	-18.2	69.14	8.31	10.66	16.30	95% (decrease)
hdc2338	1.52	0.009	1.47	0.008	-3.5	71.94	8.48	10.87	16.62	ns
hdc2359	10.68	0.192	10.23	0.269	-4.2	38.95	6.24	8.00	12.23	ns
hdc2529	5.48	0.258	4.97	0.377	-9.2	196.32	14.01	17.96	27.46	ns
nps0059	0.55	0.005	0.68	0.007	23.4	480.07	21.91	28.09	42.94	ns
nps0522	3.72	0.064	3.48	0.101	-6.4	114.32	10.69	13.71	20.96	ns
nps0654	8.25	0.155	9.43	0.113	14.4	46.30	6.80	8.72	13.34	95% (increase)
nps1363	1.01	0.015	1.12	0.016	11.6	346.22	18.61	23.85	36.47	ns
sjs0081	1.90	0.009	1.48	0.040	-21.8	125.59	11.21	14.37	21.97	80% (decrease)
sjs0311	1.84	0.013	1.72	0.037	-6.5	144.3	12.01	15.40	23.54	ns
sjs0351	25.45	0.215	26.07	0.073	2.4	4.61	2.15	2.75	4.21	ns
sjs0365	1.83	0.005	1.60	0.010	-12.6	40.5	6.36	8.16	12.47	95% (decrease)
sjs0617	1.42	0.110	1.92	0.111	34.7	1,536.78	39.20	50.26	76.84	ns
sjs0649	0.02	0.000	0.03	0.000	44.8	4,109.9	64.11	82.19	125.65	ns
sjs0819	0.62	0.006	0.29	0.004	-53.3	133.1	11.54	14.79	22.62	95% (decrease)
sjs2646	1.35	0.005	1.35	0.005	0.5	55.3	7.43	9.53	14.57	ns
sjs2678	13.84	0.909	11.67	1.473	-15.7	110.7	10.52	13.49	20.62	80% (decrease)
sjs2741	10.72	10.170	11.85	6.069	10.6	1,611.1	40.14	51.46	78.67	ns
sjs2813	2.87	0.059	2.45	0.065	-14.6	131.1	11.45	14.68	22.45	ns
swh0718	0.04	0.000	0.14	0.003	242.3	46,608.3	215.89	276.77	423.14	ns
swh0848	24.96	2.010	24.72	6.689	-1.0	139.0	11.79	15.11	23.11	ns
swh0943	17.80	0.380	17.47	0.087	-1.9	14.3	3.78	4.85	7.41	ns
swh1556	5.70	0.095	5.94	0.051	4.1	47.4	6.89	8.83	13.50	ns
swh1575	15.60	0.001	17.01	0.416	9.1	17.2	4.14	5.31	8.12	95% (increase)
swh1593	4.09	0.226	3.96	0.055	-3.2	160.1	12.65	16.22	24.80	ns
swh1625	0.22	0.006	0.22	0.005	-2.4	2,266.2	47.60	61.03	93.30	ns
swh1647	6.07	0.133	6.20	0.109	2.2	67.3	8.21	10.52	16.08	ns

ns = change is not significant

Appendix E   Relative change in *Z. marina* area for sites sampled in 2003 and 2004

Site	2003 *Z. marina* Area (ha)	2003 Variance	2004 *Z. marina* Area (ha)	2004 Variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
core001	2,818.28	42,551.420	3,458.98	39,006.578	22.7	129.81	11.39	14.6	22.3	95% (increase)
core002	2.98	0.036	3.30	0.065	10.7	122.48	11.07	14.2	21.7	ns
core003	489.91	407.399	542.86	300.778	10.8	33.37	5.78	7.4	11.3	80% (increase)
core004	167.07	86.931	126.60	193.629	-24.2	87.26	9.34	12.0	18.3	95% (decrease)
core005	0.67	0.037	1.22	0.091	81.6	4,746.72	68.90	88.3	135.0	ns
core006	6.17	0.371	4.98	0.656	-19.2	236.13	15.37	19.7	30.1	ns
cps1069	9.11	1.208	10.29	0.811	12.9	283.57	16.84	21.6	33.0	ns
cps1128	2.73	0.143	3.07	0.060	12.4	322.77	17.97	23.0	35.2	ns
cps1156	6.15	0.223	6.46	0.141	4.9	102.13	10.11	13.0	19.8	ns
cps1164	5.84	0.088	6.50	0.044	11.2	44.78	6.69	8.6	13.1	80% (increase)
cps1175	4.23	0.032	4.12	0.028	-2.7	32.40	5.69	7.3	11.2	ns
cps1277	0.97	0.067	1.49	0.111	52.9	2,829.89	53.20	68.2	104.3	ns
cps1686	7.65	0.265	6.69	0.191	-12.5	67.32	8.20	10.5	16.1	80% (decrease)
cps1821	0.91	0.035	0.91	0.037	-0.8	859.23	29.31	37.6	57.5	ns
cps2201	8.37	0.149	8.07	0.236	-3.6	53.38	7.31	9.4	14.3	ns
cps2218	4.32	0.478	3.88	0.090	-10.1	255.9	16.00	20.5	31.4	ns
cps2221	9.66	0.224	8.90	0.347	-7.8	57.6	7.59	9.7	14.9	ns
cps2573	4.22	1.224	4.71	0.697	11.7	1,249.17	35.34	45.3	69.3	ns
flats08	41.79	36.319	60.96	16.249	45.9	535.43	23.14	29.7	45.4	95% (increase)
flats11	1,104.11	1,758.532	1,202.85	2,446.663	8.9	37.19	6.10	7.8	12.0	80% (increase)
flats18	39.00	22.077	32.47	7.448	-16.7	149.62	12.23	15.7	24.0	80% (decrease)
flats19	152.35	324.882	175.10	198.357	14.9	270.35	16.44	21.1	32.2	ns
flats20	221.86	473.461	235.51	452.897	6.2	200.41	14.16	18.1	27.7	ns
flats35	24.31	8.800	24.76	18.548	1.9	468.40	21.64	27.7	42.4	ns
flats37	17.61	9.416	12.88	7.983	-26.8	419.74	20.49	26.3	40.2	80% (decrease)
flats43	11.11	2.394	10.88	2.222	-2.1	365.54	19.12	24.5	37.5	ns
flats62	10.99	0.842	9.45	1.992	-14.0	216.48	14.71	18.9	28.8	ns
hdc2239	8.74	0.457	7.02	0.188	-19.6	63.30	7.96	10.2	15.6	95% (decrease)
hdc2338	1.47	0.008	1.65	0.004	12.4	66.71	8.17	10.5	16.0	80% (increase)
hdc2344	2.04	0.010	1.47	0.023	-27.7	68.21	8.26	10.6	16.2	95% (decrease)
hdc2359	10.23	0.269	10.06	0.132	-1.7	37.38	6.11	7.8	12.0	ns
hdc2529	4.97	0.377	5.58	0.203	12.2	274.09	16.56	21.2	32.4	ns
nps0059	0.68	0.007	0.65	0.002	-4.4	183.28	13.54	17.4	26.5	ns
nps0522	3.48	0.101	2.92	0.201	-16.2	225.00	15.00	19.2	29.4	ns
nps0654	9.43	0.113	9.27	0.256	-1.7	40.97	6.40	8.2	12.5	ns
nps1320	13.93	0.301	15.15	0.301	8.7	33.87	5.82	7.5	11.4	80% (increase)
nps1363	1.12	0.016	1.07	0.008	-4.3	177.64	13.33	17.1	26.1	ns
sjs0081	1.48	0.040	1.04	0.005	-29.6	112.74	10.62	13.6	20.8	95% (decrease)
sjs0311	1.72	0.037	1.93	0.041	12.0	295.2	17.18	22.0	33.7	ns
sjs0351	26.07	0.073	24.59	0.230	-5.7	4.34	2.08	2.7	4.1	95% (decrease)
sjs0617	1.92	0.111	2.10	0.083	9.6	589.80	24.29	31.1	47.6	ns
sjs0635	3.24	0.080	2.88	0.074	-11.3	130.24	11.41	14.6	22.4	ns
sjs0649	0.03	0.000	0.02	0.000	-28.3	530.3	23.03	29.5	45.1	ns
sjs0683	0.95	0.015	0.85	0.018	-11.2	331.44	18.21	23.3	35.7	ns
sjs0819	0.29	0.004	0.33	0.009	12.8	1,584.9	39.81	51.0	78.0	ns
sjs0989	7.28	0.058	7.83	0.076	7.5	26.9	5.18	6.6	10.2	80% (increase)

Appendix E Relative change in *Z. marina* area for sites sampled in 2003 and 2004

Site	2003 *Z. marina* Area (ha)	2003 Variance	2004 *Z. marina* Area (ha)	2004 Variance	Relative Change (%)	Variance of Change	SE of Change	80% CI (half width)	95% CI (half width)	Confidence in Detected Change
sjs2646	1.35	0.005	1.45	0.007	6.9	68.7	8.29	10.6	16.2	ns
sjs2741	11.85	6.069	18.25	6.432	54.0	1,482.6	38.50	49.4	75.5	80% (increase)
sjs2775	3.30	0.143	5.71	0.282	73.1	654.5	25.58	32.8	50.1	95% (increase)
swh0848	24.72	6.689	25.02	0.990	1.2	128.3	11.33	14.5	22.2	ns
swh0940	7.33	0.079	7.04	0.167	-3.9	44.7	6.68	8.6	13.1	ns
swh0943	17.47	0.087	17.94	0.238	2.7	10.8	3.28	4.2	6.4	ns
swh1556	5.94	0.051	5.59	0.099	-5.9	41.2	6.42	8.2	12.6	ns
swh1575	17.01	0.416	16.38	0.822	-3.7	41.7	6.46	8.3	12.7	ns
swh1593	3.96	0.055	2.84	0.081	-28.1	70.0	8.37	10.7	16.4	95% (decrease)
swh1625	0.22	0.005	0.18	0.002	-18.0	1,265.4	35.57	45.6	69.7	ns

ns = change is not significant

Appendix F *Z. marina* Depth Estimates at 2003 SVMP Sample Sites

(BioSonics depth sounder)

Site	Location	Minimum Eelgrass Depth						Maximum Eelgrass Depth					
		n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)
Core													
Core001	Padilla Bay	10	0.7	0.5	0.1	0.3	0.6	10	-3.8	-3.3	0.2	-3.6	-3.0
Core002	Picnic Cove	24	-0.2	-2.3	0.3	-3.0	-1.6	25	-5.9	-5.2	0.1	-5.3	-5.0
Core003	Jamestown	9	0.4	0.0	0.2	-0.4	0.3	23	-7.9	-6.1	0.3	-6.6	-5.5
Core004	Lynch Cove	11	0.0	-0.4	0.1	-0.5	-0.2	14	-3.7	-3.0	0.1	-3.2	-2.8
Core005	Dumas Bay	12	-0.4	-0.9	0.1	-1.1	-0.7	12	-1.8	-1.6	0.0	-1.6	-1.5
Core006	Burley Spit	15	-0.7	-1.1	0.1	-1.2	-1.0	25	-3.4	-2.6	0.1	-2.7	-2.5
Flats													
Flats08	Portage Bay S.	14	-0.2	-0.5	0.1	-0.6	-0.4	14	-3.0	-2.3	0.1	-2.6	-2.0
Flats11	Samish Bay N.	8	0.5	0.2	0.2	-0.2	0.5	17	-7.9	-3.5	0.3	-4.1	-2.9
Flats18	Similk Bay	20	0.7	-0.4	0.2	-0.8	0.0	20	-3.0	-2.0	0.2	-2.3	-1.7
Flats19	Pull and Be Damned	19	1.0	0.4	0.1	0.2	0.5	20	-1.9	-1.0	0.1	-1.3	-0.8
Flats20	Skagit Bay N.	18	0.0	-0.4	0.1	-0.5	-0.2	18	-2.9	-1.6	0.1	-1.8	-1.3
Flats35	Nisqually Delta E.	14	0.3	0.3	0.1	0.1	0.5	14	-0.9	-0.7	0.0	-0.8	-0.6
Flats37	Wing Point	13	-0.5	-1.3	0.3	-1.9	-0.7	13	-7.1	-4.9	0.4	-5.7	-4.0
Flats43	Dabob Bay	20	-0.2	-0.5	0.1	-0.6	-0.4	19	-7.3	-4.2	0.5	-5.2	-3.2
Flats62	Swifts Bay	22	-0.1	-0.8	0.2	-1.2	-0.3	29	-6.7	-2.9	0.4	-3.7	-2.2
Narrow Fringe													
cps1069	Murden Cove (Bainbridge Island)	12	-0.1	-0.6	0.1	-0.8	-0.4	13	-4.6	-3.6	0.2	-4.1	-3.1
cps1118	Neill Point (Vashon Island)	14	0.5	0.0	0.1	-0.2	0.2	15	-3.3	-1.8	0.2	-2.2	-1.4
cps1128	Paradise Cove (Vashon Island)	10	1.0	0.0	0.3	-0.7	0.8	11	-5.9	-4.3	0.3	-5.0	-3.6
cps1156	Klahanic Beach (Vashon Island)	14	1.1	0.4	0.2	0.1	0.7	14	-4.3	-2.3	0.2	-2.8	-1.8
cps1164	N. of Pt. Robinson (Maury Island)	13	-0.2	-0.6	0.1	-0.9	-0.4	13	-4.8	-2.7	0.2	-3.1	-2.3
cps1175	Piner Point (Maury Island)	14	0.2	-0.2	0.0	-0.2	-0.1	14	-4.1	-2.9	0.2	-3.2	-2.5
cps1277	Thompson Cove (Anderson Island)	12	0.1	-0.9	0.2	-1.5	-0.4	12	-3.2	-1.9	0.2	-2.4	-1.4
cps1295	NW Ketron Island	13	0.2	-0.2	0.1	-0.5	0.0	12	-3.6	-2.1	0.3	-2.7	-1.5
cps1686	Fort Lawton	9	0.2	-0.4	0.1	-0.6	-0.2	10	-6.4	-4.9	0.3	-5.6	-4.3
cps1821	Cormorant Passage	10	-0.4	-0.8	0.1	-1.0	-0.6	10	-4.8	-3.5	0.4	-4.3	-2.7
cps2201	South of President Point	11	0.2	-0.4	0.1	-0.6	-0.1	14	-6.3	-5.1	0.2	-5.5	-4.6
cps2545	Olele Point	15	-0.9	-1.2	0.1	-1.3	-1.0	14	-4.6	-3.5	0.1	-3.8	-3.3
cps2573	Ft. Flagler	10	-0.2	-1.0	0.2	-1.6	-0.5	10	-7.6	-4.1	0.7	-5.8	-2.5
hdc2338	Across from Union	19	-0.7	-1.2	0.1	-1.4	-1.1	17	-4.8	-3.2	0.2	-3.6	-2.8
hdc2344	Great Peninsula	20	-0.8	-1.4	0.1	-1.6	-1.2	20	-4.2	-3.4	0.1	-3.5	-3.2
hdc2359	Lynch Cove Fringe	11	-0.2	-0.6	0.1	-0.8	-0.4	11	-4.5	-3.9	0.1	-4.1	-3.7
hdc2529	S. of Tala Point	11	0.9	0.2	0.2	-0.2	0.6	11	-4.9	-3.6	0.2	-4.1	-3.2
nps0059	Sinclair Island	13	-1.2	-2.7	0.3	-3.3	-2.0	14	-6.9	-5.8	0.2	-6.2	-5.4
nps0522	Eliza Island NE	12	-1.5	-2.1	0.1	-2.3	-1.9	12	-8.4	-4.2	0.4	-5.2	-3.4
nps1363	Village Pt. (Lummi Island)	19	-1.6	-3.3	0.3	-4.0	-2.7	19	-7.0	-5.2	0.3	-5.8	-4.7
sjs0081	Broken Point (Shaw Island)	18	-0.6	-0.9	0.1	-1.0	-0.8	15	-7.6	-5.5	0.4	-6.4	-4.7
sjs0311	Clark Island	12	-0.3	-0.7	0.1	-0.8	-0.5	14	-7.1	-4.1	0.4	-4.9	-3.3
sjs0365	Thatcher Pass	14	-0.2	-1.2	0.2	-1.6	-0.8	14	-7.3	-5.2	0.5	-6.3	-4.2
sjs0617	Lopez Sound Road	12	-0.2	-0.3	0.0	-0.4	-0.2	14	-7.7	-4.1	0.7	-5.6	-2.7

Appendix F *Z. marina* Depth Estimates at 2003 SVMP Sample Sites

(BioSonics depth sounder)

Site	Location	Minimum Eelgrass Depth						Maximum Eelgrass Depth					
		n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)
sjs0635	Watmough Bay (Lopez Island)	10	-4.3	-4.8	0.2	-5.1	-4.4	11	-8.0	-6.3	0.2	-6.7	-5.8
sjs0649	Canoe Island (Shaw Island)	4	-3.4	-3.4	0.0	-3.6	-3.3	4	-5.9	-5.4	0.2	-6.2	-4.6
sjs0683	Brown Island N.	19	-0.9	-2.8	0.3	-3.4	-2.2	19	-8.3	-5.6	0.3	-6.3	-4.9
sjs0819	N of Partridge Point	10	-4.2	-5.4	0.2	-5.9	-4.9	8	-6.6	-6.1	0.2	-6.4	-5.8
sjs0989	Protection Island SW	11	0.1	-0.3	0.1	-0.4	-0.2	11	-9.2	-6.7	0.7	-8.4	-5.1
sjs2646	Discovery Bay	11	0.0	-0.7	0.1	-0.9	-0.4	11	-4.7	-3.1	0.3	-3.9	-2.4
sjs2813	Rasmusson Creek	15	-3.7	-4.7	0.2	-5.2	-4.1	15	-9.2	-6.9	0.3	-7.5	-6.4
swh0718	Swinomish Channel	4	-0.5	-0.8	0.3	-1.6	0.0	4	-3.0	-2.0	0.4	-3.2	-0.7
swh0940	Holmes Harbor E. (Whidbey Island)	14	0.0	-0.2	0.0	-0.3	-0.2	14	-4.2	-3.8	0.1	-4.0	-3.7
swh1556	NW Camano Island	19	-0.2	-0.5	0.1	-0.6	-0.5	17	-3.9	-3.2	0.1	-3.4	-2.9
swh1593	Camano Island, Cornell	15	0.3	0.0	0.1	-0.2	0.2	16	-2.0	-1.6	0.1	-1.7	-1.5
swh1625	So of Tulalip Bay	10	0.0	-0.5	0.1	-0.8	-0.2	10	-1.3	-0.7	0.2	-1.1	-0.4
swh1647	Mukilteo	10	-0.8	-1.2	0.1	-1.5	-1.0	10	-5.5	-4.3	0.4	-5.2	-3.4
Wide Fringe													
cps2218	Pilot Pt.	13	1.0	0.4	0.1	0.1	0.7	14	-5.3	-1.7	0.4	-2.5	-0.9
cps2221	Point no Point	11	0.7	0.4	0.1	0.3	0.5	11	-6.1	-4.6	0.5	-5.9	-3.4
hdc2239	Hood Canal NE	11	1.0	0.6	0.1	0.4	0.8	11	-6.2	-4.4	0.2	-4.9	-3.9
nps0654	Yellow Reef (Guemes Island)	10	-0.8	-1.3	0.1	-1.6	-1.0	10	-6.1	-5.2	0.3	-5.9	-4.6
nps1320	Semiamo Spit	15	0.2	0.0	0.0	-0.1	0.1	15	-3.8	-3.5	0.1	-3.6	-3.4
sjs0351	NW Waldron Island	11	0.1	-0.1	0.0	-0.2	0.0	11	-9.6	-8.3	0.2	-8.7	-7.9
sjs2678	Dungeness Spit Lighthouse Res.	15	-3.6	-4.6	0.2	-5.0	-4.2	15	-8.1	-7.5	0.1	-7.8	-7.2
sjs2741	West of Crescent Bay	15	-0.4	-4.2	0.6	-5.5	-2.9	15	-9.0	-8.0	0.2	-8.3	-7.6
sjs2775	Pysht River	12	-1.6	-3.4	0.4	-4.3	-2.6	12	-6.9	-6.0	0.2	-6.5	-5.5
swh0848	Ala Spit	10	0.4	-0.2	0.2	-0.6	0.2	11	-3.1	-2.3	0.1	-2.6	-2.0
swh0943	Hackney Island (Whidbey)	11	0.2	-0.5	0.1	-0.9	-0.3	19	-5.2	-3.9	0.2	-4.2	-3.6
swh1575	Camp Dianna, Camano Island	11	0.1	-0.2	0.0	-0.2	-0.1	11	-3.5	-3.0	0.1	-3.2	-2.9

Appendix G *Z. marina* Depth Estimates at 2004 SVMP Sample Sites

(BioSonics depth sounder)

		Minimum Eelgrass Depth						Maximum Eelgrass Depth					
Site	Location	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)
Core													
Core001	Padilla Bay	11	0.8	0.5	0.2	0.4	0.6	10	-4.3	-3.7	0.4	-4.0	-3.5
Core002	Picnic Cove	12	-0.3	-2.6	1.6	-3.7	-1.5	12	-6.4	-5.3	0.5	-5.6	-4.9
Core003	Jamestown	10	0.2	0.1	0.1	0.0	0.1	11	-7.4	-6.0	1.0	-6.7	-5.3
Core004	Lynch Cove	13	0.0	-0.5	0.3	-0.6	-0.3	13	-3.7	-3.0	0.8	-3.5	-2.5
Core005	Dumas Bay	8	-0.3	-0.6	0.3	-0.8	-0.3	8	-1.7	-1.6	0.2	-1.7	-1.4
Core006	Burley Spit	15	-0.7	-0.9	0.1	-1.0	-0.9	15	-2.8	-2.5	0.1	-2.6	-2.4
Persistent Flats													
Flats11	Samish Bay N.	8	0.5	0.1	0.4	-0.2	0.4	8	-4.5	-3.4	0.5	-3.8	-3.1
Flats12	Samish Bay S.	8	0.7	0.5	0.3	0.3	0.7	8	-3.2	-3.0	0.2	-3.1	-2.9
Flats20	Skagit Bay N.	18	-0.2	-0.5	0.2	-0.6	-0.3	18	-2.9	-1.4	0.4	-1.7	-1.2
Rotational Flats													
Flats08	Portage Bay S.	14	-0.1	-0.5	0.2	-0.6	-0.4	14	-3.2	-2.6	0.3	-2.8	-2.4
Flats18	Similk Bay	24	0.5	-0.4	0.4	-0.7	-0.2	25	-3.5	-2.2	0.4	-2.4	-1.9
Flats19	Pull and Be Damned	22	0.8	-0.2	0.5	-0.5	0.1	22	-2.3	-1.4	0.5	-1.7	-1.2
Flats35	Nisqually Delta E.	12	0.3	0.0	0.2	-0.1	0.2	12	-1.5	-0.9	0.3	-1.1	-0.8
Flats37	Wing Point	14	-0.2	-1.1	0.5	-1.5	-0.8	14	-6.9	-4.6	1.2	-5.5	-3.8
Flats41	Dosewallips	12	0.2	-0.2	0.3	-0.4	0.0	12	-5.3	-3.8	0.9	-4.5	-3.2
Flats43	Dabob Bay	20	0.2	-0.5	0.2	-0.7	-0.4	20	-5.0	-3.4	0.7	-3.9	-3.0
Flats62	Swifts Bay	17	-0.1	-0.9	0.7	-1.4	-0.4	21	-6.9	-2.3	1.2	-3.1	-1.6
Flats70	South Fork Skagit River	9	-0.2	-0.5	0.2	-0.6	-0.3	14	-3.5	-2.7	0.4	-3.0	-2.5
		-	-						-				
Narrow Fringe													
cps1069	Murden Cove (Bainbridge Island)	14	-0.1	-0.5	0.3	-0.7	-0.3	14	-4.8	-4.3	0.3	-4.5	-4.1
cps1128	Paradise Cove (Vashon Island)	15	0.9	-0.2	0.9	-0.8	0.4	16	-5.1	-4.1	0.9	-4.6	-3.4
cps1156	Klahanic Beach (Vashon Island)	14	1.3	0.4	0.5	0.1	0.8	14	-3.4	-2.0	0.7	-2.5	-1.6
cps1164	N. of Pt. Robinson (Maury Island)	20	-0.1	-0.6	0.2	-0.8	-0.5	20	-3.9	-2.5	0.3	-2.7	-2.3
cps1175	Piner Point (Maury Island)	18	0.2	-0.2	0.1	-0.3	-0.1	18	-4.4	-3.1	0.6	-3.4	-2.7
cps1277	Thompson Cove (Anderson Island)	11	0.1	-0.9	0.8	-1.5	-0.4	11	-3.2	-1.9	0.9	-2.4	-1.4
cps1686	Fort Lawton	11	-0.2	-0.6	0.3	-0.8	-0.4	11	-7.9	-5.1	1.4	-6.0	-4.1
cps1750	Des Moines Beach	10	-0.1	-0.1	0.6	-1.0	-0.3	11	-8.1	-5.4	2.2	-6.9	-3.9
cps1820	Gordon Point	1	-0.7	N/A	N/A	N/A	N/A	1	-0.7	N/A	N/A	N/A	N/A
cps1821	Cormorant Passage	13	-0.5	-0.9	0.3	-1.1	-0.7	15	-8.1	-4.0	1.4	-4.9	-3.1
cps1967	Vaughn Bay (Case Inlet)	11	-0.7	-1.0	0.3	-1.2	-0.8	11	-3.6	-3.0	0.6	-3.4	-2.6
cps2201	South of President Point	13	0.4	-0.2	0.5	-0.5	0.1	14	-10.1	-6.3	1.6	-7.3	-5.2
cps2218	Pilot Pt.	13	1.1	0.5	0.5	0.2	0.8	14	-5.7	-1.7	1.3	-2.6	-0.9
cps2573	Ft. Flagler	19	-0.2	-0.9	0.4	-1.2	-0.7	20	-8.3	-3.7	1.9	-4.9	-2.5
hdc2338	Across from Union	24	-0.7	-1.2	0.2	-1.3	-1.0	24	-4.3	-3.2	0.4	-3.4	-2.9
hdc2344	Great Peninsula	20	-0.6	-1.4	0.4	-1.7	-1.2	20	-5.4	-3.2	0.6	-3.6	-2.8
hdc2359	Lynch Cove Fringe	11	-0.2	-0.4	0.2	-0.5	-0.2	11	-4.0	-3.4	0.3	-3.6	-3.2
hdc2465	SE of Dabob Bay	14	-0.3	-0.7	0.3	-0.9	-0.6	14	-4.4	-3.3	0.8	-3.7	-2.7
hdc2479	Toanados Peninsula, West Side	11	-0.5	-0.7	0.1	-0.8	-0.6	11	-5.2	-4.1	0.5	-4.4	-3.8

Appendix G *Z. marina* Depth Estimates at 2004 SVMP Sample Sites

(BioSonics depth sounder)

Site	Location	Minimum Eelgrass Depth						Maximum Eelgrass Depth					
		n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)
hdc2529	S. of Tala Point	15	1.0	0.2	0.5	-0.1	0.5	15	-4.7	-3.7	0.5	-4.0	-3.3
nps0059	Sinclair Island	15	-1.0	-2.3	0.8	-2.8	-1.8	15	-6.5	-5.8	0.6	-6.2	-5.4
nps0522	Eliza Island NE	10	-0.7	-1.8	0.8	-2.4	-1.2	10	-4.5	-3.7	0.5	-4.1	-3.4
nps0670	Boat Harbor (Guemes Island)	10	-0.6	-1.0	0.4	-1.2	-0.7	10	-2.9	-2.4	0.5	-2.7	-2.1
nps1363	Village Pt. (Lummi Island)	22	-1.7	-2.9	0.7	-3.3	-2.4	22	-6.6	-4.6	0.7	-5.0	-4.1
nps1392	Lummi Point (Lummi Island)	14	0.0	-0.5	0.4	-0.7	-0.2	16	-5.0	-3.7	0.5	-4.0	-3.4
sjs0081	Broken Point (Shaw Island)	19	-0.6	-1.0	0.2	-1.1	-0.9	19	-7.3	-3.9	1.5	-4.8	-2.9
sjs0311	Clark Island	14	-0.3	-0.6	0.2	-0.8	-0.5	14	-5.4	-3.9	0.8	-4.5	-3.4
sjs0617	Lopez Sound Road	15	-0.2	-0.5	0.3	-0.8	-0.3	17	-6.4	-4.0	1.9	-5.2	-2.7
sjs0635	Watmough Bay (Lopez Island)	14	-4.0	-4.5	0.4	-4.8	-4.3	14	-7.3	-5.3	0.5	-6.6	-5.9
sjs0649	Canoe Island (Shaw Island)	3	-2.9	-3.5	1.2	-5.1	-1.9	4	-5.9	-5.4	0.6	-6.0	-4.8
sjs0683	Brown Island N.	12	-1.3	-2.5	0.7	-3.0	-2.0	15	-7.6	-5.7	0.8	-6.2	-5.1
sjs0819	N of Partridge Point	11	-4.4	-5.3	0.7	-5.8	-4.8	12	-6.6	-6.2	0.6	-6.6	-5.8
sjs0989	Protection Island SW	12	-0.1	-0.5	0.3	-0.6	-0.3	15	-10.5	-7.1	2.2	-8.5	-5.7
sjs2645	Gardiner, Discovery Bay	11	-0.8	-1.2	0.5	-1.5	-0.9	11	-6.2	-4.5	0.8	-5.1	-3.9
sjs2646	Discovery Bay	11	0.1	-0.4	0.4	-0.7	-0.1	11	-4.6	-3.2	1.0	-3.9	-2.5
swh0940	Holmes Harbor E. (Whidbey Island)	10	0.5	-0.1	0.3	-0.3	0.2	11	-5.3	-3.9	0.6	-4.3	-3.5
swh1556	NW Camano Island	15	-0.2	-0.5	0.1	-0.6	-0.4	15	-3.7	-3.1	0.5	-3.4	-2.8
swh1557	Rockaway Beach	12	0.0	-0.5	0.3	-0.7	-0.3	12	-4.0	-3.0	0.5	-3.4	-2.7
swh1593	Camano Island, Cornell	11	0.0	-0.5	0.2	-0.7	-0.4	11	-1.8	-1.6	0.3	-1.7	-1.4
swh1625	So of Tulalip Bay	6	0.0	-0.2	0.3	-0.5	0.0	6	-0.9	-0.4	0.5	-0.7	0.0
Wide Fringe													
cps2221	Point no Point	11	0.8	0.2	0.5	-0.1	0.6	11	-5.9	-4.5	1.2	-5.2	-3.6
hdc2239	Hood Canal NE	15	0.9	0.4	0.2	0.2	0.5	15	-5.2	-3.7	0.8	-4.2	-3.2
hdc2383	Anna's Bay	13	0.0	-0.5	0.2	-0.6	-0.3	13	-2.2	-1.4	0.3	-1.6	-1.2
nps0654	Yellow Reef (Guemes Island)	11	-1.4	-1.9	0.4	-2.2	-1.6	10	-6.0	-5.1	1.1	-5.9	-4.4
nps1320	Semiamo Spit	11	0.2	-0.1	0.2	-0.2	0.1	11	-3.9	-3.7	0.1	-3.8	-3.6
nps1433	Post Pt. (Fairhaven)	9	-0.1	-0.9	1.2	-1.7	-0.1	16	-4.1	-3.4	0.5	-3.7	-3.2
sjs0351	NW Waldron Island	11	0.1	-0.1	0.1	-0.2	0.0	11	-8.3	-7.8	0.4	-8.0	-7.6
sjs2741	West of Crescent Bay	12	-0.7	-3.7	2.5	-5.5	-2.1	13	-9.2	-8.1	0.8	-8.6	-7.6
sjs2775	Pysht River	10	-1.5	-2.6	1.2	-3.5	-1.8	10	-8.7	-6.6	0.9	-7.3	-6.0
swh0848	Ala Spit	10	-0.2	-0.7	0.3	-0.9	-0.5	18	-3.4	-2.8	0.3	-3.0	-2.6
swh0918	Pratts Bluff	11	-0.1	-0.4	0.3	-0.6	-0.2	11	-3.9	-3.5	0.2	-3.7	-3.4
swh0943	Hackney Island (Whidbey)	9	-0.2	-0.6	0.2	-0.8	-0.5	17	-4.6	-3.8	0.3	-4.1	-3.6
swh1575	Camp Dianna, Camano Island	11	0.2	-0.2	0.1	-0.2	-0.1	11	-3.9	-3.1	0.3	-3.3	-2.9

Appendix H *Z. marina* Depth Estimates at 2004 Focus Region Sites

(BioSonics depth sounder)

Site	Location	Minimum Eelgrass Depth						Maximum Eelgrass Depth					
		n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)
Flats													
Flats51	Provost Harbor (Stuart Island)	17	-0.8	-1.5	0.4	-1.8	-1.2	18	-7.8	-5.2	0.9	-5.7	-4.6
Flats52	Nelson Bay	11	-0.1	-1.1	0.7	-1.6	-0.6	12	-9.4	-6.6	2.0	-7.9	-5.2
Flats55	Mitchell Bay	10	-1.1	-3.4	1.7	-4.6	-2.3	10	-6.3	-5.1	1.5	-6.1	-4.0
Flats56	False Bay (San Juan Island)	11	0.0	-0.5	0.6	-3.2	-0.4	11	-7.2	-5.9	1.4	-6.9	-4.9
Flats58	Barlow Bay	11	0.0	-0.8	0.4	-1.0	-0.5	12	-2.9	-2.3	0.5	-2.6	-2.0
Flats61	Shoal Bay	12	0.6	-0.1	0.3	-0.3	0.2	21	-7.3	-3.4	1.6	-4.5	-2.4
Flats63	Blind Bay	20	-0.5	-1.8	0.4	-2.1	-1.6	20	-5.5	-3.0	0.7	-3.4	-2.6
Flats67	Fossil Bay (Sucia Island)	14	-0.3	-2.0	0.8	-2.5	-1.4	15	-5.5	-3.0	1.1	-3.7	-2.2
Fringe													
sjs0002	S. Strawberry Bay (Cypress Island)	11	-0.6	-2.4	1.3	-3.2	-1.5	11	-6.9	-5.8	0.5	-6.2	-5.4
sjs0115	White Cliff (Decatur Island)	10	-0.7	-1.1	0.3	-1.3	-0.9	15	-8.0	-7.3	0.3	-7.5	-7.2
sjs0138	North side of North Bay	7	-0.3	-2.5	2.0	-4.0	-1.0	7	-6.8	-5.2	1.3	-6.2	-4.2
sjs0140	Pear Point (San Juan Island)	9	-2.4	-3.4	0.7	-3.8	-2.9	9	-7.9	-6.9	0.9	-7.5	-6.3
sjs0154	San Juan Channel, N. of Terrace Dr.	12	-1.6	-2.7	0.8	-3.2	-2.1	12	-7.3	-5.3	1.1	-6.0	-4.5
sjs0182	Smugglers Cove (San Juan Island)	11	-2.0	-3.3	1.1	-13.4	-8.5	11	-9.2	-6.8	1.5	-7.8	-5.8
sjs0192	S of Edwards Reef (San Juan Island)	11	-4.0	-5.9	1.0	-6.6	-5.2	11	-8.6	-7.6	0.6	-8.0	-7.2
sjs0311	Clark Island	14	-0.3	-0.6	0.2	-0.8	-0.5	14	-5.4	-3.9	0.8	-4.5	-3.4
sjs0346	Waldron Dock (Waldron Island)	10	-1.0	-2.4	1.2	-3.3	-1.6	10	-7.2	-6.1	1.1	-6.9	-5.4
sjs0359	S of Mail Bay (Waldron Island)	8	-1.7	-2.5	1.0	-10.6	-5.7	8	-6.1	-4.9	1.0	-5.6	-4.2
sjs0392	E. Sound County Park (Orcas Island)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
sjs0434	Deer Harbor (Orcas Island)	13	-0.2	-0.5	0.2	-0.7	-0.4	13	-5.5	-4.7	0.9	-5.3	-4.0
sjs0437	Steep Point (Orcas Island)	10	-0.8	-1.0	0.2	-1.2	-0.9	10	-8.1	-6.1	1.7	-7.3	-4.9
sjs0453	Point Doughty (Orcas Island)	9	-0.4	-1.0	0.7	-1.5	-0.5	9	-7.0	-5.4	1.2	-6.2	-4.6
sjs0499	NW John's Island	12	-0.2	-0.9	0.5	-1.2	-0.6	12	-8.7	-7.1	2.0	-8.5	-5.7
sjs0557	North of Crane Island	9	-1.7	-3.0	1.1	-12.5	-7.4	9	-8.7	-7.2	1.2	-8.0	-6.3

Appendix I *Z. marina* Area and Depth Estimates at 2004 Quartermaster Harbor Sites

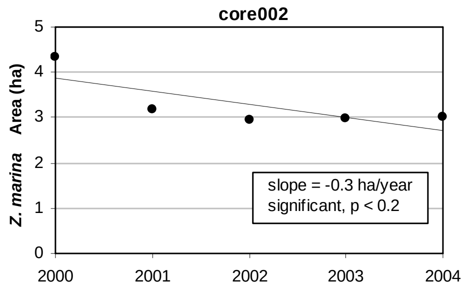
Site	Location	Approximate Latitude (degrees)	Approximate Longitude (degrees)	Date Sampled	Number of Transects	*Z. marina* Fraction Along Transects	*Z. marina* Area at Site (hectares)	Variance	Coefficient of Variation	Estimated *Z. marina* Area Confidence Interval (hectares) 80% Lower Limit	80% Upper Limit
Flats											
Flats33	Quartermaster Harbor	47.39890	-122.45153	21-Sep	11	0.2822	0.95	0.032	0.19	0.72	1.18
Narrow Fringe											
cps1181	Quartermaster Hbr. Fringe #1	47.37444	-122.45261	22-Sep	11	0.6235	1.33	0.012	0.08	1.19	1.47
cps1182	Quartermaster Hbr. Fringe #2	47.38178	-122.44671	22-Sep	11	0.7393	4.60	0.046	0.05	4.32	4.87
cps1186	Quartermaster Hbr. Fringe #3	47.38550	-122.44833	22-Sep	11	0.6783	0.47	0.001	0.06	0.43	0.50

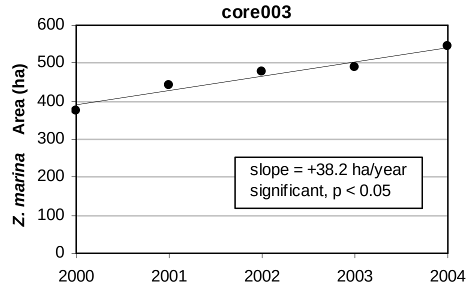
Table I-1. *Z. marina* area estimates at 2004 Quartermaster Harbor sites.

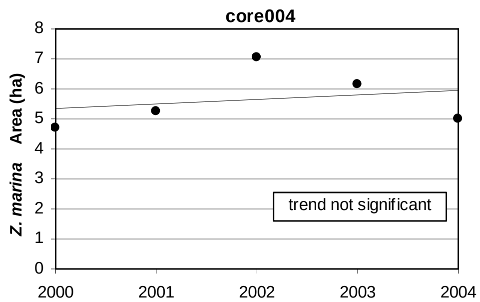
Site	Location	Minimum Eelgrass Depth						Maximum Eelgrass Depth					
		n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)	n	Absolute Depth (m)	Mean Depth (m)	Standard Error	95% Lower Limit (m)	95% Upper Limit (m)
Flats													
Flats33	Quartermaster Harbor	9	-0.1	-0.4	0.3	-0.6	-0.2	9	-2.0	-1.2	0.5	-1.6	-0.8
Fringe													
cps1181	Quartermaster Hbr. Fringe #1	10	-0.3	-0.6	0.1	-0.7	-0.5	10	-2.6	-2.0	0.4	-2.3	-1.8
cps1182	Quartermaster Hbr. Fringe #2	11	-2.1	-2.1	0.2	-0.7	-0.5	11	-3.4	-2.5	0.5	-2.9	-2.2
cps1186	Quartermaster Hbr. Fringe #3	11	-2.1	-2.1	0.2	-1.1	-0.9	11	-2.9	-2.5	0.5	-2.8	-2.1

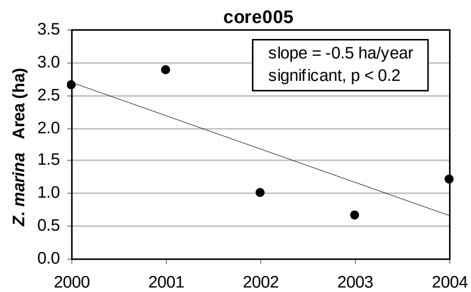
Table I-2. *Z. marina* depth estimates at 2004 Quartermaster Harbor sites.

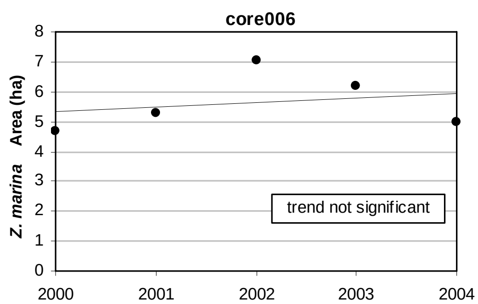
Appendix J Site-Level Five-Year Trend Analyses

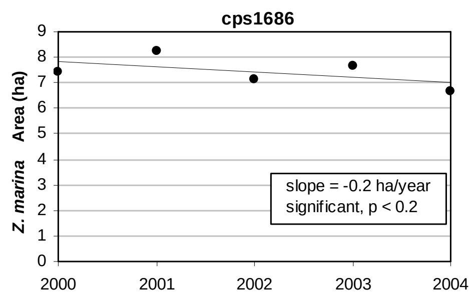


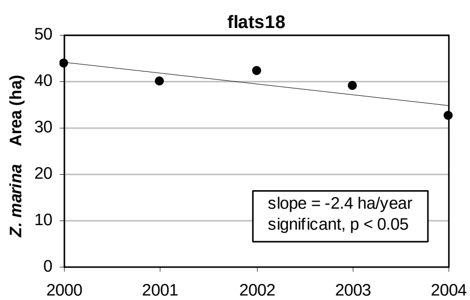


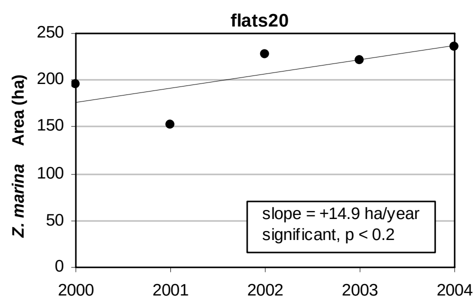


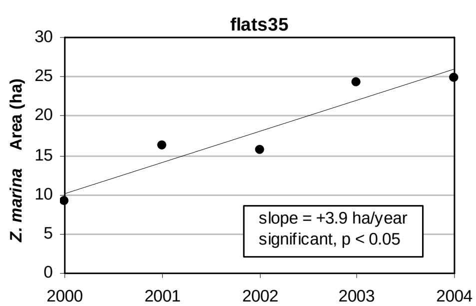


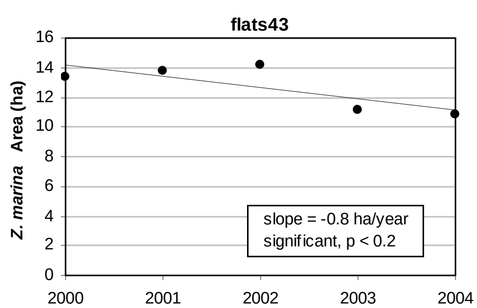


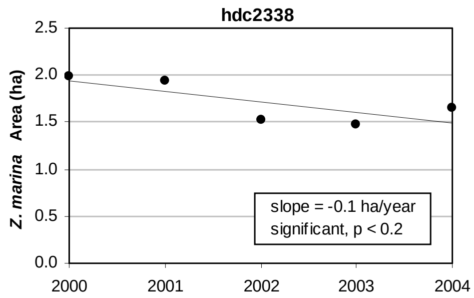


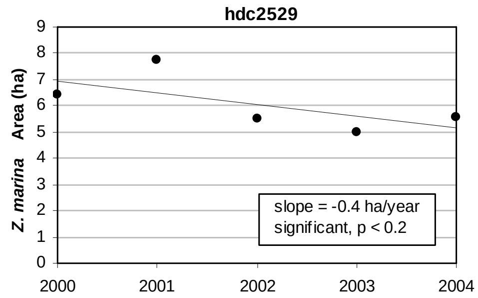


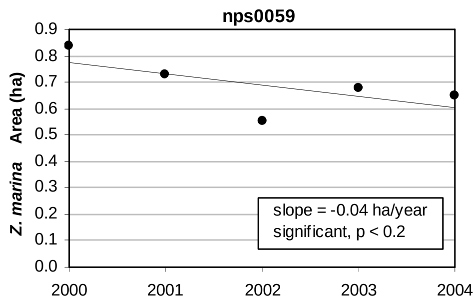


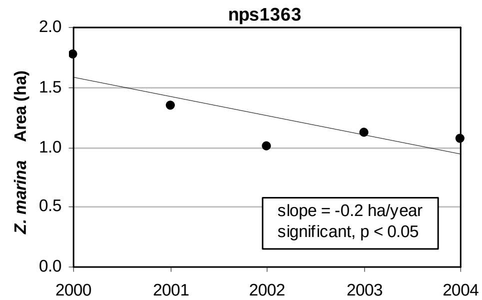


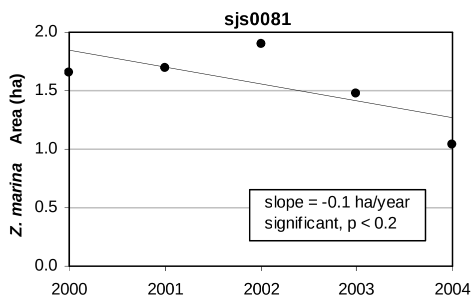


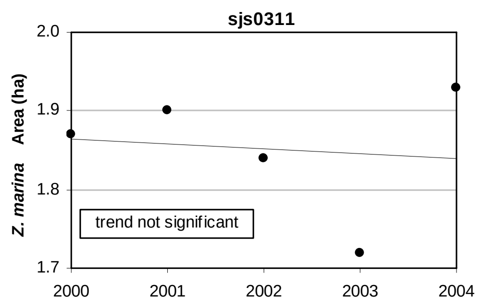

hdc2338
Z. marina Area (ha)
slope = -0.1 ha/year
significant, p < 0.2

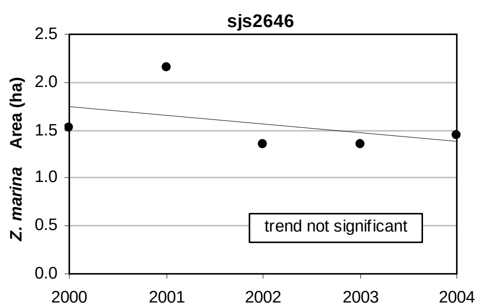

hdc2529
Z. marina Area (ha)
slope = -0.4 ha/year
significant, p < 0.2

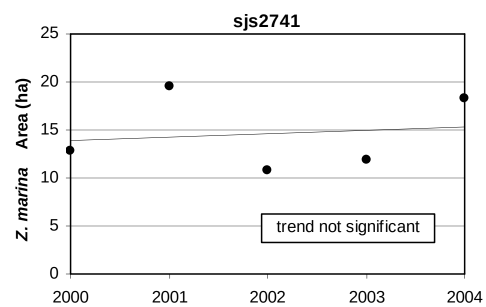

nps0059
Z. marina Area (ha)
slope = -0.04 ha/year
significant, p < 0.2

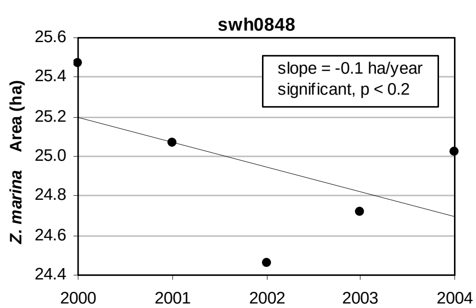

nps1363
Z. marina Area (ha)
slope = -0.2 ha/year
significant, p < 0.05

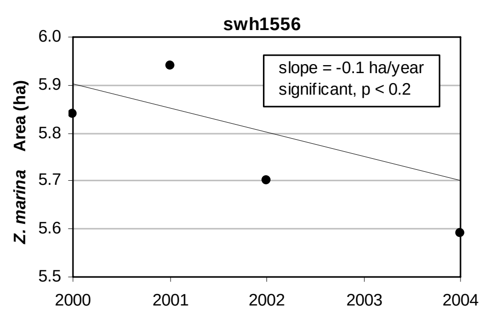

sjs0081
Z. marina Area (ha)
slope = -0.1 ha/year
significant, p < 0.2

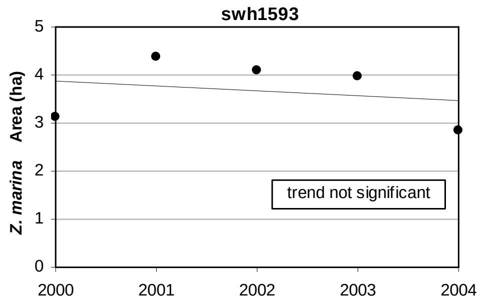

sjs0311
Z. marina Area (ha)
trend not significant

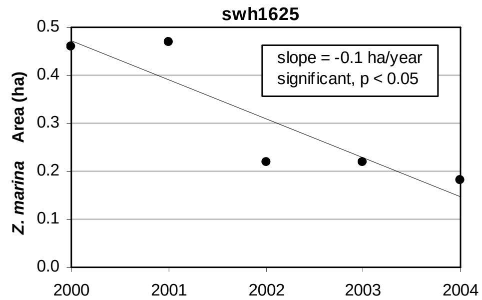

sjs2646
Z. marina Area (ha)
trend not significant


sjs2741
Z. marina Area (ha)
trend not significant


swh0848
Z. marina Area (ha)
slope = -0.1 ha/year
significant, p < 0.2


swh1556
Z. marina Area (ha)
slope = -0.1 ha/year
significant, p < 0.2


swh1593
Z. marina Area (ha)
5
4
3
2
1
0
2000
2001
2002
2003
2004
trend not significant


swh1625
Z. marina Area (ha)
0.5
0.4
0.3
0.2
0.1
0.0
2000
2001
2002
2003
2004
slope = -0.1 ha/year
significant, p < 0.05

Appendix K Multiple Parameter Assessment of Site-Level Change

All site-level results that were used for a multi-parameter assessment of change are shown in Table K-1. The assessment is summarized in section "Multi-Parameter Assessment", p.51.

site	*Z. marina* area change		maximum depth change		minimum depth change		number of indications of decline	5-year trend
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04		
core001	decreased *	increased **	expanded	expanded *	expanded		1	
core002	increased	increased	expanded *	expanded	receded **	receded	2	decreasing*
core003	increased	increased *	expanded **	receded	expanded	expanded	1	expanding**
core004	increased	decreased **	receded			receded	3	no trend
core005	decreased	increased	expanded		receded **	expanded	2	decreasing*
core006	decreased	decreased		receded	receded	expanded *	4	no trend
cps1069		increased		expanded **		expanded	0	
cps1118	increased *		receded *		expanded		1	
cps1128	increased	increased	expanded	receded	expanded *	receded	2	
cps1156	increased	increased	receded	receded	expanded *		2	
cps1164	increased	increased *	expanded	receded	expanded *		1	
cps1175		decreased		expanded			1	
cps1277		increased					0	
cps1295	increased		receded		expanded		1	
cps1686	increased	decreased *	receded	expanded	expanded	receded	3	decreasing*
cps1821		decreased		expanded		receded	2	
cps2201		decreased		expanded **		expanded	1	
cps2218	increased	decreased	receded *	receded	expanded	expanded	3	
cps2221	increased	decreased		receded	expanded	receded	3	
cps2545	increased *		receded *		expanded		1	
cps2573	increased	increased	expanded	receded	receded	expanded	2	
flats08		increased **		expanded *			0	
flats11	decreased	increased *	expanded	receded	expanded	receded	3	
flats18	decreased	decreased *	receded	expanded			3	decreasing**
flats19		increased		expanded *		receded **	1	
flats20	decreased	increased	receded	receded	expanded	receded	4	expanding**
flats35	increased *	increased	receded	expanded	expanded	receded *	2	expanding**
flats37	increased	decreased *	receded	receded	receded	expanded	4	
flats43	decreased *	decreased	expanded *	receded **	receded *		4	decreasing*
flats62	decreased	decreased		receded *	receded	receded	5	
hdc2239	decreased **	decreased **	receded	receded **		receded	5	
hdc2338	decreased	increased *	receded *		expanded *		2	decreasing*
hdc2344		decreased **		receded			2	
hdc2359	decreased	decreased	expanded	receded **	receded *	expanded	4	
hdc2529	decreased	increased		expanded	expanded		1	decreasing*
nps0059	increased	decreased	receded		expanded	expanded	2	decreasing*
nps0522	decreased	decreased	expanded	receded	expanded	expanded	3	
nps0654	increased **	decreased	expanded **	receded	receded	receded **	4	
nps1320		increased *		expanded *		receded	1	
nps1363	increased	decreased	expanded **	receded **	receded **	expanded *	3	decreasing**
sjs0081	decreased *	decreased **	receded	receded **	expanded	receded	5	decreasing*
sjs0311	decreased	increased		receded	expanded	expanded	2	no trend
sjs0351	increased	decreased **	expanded	receded			2	
sjs0365	decreased **				receded		2	
sjs0617	increased	increased	receded	receded	expanded	receded	3	
sjs0635		decreased		receded **		expanded *	2	
sjs0649	increased	decreased	receded		expanded *	receded	3	
sjs0683		decreased		expanded		expanded	1	
sjs0819	decreased **	increased	receded	expanded	receded	expanded	3	
sjs0989		increased *		expanded		receded	1	
sjs2646	increased	increased	expanded	expanded	receded	expanded	1	no trend
sjs2678	decreased *		expanded		receded		2	
sjs2741	increased	increased *	receded	expanded	expanded	expanded	1	no trend
sjs2775		increased **		expanded *		expanded *	0	

site	*Z. marina* area change		maximum depth change		minimum depth change		number of indications of decline	5-year trend
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04		
sjs2813	decreased				receded		2	
swh0718	increased				expanded		0	
swh0848	decreased	increased	receded	expanded **	expanded	receded *	3	decreasing*
swh0940		decreased		expanded		expanded	1	
swh0943	decreased	increased	receded **	receded	expanded **	receded	4	
swh1556	increased	decreased	expanded	receded			2	decreasing*
swh1575	increased **	decreased	expanded	expanded			1	
swh1593	decreased	decreased **	receded *		expanded	receded **	4	no trend
swh1625	decreased	decreased	expanded	receded		expanded	3	decreasing**
swh1647	increased		receded *		expanded		1	

Table K-1. Summary of measures of site-level change in *Z.marina* for all sites sampled in consecutive years, either 2002-2003 or 2003-2004. Six measures of change are shown based on three parameters and two different change intervals. Most sites do not have values for all six measures. Results of the five-year trend tests are also included. Statistical significance of individual measures of change is indicated for p<0.2 (*) and p<0.05 (**). Sites considered to have sufficient evidence for heightened concern are bolded.

In general, the focus was to identify sites with decline in *Z. marina*. The number of the six parameters indicating decline was first compared to the results of the five-year trend analysis. Agreement in the evidence clearly identified a site of concern. When the evidence was conflicting, secondary factors were considered. Some examples are given below of how conflicting evidence was weighed.

core002: Four indicators of expansion overruled a five-year decreasing trend (only 80% confidence). Also, the temporal pattern of data used in the five-year trend analysis showed recent stability (Appendix J). Hence this was not identified as a site of concern.

core005: Three indicators of expansion overruled a five-year decreasing trend (only 80% confidence). Also, the temporal pattern of data used in the five-year trend analysis showed recent stability (Appendix J). Hence this was not identified as a site of concern.

core006: The four indicators of decline stand since there was no five-year trend and the temporal pattern indicates a decline in recent years although neutral overall (Appendix J). This site was identified as a site of concern.

cps1686: Three indicators of decline (including the most recent area change) lend support to the five-year decline, although it was only significant with 80% confidence. This site was identified as a site of concern.

flats18: Three of the four available parameter values indicate decline (including area change in both intervals), consistent with the five-year decline at 95% confidence. This was identified as a site of concern.

flats20: Four indicators of decline overruled by significant five-year expanding trend (95% confidence). This site was not identified as a site of concern.

Appendix L Sites Used in Focus Area Analysis

geomorphic category	study	site	sound-wide stratum	focus area stratum
fringe	focus area study	sjs0002	narrow fringe	fringe-other
		sjs0115	narrow fringe	fringe-other
		sjs0138	narrow fringe	fringe-other
		sjs0140	narrow fringe	fringe-other
		sjs0153	narrow fringe	fringe-other
		sjs0154	narrow fringe	fringe-other
		sjs0182	narrow fringe	fringe-other
		sjs0192	narrow fringe	fringe-other
		sjs0311	narrow fringe	fringe-other
		sjs0346	narrow fringe	fringe-other
		sjs0359	narrow fringe	fringe-other
		sjs0392	narrow fringe	fringe-other
		sjs0434	narrow fringe	fringe-other
		sjs0437	narrow fringe	fringe-other
		sjs0453	narrow fringe	fringe-other
		sjs0499	narrow fringe	fringe-other
		sjs0557	narrow fringe	fringe-other
		sjs0345	narrow fringe	fringe-absent
		sjs0400	narrow fringe	fringe-absent
		sjs1303	narrow fringe	fringe-absent
	sound-wide study	sjs0081	narrow fringe	fringe-other
		sjs0351	wide fringe	fringe-other
		sjs0617	narrow fringe	fringe-other
		sjs0635	narrow fringe	fringe-other
		sjs0649	narrow fringe	fringe-other
		sjs0683	narrow fringe	fringe-other
		sjs0695	narrow fringe	fringe-absent
flat	focus area study	flats51	rotational flats	flats-other
		flats52	rotational flats	flats-other
		flats55	rotational flats	flats-other
		flats56	rotational flats	flats-other
		flats58	rotational flats	flats-other
		flats61	rotational flats	flats-other
		flats63	rotational flats	flats-other
		flats67	rotational flats	flats-other
	sound-wide study	core002	core	flats-other
		flats62	rotational flats	flats-other
	independent observation	flats53	rotational flats	flats-absent

Table L-1. Complete list of sites used to calculate the San Juan Co.–Cypress Is. focus area status estimate. This list includes sites sampled explicitly as part of the focus area study, sites sampled as part of the Puget Sound study and one site with independent recent observations (flats53, Westcott Bay).

Appendix M Details of Sound-Wide Status Estimates

In section 3.2.1 (p.27) we presented our most reliable estimate of sound-wide status of *Z. marina* area. In this appendix, we put this in the context of all our status estimates and break down these estimates by stratum.

M.1 Overall Status

As described in Skalski (2003), following every field season we produce estimates of sound-wide *Z. marina* area that we refer to as 'initial' estimates. The initial estimate is adjusted when data from the following field season become available using a retrospective adjustment technique. The purpose of the adjustment is to increase precision. Currently we interpret the adjusted estimates rather cautiously because of concerns about bias, particularly when the technique is applied to the flats stratum (see Dowty 2005).

Figure M-1 shows all initial and adjusted estimates.

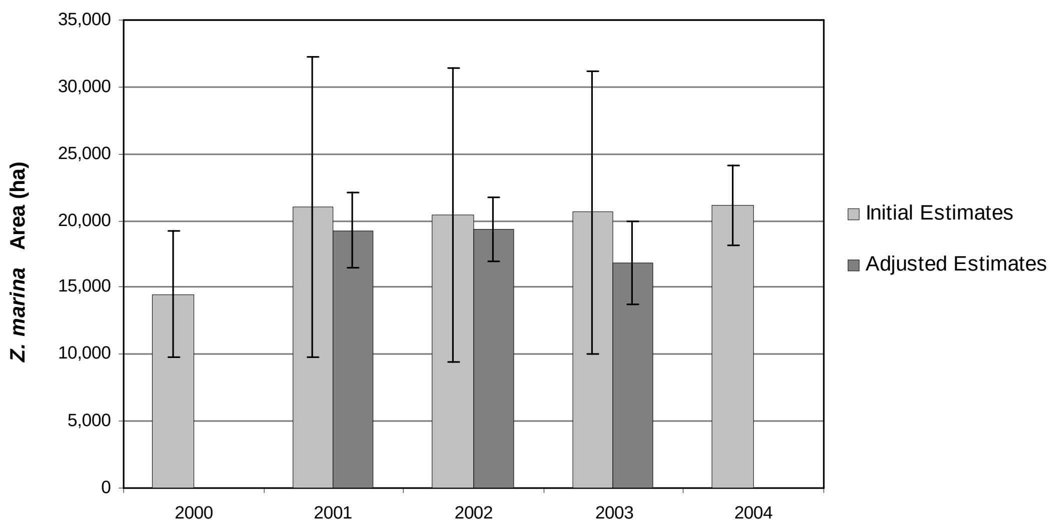


Figure M-1. Sound-wide *Z. marina* area and uncertainty estimates, 2000-2004. Error bars indicate 95% confidence intervals. Values shown in Table M-1.

The 2003 and 2004 initial status estimates are very consistent with estimates from the two previous years, roughly 20,000 ha. In contrast, the precision of the 2004 initial estimate is sharply improved relative to the previous initial estimates. This improvement is associated with the change in flats stratification made in 2004 as evidenced by the stratum-level results.

	2000	2001	2002	2003	2004
Initial Estimate (ha)	14,470	20,990	20,390	20,620	21,140
Standard Error	2,410	5,720	5,600	5,380	1,530
CV	0.17	0.27	0.27	0.26	0.07
Conf. Interval (95%)	4,720	11,210	10,980	10,540	3,010
Adjusted Estimate (ha)		19,270	19,350	16,870	
Standard Error		1,450	1,210	1,600	
CV		0.08	0.06	0.09	
Conf. Interval (95%)		2,840	2,370	3,130	

Table M-1. Sound-wide *Z. marina* area and uncertainty estimates, 2000-2004.

M.2 Stratum-Level Status

Figure M-2 shows the initial estimates for 2000-2004 broken down by individual strata.

Since the rotational-flats stratum was modified in 2004 (reduced by 16% in total site area) by moving three sites to the new persistent-flats stratum, the 2004 result in the rotational-flats stratum is not directly comparable to the earlier years. Comparison of the sum of the 2004 estimates in the rotational and persistent-flats strata with earlier years would be more appropriate (see Figure M-3 for this comparison).

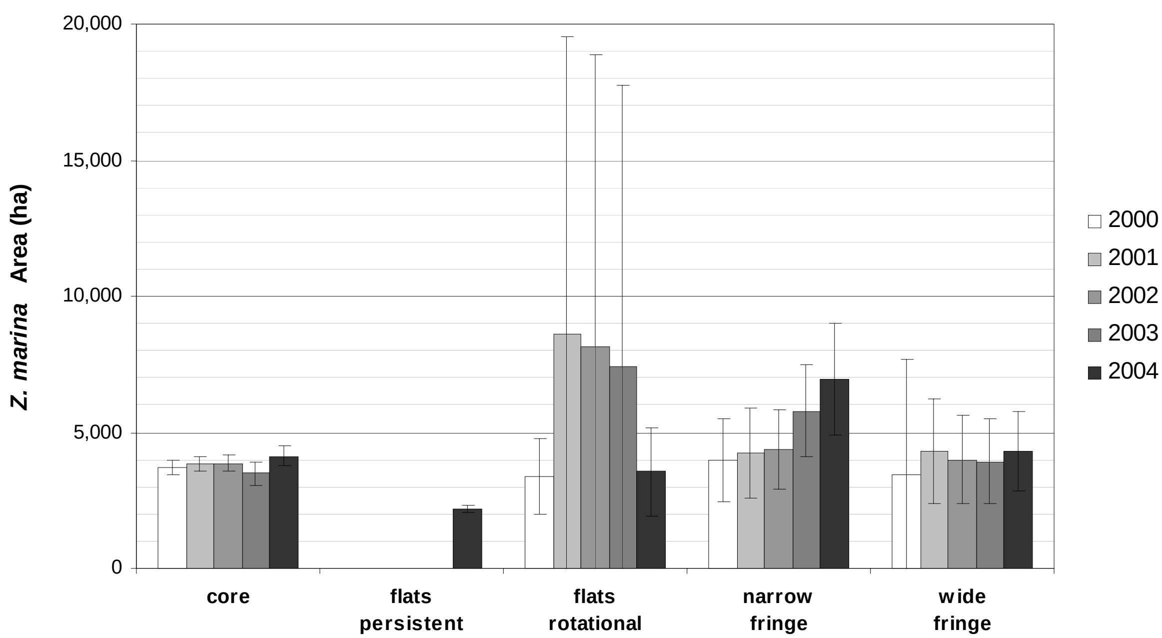


Figure M-2. Sound-wide initial *Z. marina* area estimates for 2000-2004, broken down by stratum. Error bars indicate 95% confidence interval.

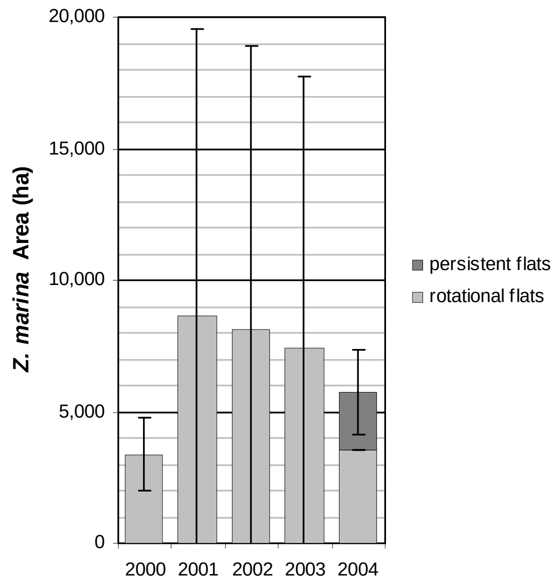


Figure M-3. Sound-wide initial *Z. marina* area estimates for the flats strata with rotational and persistent-flats strata combined in 2004.

These initial estimate results are summarized in the following four points.

1. There is a strong improvement in the precision in the rotational flats initial estimate – even when uncertainty in the persistent flats stratum is considered. This improvement is due to the change in the flats stratification in 2004.
2. The combined flats estimate (rotational and persistent flats strata) decreased in 2004 relative to the three previous years, although this is not statistically significant. This change appears to reflect random effects of site rotation. The two new flat sites that rotated into the sample pool in 2004 (flats41, flats70) had an average *Z. marina* area ratio *R* that was less than the average for 2003 flats (0.14 vs. 0.20). A separate analysis produced an estimate that *Z. marina* area increased between 2003 and 2004 in flat sites (paired-site analysis, Figure N-1, p.93). This increases the likelihood that the decrease seen in the 2004 status estimate (Figure M-3) is an artifact due to site rotation.
3. There is an increase in the 2004 initial estimate in the narrow fringe stratum of +21% relative to 2003 (Figure M-2), although this too is not statistically significant. This increase also reflects random effects of site rotation. The paired-site analysis produced an estimate of no change between 2003 and 2004 (Figure N-1) and the nine new narrow fringe sites had, on average, greater *Z. marina* area than the 46 sites sampled in 2003 (4.6 ha/site vs. 2.8 ha/site).
4. The modest increase in the 2004 estimate of *Z. marina* area in the core stratum (+19% relative to 2003) is almost entirely due to an increase in the site estimate at core001, Padilla Bay.

The *Z. marina* area results from the retrospective adjustment procedure are given in Figure M-4. The 2002 estimate in the wide fringe stratum could not be adjusted because inadvertently only one wide fringe site was rotated out when the 2003 sites were selected. The adjustment calculation was not possible because this left zero degrees of freedom. Also, the 2003 estimate in the flats stratum could not be adjusted within the current analysis framework (Skalski 2003) because of the change to the stratification in 2004.

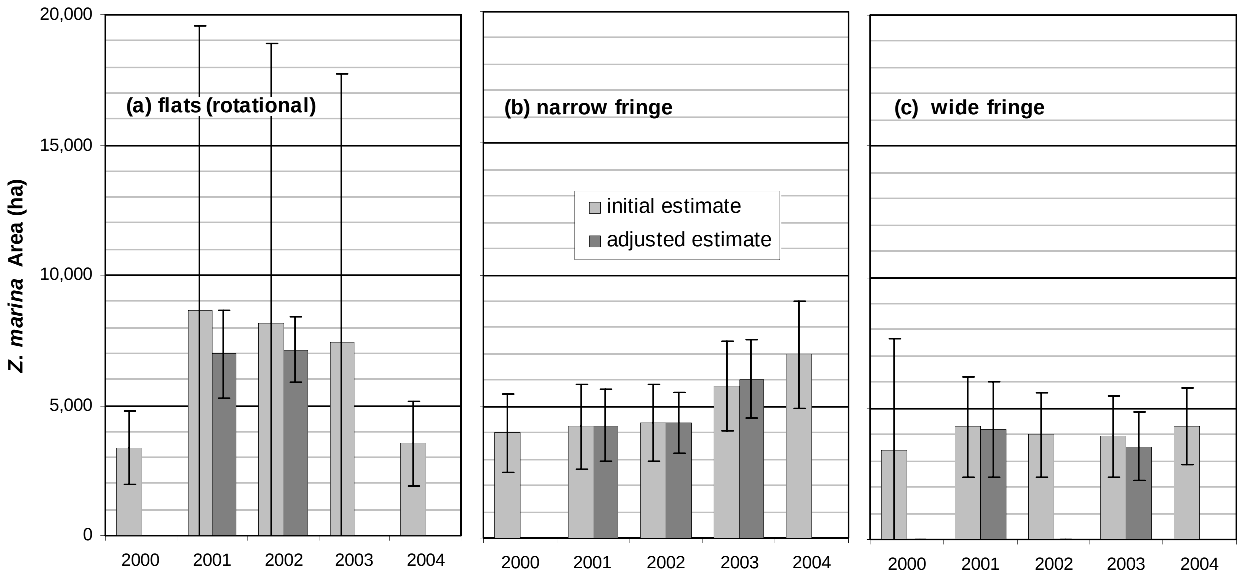


Figure M-4. Effects of retrospective adjustment on sound-wide stratum-level estimates of *Z. marina* area for the (a) rotational flats, (b) narrow fringe and (c) wide fringe strata. Error bars indicate the 95% confidence interval.

Appendix N Details of Sound-Wide Change Estimates

This appendix presents further details on the sound-wide change results (see section 3.3.1, p.30. The aggregated results presented earlier are broken down here by strata.

Figure N-1 and Table N-1 show the year-to-year change within each stratum for 2000-2004. For the purposes of this analysis, two sites that were moved to the new persistent flats stratum in 2004 (flats11 and flats20) were considered part of the previous flats stratum since paired data was then available for these sites.

Figure N-2 shows the weightings that are applied to the stratum-level results in producting the overall sound-wide results presented in section 3.3.1.

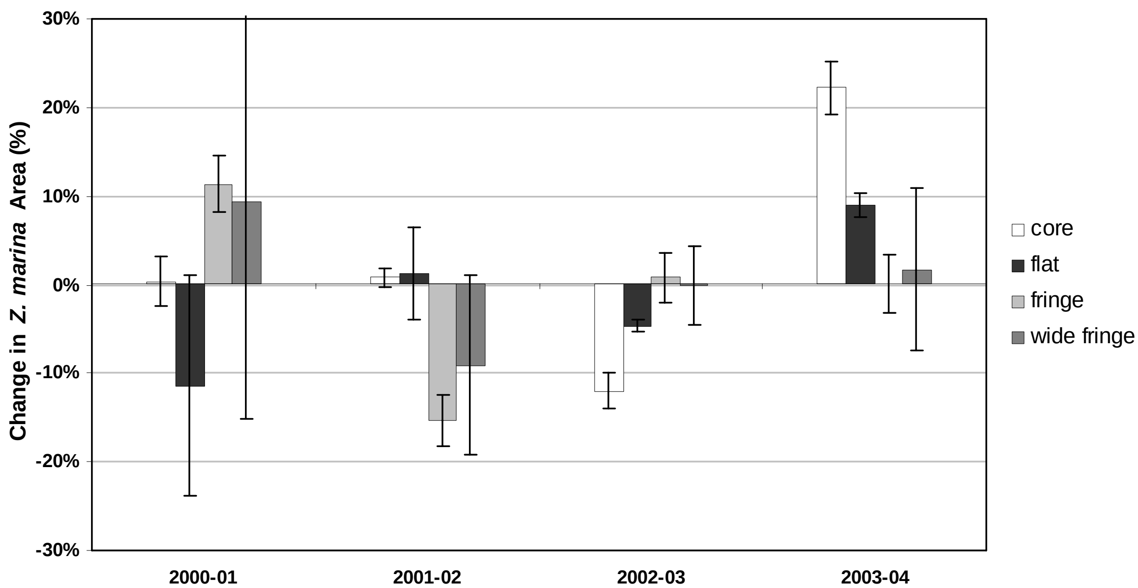


Figure N-1. Sound-wide year-to-year change in *Z. marina* area within individual strata, 2000-2004. Values are given in Table N-1. Error bars are 95% confidence intervals.

Additional analysis (not shown here) examined each stratum-level change in terms of the individual constituent sites.

Several key points emerge from these stratum-level results.

1. There is a very strong statistically significant increase in *Z. marina* area in the core and flats strata.
2. These increases in core and flats follow significant declines in 2002-03.
3. No apparent multi-year trends are apparent at the stratum-level.
4. The increase in core is primarily attributable to a significant increase at core001 (Padilla Bay).

5. The increase in flats is largely attributable to flats08 (Portage Bay N) and flats19 (Pull and Be Damned Point).

Change in *Z. marina* Area				
	2000-01	2001-02	2002-03	2003-04
core	0.3%	0.8%	-12.0%	22.2%
flat	-11.4%	1.3%	-4.6%	14.2%
fringe	11.3%	-15.3%	0.8%	0.1%
wide fringe	9.3%	-9.1%	-0.1%	1.7%
Confidence Interval (half-widths)				
80%	2000-01	2001-02	2002-03	2003-04
core	1.8%	0.7%	1.3%	1.9%
flat	8.2%	3.4%	0.5%	5.8%
fringe	2.1%	1.9%	1.8%	2.1%
wide fringe	16.0%	6.6%	2.9%	6.0%
95%	2000-01	2001-02	2002-03	2003-04
core	2.8%	1.0%	2.0%	3.0%
flat	12.5%	5.2%	0.7%	8.9%
fringe	3.2%	2.9%	2.8%	3.3%
wide fringe	24.4%	10.1%	4.5%	9.1%

Table N-1. Sound-wide year-to-year change in *Z. marina* area and confidence intervals by individual stratum.

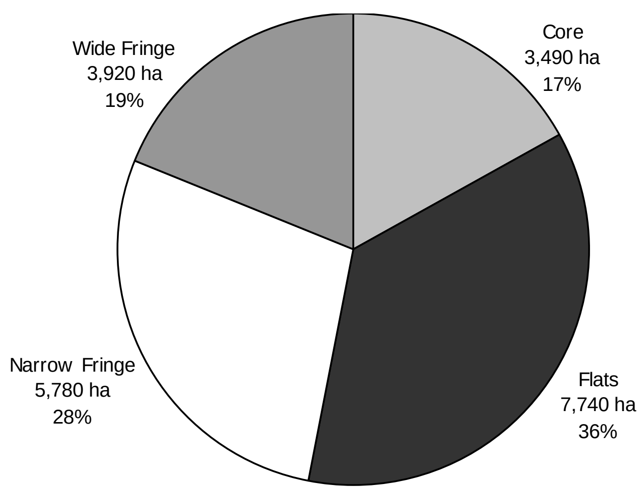


Figure N-2. The weightings applied to each stratum in deriving the 2003-04 sound-wide change estimate. The weightings are based on the 2003 status estimates.

Appendix O Sample Size Summary for Puget Sound Sampling

			Central Puget Sound	Hood Canal	San Juan-Straits	Saratoga-Whidbey	North Puget Sound	stratum total	year total
2000 Sample	sound-wide strata	Core	2	1	2	0	1	6	61
		Flats	1	1	4	3	0	9	
		Narrow Fringe	16	8	11	4	3	42	
		Wide Fringe	0	0	3	1	0	4	
	regional strata	flats	1	2	6	3	1	13	
		fringe	18	8	14	5	3	48	
2001 Sample	sound-wide strata	Core	2	1	2	0	1	6	72
		Flats	1	1	4	3	1	10	
		Narrow Fringe	16	8	12	5	3	44	
		Wide Fringe	1	1	7	3	0	12	
	regional strata	flats	1	2	6	3	2	14	
		fringe	19	9	19	8	3	58	
		flats (00-01 match)	1	2	6	3	1	13	
		fringe (00-01 match)	18	8	14	5	3	48	
2002 Sample	sound-wide strata	Core	2	1	2	0	1	6	73
		Flats	2	1	2	3	2	10	
		Narrow Fringe	19	5	11	5	4	44	
		Wide Fringe	2	1	6	3	1	13	
	regional strata	flats	2	2	4	3	3	14	
		fringe	23	6	17	8	5	59	
		flats (01-02 match)	1	2	4	3	2	12	
		fringe (01-02 match)	16	5	15	8	3	47	
2003 Sample	sound-wide strata	Core	2	1	2	0	1	6	76
		Flats	2	1	1	3	3	10	
		Narrow Fringe	20	4	12	6	4	46	
		Wide Fringe	1	1	7	3	2	14	
	regional strata	flats	2	2	3	3	4	14	
		fringe	23	5	19	9	6	62	
		flats (02-03 match)	2	2	3	2	3	12	
		fringe (02-03 match)	18	4	15	8	5	50	
2004 Sample	sound-wide strata	Core	2	1	2	0	1	6	79
		Flats-persistent	0	0	0	1	2	3	
		Flats-rotational	2	2	1	3	2	10	
		Narrow Fringe	18	6	11	5	6	46	
		Wide Fringe	1	2	4	4	3	14	
	regional strata	flats	2	3	3	4	5	17	
		fringe	21	8	15	9	9	62	
		flats (03-04 match)	2	2	3	3	4	14	
		fringe (03-04 match)	18	5	14	7	6	50	

Table O-1. Sample sizes for each region broken down by sound-wide stratum and regional stratum. For regional strata, the number of paired (matching) sites with the previous year is also shown. Focus area sites and Quartermaster Harbor sites sampled in 2004 are not included.