RESOURCES

NATURAL

# Submerged Vegetation Monitoring Program

# Geospatial Database User Manual

January 2014

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

# Submerged Vegetation Monitoring Program

# Geospatial Database User Manual

———————————————————————————————

*January 2014*

Nearshore Habitat Program
Aquatic Resources Division

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

# Acknowledgements

The Nearshore Habitat Program is part of the Washington Department of Natural Resources' (DNR) Aquatic Resources Division, the steward for state-owned aquatic lands. Program funding is provided through the Aquatic Lands Enhancement Act. The Nearshore Habitat Program monitors and evaluates the status and trends of marine vegetation for DNR and the Puget Sound Partnership.

Washington State Department of Natural Resources
Aquatic Resources Division
1111 Washington St. SE
P.O. Box 47027
Olympia, WA 98504-7027

www.dnr.wa.gov

Copies of this report may be obtained from:
http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_monitoring.aspx

# Contents

# Executive Summary

The purpose of this manual is to describe the structure and content of The Washington Department of Natural Resources (DNR's) eelgrass (*Zostera marina* L.) monitoring data in sufficient detail for users to comfortably use the database and understand its limitations. This manual was prepared to accompany the first release of the monitoring database that contains 2000-2012 data. DNR's eelgrass monitoring data is collected annually and maintained by the Submerged Vegetation Monitoring Program (SVMP), a long term monitoring program that tracks the areal extent and depth distribution of eelgrass throughout greater Puget Sound in Washington State, USA.

Eelgrass is an important natural resource of the marine nearshore that is utilized by many species and provides high productivity. Activities that potentially affect eelgrass must comply with existing regulations aimed at protecting eelgrass and other shoreline resources. Because of the critical ecosystem role of eelgrass, DNR's monitoring results are used as a key ecosystem indicator by DNR and the Puget Sound Partnership.

The basic approach of the monitoring program is to sample portions of the shoreline, rather than completing a comprehensive survey. This allows for the use of intensive techniques that produce high quality data but would be prohibitive to apply on a comprehensive basis. The result is a dataset that covers discrete sites scattered across Puget Sound. Towed underwater video is deployed along random transects at the selected sites and later classified for presence of eelgrass (*Z. marina*), surfgrass (*Phyllospadix* spp.) and *Z. japonica*. This approach accurately distinguishes seagrass species and algae and is not compromised by deep growing eelgrass that is inaccessible to methods typically used for large comprehensive surveys (e.g., aerial photography). A detailed statistical framework allows for annual estimates of eelgrass area over greater Puget Sound with known estimates of uncertainty that allow for statistically rigorous tests for change at the soundwide scale as well as the site scale.

The study area includes marine and estuarine areas of greater Puget Sound within Washington State. This includes areas east of Cape Flattery, at the mouth of the Strait of Juan de Fuca, and south of Pt. Roberts. The extreme reaches of southern Puget Sound are excluded from the study area because eelgrass occurs rarely in this area. The study area is divided into five regions, based on oceanographic sub-basins: Central Puget Sound (CPS), Hood Canal (HDC), North Puget Sound (NPS), San Juan Islands-Strait of Juan de Fuca (SJS) and the Saratoga Passage-Whidbey Basin (SWH). The Central Puget Sound region includes an area south of the Tacoma Narrows that is typically considered southern Puget Sound.

Sampling generally occurs between May and September, the period of highest vegetation biomass. Site sampling is a two-step process where an “eelgrass polygon” is first delineated, encompassing all observations of eelgrass found in reconnaissance surveys and contiguous areas deemed to have a likelihood of eelgrass presence. At each site sampled, continuous underwater video, position, time and depth data are recorded along randomly selected transects oriented perpendicular to shore, spanning the width of the pre-determined “eelgrass polygon”.

This User Manual includes details of the sampling methodology, online data access, database structure and a description of all data table attributes.

# 1 Introduction

## *1.1 Overview of the Submerged Vegetation Monitoring Program*

The Submerged Vegetation Monitoring Program (SVMP) has conducted annual monitoring of the status and trends of native seagrass in greater Puget Sound since 2000. The native seagrasses monitored include the dominant eelgrass (*Zostera marina*) as well as the less abundant surfgrass (*Phyllospadix scouleri* and *P. serrulatus*). The SVMP uses the monitoring data to produce estimates of the area of these native species at individual sites and for the entire study area. Since eelgrass dominates, the SVMP typically refers to these estimates as "eelgrass area" estimates but, in fact, they also include the area of surfgrass. Observations of the seagrass *Zostera japonica* are also recorded but these are excluded from SVMP area estimates because this species is non-native and has distinct resource management issues (Bando 2006, Mach et al. 2010, Shafer et al. 2013). Observations of all of these seagrasses are included in the eelgrass monitoring dataset that is described in this user manual.

The SVMP is implemented by the Washington State Department of Natural Resources (DNR). The DNR initiated eelgrass monitoring in its role as manager of state-owned aquatic lands and the attached or embedded resources such as eelgrass. State-owned aquatic lands include all subtidal areas and a substantial amount of the state's intertidal lands. The legislature has stipulated management guidelines for state-owned aquatic lands that balance various uses of state aquatic resources with "ensuring environmental protection" (RCW 79.105.030). Eelgrass provides a suite of ecological functions and is a sensitive indicator of estuarine health. Given the key ecological functions of eelgrass and its value as a resource under DNR's management, the tracking of seagrass resources by the SVMP serves DNR's direct mandate. It also serves the mandate of the Puget Sound Partnership to track indicators of ecosystem health and conduct the coordinated, integrated monitoring and assessment needed for these indicators.

The SVMP is one component of the regional monitoring program known as the Puget Sound Ecosystem Monitoring Program. This is a multi-agency effort mandated by the state legislature (RCW 90.71.060) to monitor diverse physical and biotic aspects of the Puget Sound ecosystem. The SVMP eelgrass monitoring data provide the basis for a vital sign that has been used for integrated assessments of Puget Sound (Puget Sound Action Team 2007, 2005, 2002; Puget Sound Water Quality Action Team 2000; Puget Sound Partnership 2013a, 2012, 2010).

Washington State agencies recognize the value of eelgrass as an aquatic resource (WAC 220-110-250, WAC 173-26-221, and RCW 90.58), and in 2009 the Puget Sound Partnership identified eelgrass as an important ecosystem indicator in the Action Agenda (Puget Sound Partnership 2009). The Partnership further identified eelgrass as one of the 20 dashboard ecosystem indicators to measure the health of Puget Sound, now reported as Vital Signs of Puget Sound (Puget Sound Partnership 2013b).

In order to satisfy broad data needs, the SVMP produces results at a range of spatial scales (site, region, and soundwide scales; Figure 1) based on sampling of eelgrass beds at randomly selected sites and a small number of permanent sites. At each site visited with eelgrass present, the eelgrass bed is sampled with underwater video transects. The video is classified for the presence of the seagrass species. These classified transect data are the core of the SVMP dataset.

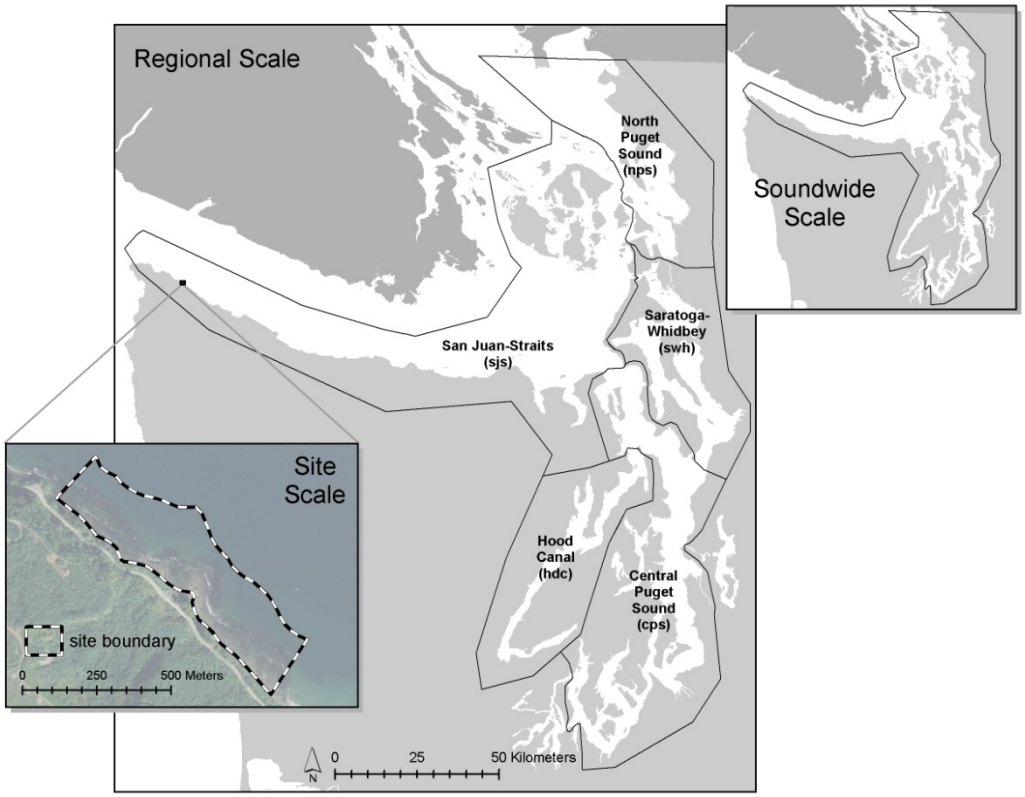


Figure 1. The SVMP monitors eelgrass condition at soundwide, regional, and site scales throughout greater Puget Sound, WA. Letters in parentheses indicate the abbreviations used for each sub-basin, or region.

Distribution of the SVMP data is critical to effectively managing eelgrass resources throughout Puget Sound. Previously, while analysis of the monitoring results was available through periodic reports, the detailed spatial data was only available upon request. With the release of this geospatial database that contains 2000-2012 data, these data are now easily accessible as a web download. Currently, efforts are underway to provide access to these data through an interactive mapping web application.

## *1.2 Objective of Manual*

The purpose of this manual is to describe the publically distributed database in sufficient detail for new users to navigate the database. In addition to a brief introduction to the monitoring project and its methods, the format and structure of the database is described and the attributes of each data layer are defined.

## *1.3 Online Access*

The database and this user manual are available through the DNR GIS data download web page: http://www.dnr.wa.gov/BusinessPermits/Topics/Data/Pages/gis_data_center.aspx

The SVMP monitoring reports that include detailed methodology, results summaries and analyses at the site, sub-region and soundwide scales are available on the SVMP web page: http://www.dnr.wa.gov/ResearchScience/Topics/AquaticHabitats/Pages/aqr_nrsh_eelgrass_monitoring.aspx

The Washington Department of Natural Resources (DNR) provides these geographic data "as is." DNR makes no guarantee or warranty concerning the accuracy of information contained in the geographic data. DNR further makes no warranties, either expressed or implied as to any other matter whatsoever, including, without limitation, the condition of the product, or its fitness for any particular purpose. The burden for determining fitness for use lies entirely with the user. Although these data have been processed successfully on computers of DNR, no warranty, expressed or implied, is made by DNR regarding the use of these data on any other system, nor does the fact of distribution constitute or imply any such warranty.

In no event shall the DNR have any liability whatsoever for payment of any consequential, incidental, indirect, special, or tort damages of any kind, including, but not limited to, any loss of profits arising out of use of or reliance on the geographic data or arising out of the delivery, installation, operation, or support by DNR.

# 2 Data Collection Methodology

## *2.1 General Approach*

Remote sensing techniques are widely used for seagrass mapping. Airborne remote sensing is particularly widely used, and offers efficiency in mapping large areas (Bulthuis 1995, Cunha et al. 2005, Ferguson and Korfmacher 1997, Fletcher et al. 2009, Hernandez-Cruz et al. 2006, Kendrick et al. 2000, Moore et al. 2000, Mumby et al. 1997, Ward et al. 1997, Young et al. 2008). However, these approaches are unable to reliably discriminate between seagrass species in mixed beds or between seagrass and macroalgae (Mumby et al. 1997; Ward et al. 2004). These approaches also cannot map deeper subtidal beds (Pasqualini et al. 1999). In this study, these limitations are critical since one objective is to distinguish eelgrass (*Z. marina*) from *Z. japonica* and macroalgae, and a large portion of the eelgrass distribution in greater Puget Sound is subtidal (Phillips 1974).

To overcome these limitations, when the Submerged Vegetation Monitoring Program (SVMP) was initiated in 2000, it selected towed underwater video as the main data collection methodology (Ardizzone et al. 2006, Grizzle et al. 2008, Lirman et al. 2008, McDonald et al. 2006, Norris et al. 1997). This is a relatively intensive technique and to feasibly apply it across greater Puget Sound, it is used within a sampling framework that provides for regional estimates of eelgrass area based on video surveys at a modest number of sites.

The general approach of the study is to employ annual stratified sampling. All of the potential eelgrass habitat in the study area was divided into 2,467 sites. These sites were divided into five strata. Two of these strata contain a small number of sites ($n = 9$ combined) that are visited each year. The other three strata contain larger numbers of sites and only a random sample of sites is visited each year for these strata. This represents the first stage of sampling. The large strata are subject to a rotational sampling design where a portion (20%) of the sample of sites is replaced with new randomly selected sites each year. Sites remain in the sample for five consecutive years before rotating out of the sample. In the second stage of sampling, the eelgrass within each selected site is sampled with a modified line intercept technique using underwater videography deployed from a boat along randomly selected transects. For each site sampled, this approach delineates the area occupied by eelgrass, measures fractional cover within this area and estimates total area of eelgrass at the site. All sampling is conducted between May and September.

A user needs assessment indicated that the anticipated users of the dataset are primarily interested in site-level data. This report describes the methods of site sampling with

underwater video transects (stage 2 sampling) and the site data. Also, the broad scale stratification and sampling design (stage 1 sampling; more detail in Skalski 2003 and Dowty 2005) are described.

### *2.2 Study Area and Regions (Sub-Basins)*

The study area is restricted to the marine waters of Washington State east of Cape Flattery, and includes the U.S. portions of the Strait of Juan de Fuca and the southern Strait of Georgia, Hood Canal, Puget Sound proper and several other smaller basins (Figure 2). These collective marine waters are referred to here as greater Puget Sound. The extreme reaches of southern Puget Sound are excluded from the study area because eelgrass occurs rarely in this area (Berry et al. 2001). The study area includes approximately 3,550 km of shoreline. The entire study area is subject to mixed semidiurnal tides with tidal range generally increasing with distance from the mouth of the Strait of Juan de Fuca. Mean spring tidal range varies from approximately 2.4 m at Cape Flattery to 4.4 m at Olympia.

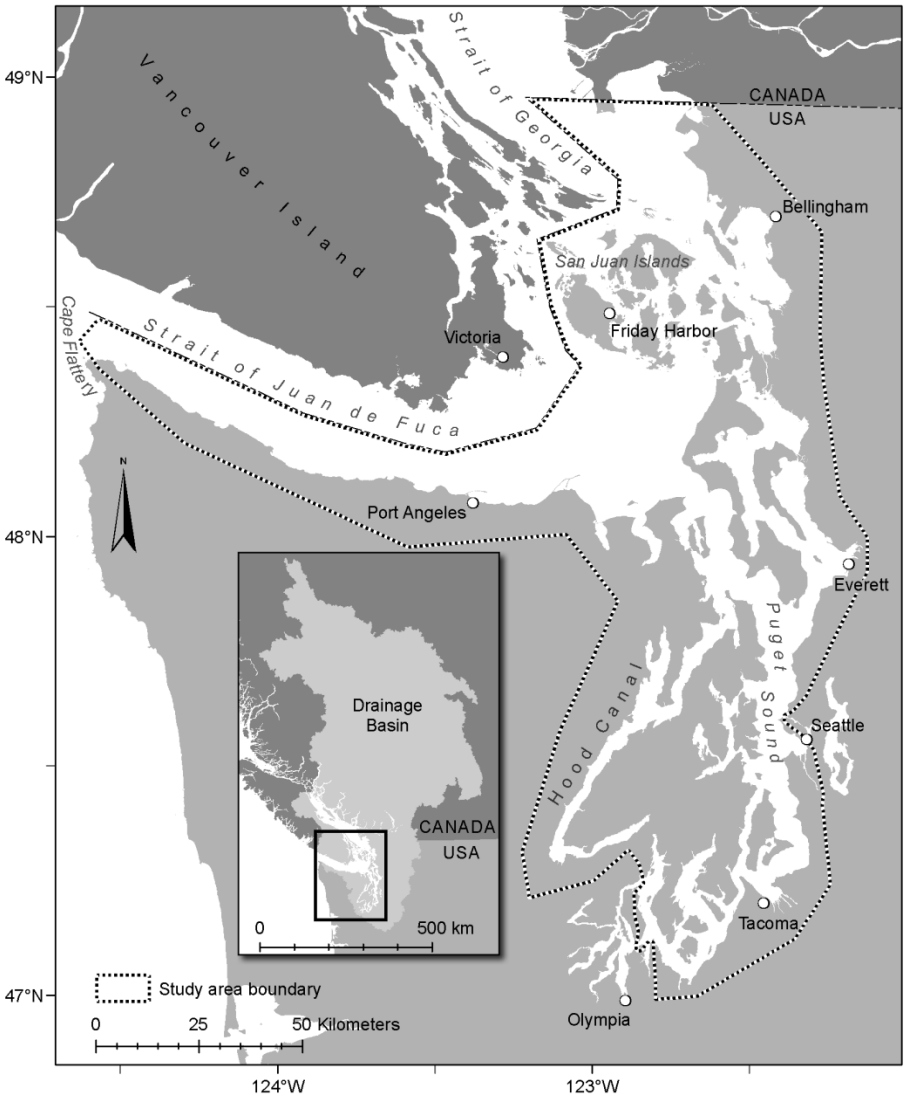


Figure 2. The greater Puget Sound study area, Washington State (USA).

There are six species of seagrasses in greater Puget Sound although not all have been observed in the SVMP transect data: *Phyllospadix torreyi* Watson, *P. scouleri* W. J. Hooker, *P. serrulatus* Ruprecht et Acherson, *Ruppia maritima* L., *Z. marina* L. and the introduced species *Z. japonica* Ascherson et Graebner (Harrison and Bigley 1982, Phillips 1984, Wyllie-Echeverria and Ackerman 2003). *Z. marina* is the dominant seagrass of greater Puget Sound (Berry et al. 2001) as well as the entire Pacific coast of North America (Wyllie-Echeverria and Ackerman 2003).

The study area was divided into five sub-basins. These are referred to as regions (see Figure 1, p.4) and for some SVMP analyses, results are presented on a region basis.

### *2.3 Sampling Frames and Stratification*

All potential eelgrass habitat within the study area was delineated in a GIS as those subtidal and intertidal areas bounded by the ordinary high water line and the -6.1 m isobath (all depth values presented are relative to Mean Lower Low Water, MLLW). In practice, sampling has not been constrained by the -6.1 m isobath in the cases where eelgrass was found to extend to greater depths. The -6.1 m isobath was derived from the gridded bathymetric data produced by the Washington Department of Fish and Wildlife (Nysewander et al. 2005). Ordinary high water was represented by a spatial data layer maintained by DNR in a GIS and derived from 1:12,000 orthorectified aerial photographs.

The potential eelgrass habitat was first divided into two categories, flats and fringe, based primarily on geomorphological considerations. A separate sampling frame was developed for each category. The flats category includes embayments, tide flats and river deltas – potential habitat that is best represented as areal sample units. Potential habitat in the fringe category falls into a narrow band parallel to the shoreline, and is well represented by linear sample units.

Flats potential habitat was manually delineated on bathymetric maps. The sampling frame for the fringe potential habitat was constructed by dividing the -6.1 m isobath into 1000 m segments. Each 1000 m segment represents a fringe sample unit, or site (Figure 3). In some cases, small isobath segments could not be placed in a 1000 m segment, for example around islands where the total isobath length would not be an even multiple of 1000 m, or where fringe potential habitat meets flats potential habitat or river mouths. Such residual segments were denoted as orphans, were excluded from the frame, and led to a deviation of 3% between the target (2,465 km) and sampled fringe populations (2,396 km).

A polygon feature class is included in SVMP dataset (sites_poly) that contains polygons that completely cover the potential eelgrass habitat in the study area. These include the flats and fringe sampling frames as well as the fringe orphans.

Each of the two sampling frames was stratified to optimize precision of estimates of soundwide eelgrass area and to allow a small number of sites to be sampled for all years and not be subject to site rotation. Four sites from the flats frame and two from the fringe frame were purposively selected and placed in the “core” stratum. These sites were selected to represent a range of geographic locations, habitat types and management

concerns (Figure 4). Each of the six sites is surveyed each year so the core stratum is censused rather than sampled. Core sites are assigned site codes with the prefix "core" – e.g., core001, core002.

The flats sampling frame ($n$ = 74 sites) is divided into three strata. The bulk of the sites ($n$ = 67) are in the "rotational flats" stratum that is sampled by a random selection of sites (typically $n$=10) that is subject to 20% site rotation each year. Four sites were placed in the core stratum as described above. Three sites were placed in the "persistent flats" stratum, and each of these sites is surveyed each year. The persistent flats stratum was created after the 2003 sampling. Previously, these three sites had been included in the rotational flats stratum (see Dowty 2005 for more detail). All flats sites are assigned site codes with the prefix "flats" – e.g., flats01, flats20.

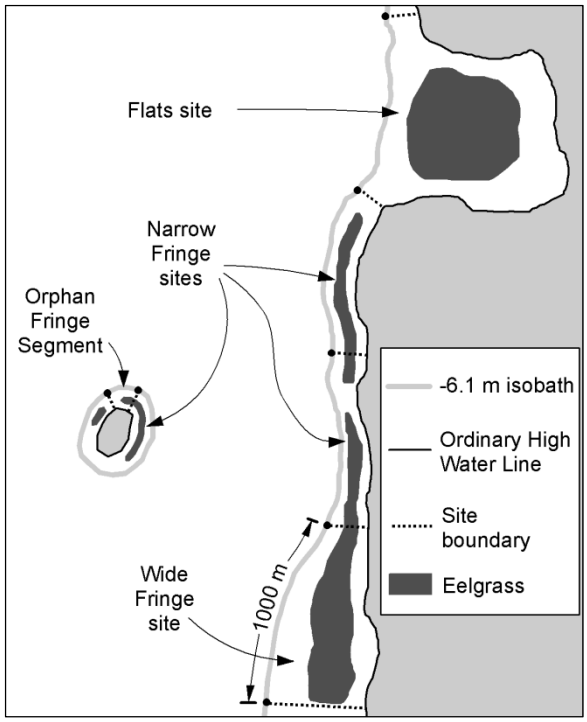


Figure 3. Potential eelgrass habitat divided into two categories, flats and fringe, based primarily on geomorphological considerations. Flats potential habitat includes large, shallow embayments. The sampling frame for the fringe potential habitat was constructed by dividing the -6.1 m isobath into 1000 m segments where each segment delineates a sample unit, or site. Isobath segments <1000 m were considered orphans and excluded from sampling. Fringe sites were placed in wide and narrow strata depending on the width of the potential habitat.

The fringe sampling frame ($n$ = 2,393) is also divided into three strata. Two sites were placed in the core stratum as described above, and the remaining sites were divided into "narrow fringe" and "wide fringe" strata based on the width of the potential habitat at each site (Figure 3). If the distance between ordinary high water and the -6.1 m isobath segment was less than 305 m for a majority of the site, the site was placed in the narrow fringe

stratum ($n$ = 1,965). Sites with greater habitat width were placed in the wide fringe stratum ($n$ = 426).

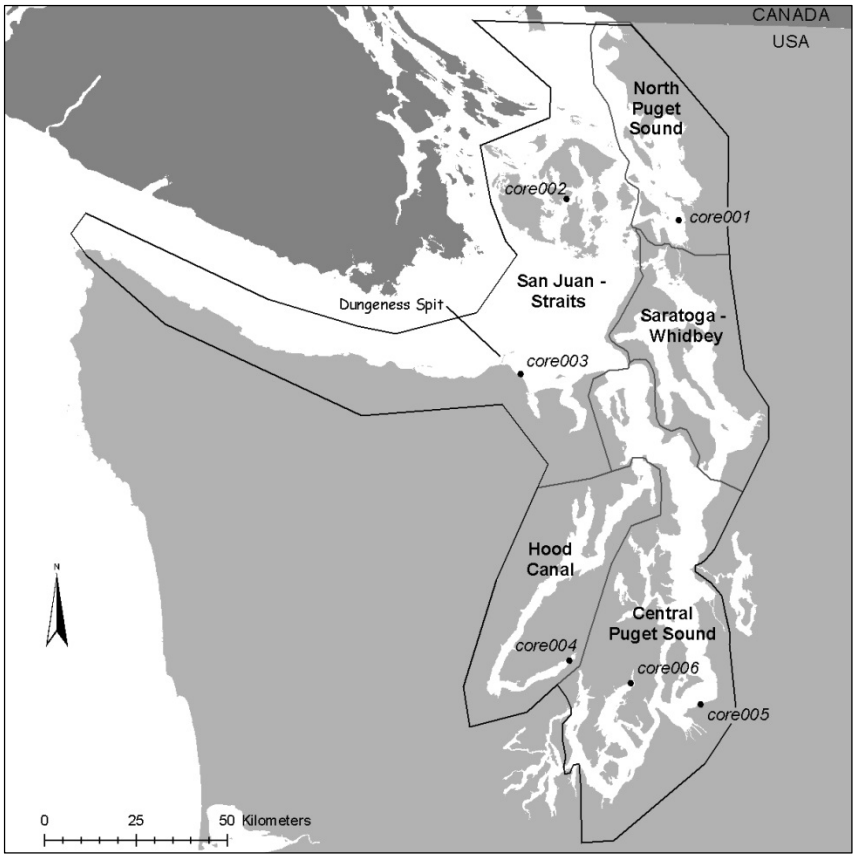


Figure 4. Locations of the six core sites in the greater Puget Sound study area.

## *2.4 Site-Level Sampling*

At each site sampled, continuous underwater video is recorded along several line transects using a modification of the methods of Norris et al. (1997). The transects are randomly selected each year and are typically restricted to a pre-defined sampling polygon that is described below. The video data are post-processed to document seagrass presence and absence. Sampling takes place during relatively high tides so the sampling vessel can reach the shallow extent of eelgrass. Generally, sampling takes place with tides of +1.8 m MLLW or higher but can vary by site and scheduling restrictions. While the dataset also contains observations of *Z. japonica*, transects frequently do not extend to the shallow edge of *Z. japonica* occurrence and therefore do not represent the entire spatial extent of *Z. japonica*.

Site sampling is a two-step process where an "eelgrass polygon" is delineated and then the transect data are collected. Reconnaissance video is first collected with real-time interpretation prior to sampling to confirm eelgrass presence and to delineate the eelgrass

polygon that encompasses all detected eelgrass and contiguous areas deemed to have a reasonable likelihood of eelgrass presence. At sites previously sampled, the previous eelgrass polygon and transect data are available and less effort is allocated to reconnaissance. The number of random transects selected varies depending on previously observed variance and tidal conditions, but the target is to collect a minimum of 11 transects per site. The transects span the width of the eelgrass polygon perpendicular to shore. The mean boat speed along the transects is approximately 0.9 m $s^{-1}$.

In cases where obstacles (e.g., buoys, moored boats, submerged rocks, dense surface canopy-forming kelp) forced the boat to deviate from the transect more than 25% of the total transect length, then the transect was discarded and another randomly selected. In cases where obstacles precluded sampling over greater than 25% of the area at a site, the site was coded as "obstructed" and not sampled. In cases where eelgrass was observed but in such low abundance that transect sampling was not practical, the site was coded as "trace". In the attribute tables for trace sites, vegetation occurrence fields are coded to indicate eelgrass is present, but the numeric estimate of eelgrass area is set to zero.

The random transects were the basis for estimating site eelgrass area and the depth range of the bed. In concept, these transects are straight lines that are locally perpendicular to the shore, although actual transects depart from these conditions to varying degrees. Other types of transects were also collected in some cases to meet particular needs. All transects fall into one of the categories listed in Table 1.

At all sites, specimens were collected as needed for species identification particularly in mixed beds of *Z. marina* with *Z. japonica* or *Phyllospadix* spp.

Table 1. Categories of underwater video transects represented in the SVMP dataset.

| Transect type | Description |
|---|---|
| Straight line perpendicular | Standard type of random transects |
| Reconnaissance | Video data collected before sampling to delineate area of eelgrass presence or other special purposes. This category includes transects coded as 'meander', 'zig-zag' or simply 'reconnaissance'. |
| Maximum depth | Short transects at the deep edge of a bed |
| Straight line parallel | Straight transect placed parallel to the shoreline |
| Bathymetry | Transects placed to determine bathymetry. |
| Aborted | Partial transect aborted due to obstruction or technical problems. This category includes transects coded either as 'aborted' or 'obstructed'. |

### *2.4.1 Survey Equipment*

The sampling has been conducted primarily from an 11 m research vessel. The vessels and survey equipment have been supplied through a contract with Marine Resources Consultants of Port Townsend, Washington. When monitoring was initiated in 2000, the underwater camera used was a SeaCam 2000 (DeepSea Power and Light, San Diego) but

this was replaced by the SuperSeaCam in 2003 because of its greater light sensitivity. The camera is mounted with a downward-looking orientation on a towfish that is approximately 45 kg. The towfish is deployed off the stern using a cargo boom and boom winch. An operator uses the boom winch to control camera height while viewing real-time video. A 250W underwater light (RiteLite, Deep Sea Power and Light) is also mounted on the towfish for use when there is insufficient ambient light. Parallel lasers (Deep Sea Power and Light) mounted 10 cm apart are used to create red dots in the video images as a scaling reference. Depths were initially measured with a Garmin Fishfinder 240 but a BioSonics DE 4000 Series echosounder was introduced in 2002 to be able to consistently find the bottom depth below a thick canopy of eelgrass and other marine vegetation.

The antenna of a differential GPS (Trimble AgGPS 132) is mounted at the top of the cargo boom so its location coincides with the video camera. Video was initially recorded on VHS tape but since 2004 the video has been recorded on both 8 mm tape (DV format) and DVD. In 2012, video was also stored on hard drives in DV format. A video overlay stamps the time on the video continuously with updates at one-second intervals.

Since 2004, a 5 m aluminum skiff has been occasionally used for sampling at a few sites that presented navigation challenges and might otherwise have been discarded due to obstacles. In these cases, underwater video was not collected along the transects. Instead, eelgrass presence was interpreted from the BioSonics echosounder data (Sabol et al. 2002). A video camera was lowered to validate questionable acoustic signals and seagrass samples were collected for species identification.

### *2.4.2 Video Post-Processing*

All underwater video from the random transects is post-processed. In concept, the video is used to classify each 1 m increment of a 1 m-wide belt transect into presence/absence categories for eelgrass (*Z. marina*), surfgrass (*Phyllospadix* spp.) and *Z. japonica*. This results in a classification with a nominal 1 $m^2$ resolution. Variations in density within each 1 $m^2$ unit are not captured. Video quality was recorded for each 1 $m^2$ unit as good or poor. Video quality was classified as poor when the vegetation could not be classified due to high turbidity or very low light conditions.

In practice, all video frames with the same 1-second GPS time stamp are classified as a single unit. The dimension of each classified unit in the along-track direction is determined by boat speed which is variable but generally in the range of 0.5 – 1.3 m $s^{-1}$. The video processors use the recorded laser beams as a scale reference. The width of the transect that is classified is nominally 1 m wide in the cross-track dimension but this is approximate and depends on camera height above the sediment surface.

Eelgrass presence is assessed only when the video processor has reasonable certainty that there is at least one rooted plant within the video frame. If a plant is visible but appears to be rooted to either side of the 1 m-wide belt it is not considered. In practice, the video processors often make a subjective determination on whether a plant is rooted within the classification area, particular when poor water clarity obscures the substrate.

The training for the video processors has been refined each year to maximize accuracy and consistency between processors. Starting in 2004, processor precision has been tracked using a subset of actual video data. Reeves et al. (2007) describe the precision within and between processors.

For the sites sampled with the skiff, where no video data is collected, the BioSonics echosounder data has been processed to determine eelgrass presence or absence.

Occasionally, the eelgrass polygon is adjusted as part of post-processing. This is done where the field-delineated polygon did not encompass all eelgrass observed during reconnaissance. It is also done where transects do not span the initial polygon, in which case the polygon is contracted to the area sampled by the transects. While post-hoc eelgrass polygon adjustment is allowed under limited circumstances in the cross-shore dimension, it is prohibited in the long shore dimension.

### *2.5 Site-Level Data Products*

For each year that a site is selected for sampling, the following geospatial data are produced:

- *Eelgrass polygon*: a polygon that delineates a generalized area within the site boundaries where eelgrass (*Z. marina*) or surfgrass (*Phyllospadix* spp.) is found (if present). This is the area subjected to transect sampling with towed underwater video. For sites with multiple years of data, the dataset contains a single polygon that is a union of all annual polygons.
- *Transects*: the random transects with species presence (*Z. marina, Z. japonica, Phyllospadix* spp.) recorded at approximately 1 meter intervals by video post-processing.

Based on these geospatial data, several site statistics and associated uncertainty are generated. These include statistics characterizing the area of eelgrass as well as the maximum and minimum depth of eelgrass at the site. These results are included in a geodatabase table. Details on the estimation of site eelgrass area are given in Skalski (2003).

# 3 Geospatial Database

### *3.1 Database Structure*

The main elements of the dataset include:

- Site boundary polygons (polygon feature class) that comprehensively cover the potential eelgrass habitat along the shoreline in the study area.
- Site points (point feature class) that represent each site in the study area as a point feature.
- Transects (point feature class) represented as a sequence of points along each transect with a nominal spacing of one meter between points (varies with boat speed).
- Generalized eelgrass polygons (polygon feature class) that indicate the general areas within a site where eelgrass was found and sampled with transects.
- Table of annual site results (geodatabase table)

In addition, polygon feature classes are included that represent the boundaries of the entire study area and the five sub-regions. A simple baselayer is included that represents Washington State and the adjacent areas of Canada.

The SVMP dataset is distributed as six zip archives of ESRI ArcGIS 10.0 file geodatabases (see section 1.3, p.5, for online access). The main reason for dividing the dataset into separate files is to make the file sizes more manageable for download. The transect point data in particular contains many features (> 6.6 million points) and these were therefore broken into five discrete databases – one database for each of the SVMP regions. The structure of the distributed dataset is presented in Table 2.

### *3.2 Attributes of Summary Information Table for Sites Surveyed*

Attributes for each site sampled have been assembled in a site summary information table. The attributes of this table are shown in Table 3.

This table is replicated in the attribute table of three feature classes in the database:

- *sites_poly* polygon feature class
- *eelgrass_generalized_poly* polygon feature class
- *sites_pt* point feature class

The attribute tables for these three feature classes have fields in additional to those shown in Table 3 that are automatically generated by ArcGIS software (e.g., OBJECTID, SHAPE, SHAPE_LENGTH, SHAPE_AREA).

Table 2. The structure of the SVMP distribution dataset. Six geodatabases are available for download. The first, "SVMP_distribute" includes all data layers except the transect data. The transect data are divided into five geodatabases – one for each of the sub-regions that are within the SVMP study area.

| geodatabase name | data element | | |
|---|---|---|---|
| | name | type | description |
| SVMP_distribute | sites_poly | polygon feature class | Boundaries for all survey sites in greater Puget Sound, including sites surveyed and sites not surveyed. Summary information is included for all sites sampled. |
| | sites_pt | point feature class | A layer that represents each site in greater Puget Sound as a point, including sites surveyed and sites not surveyed. Intended for simplified representation at large extents. Summary information is included for all sites sampled. |
| | eelgrass_generalized_poly | polygon feature class | Generalized boundary that contains areas where eelgrass was observed within each site that has been surveyed. These polygons were delineated for sampling purposes. They may include unvegetated areas and may not adhere tightly to eelgrass bed boundaries. Summary information is included for all sites sampled. |
| | study_area_boundary | polygon feature class | A single polygon delineating the greater Puget Sound study area. |
| | regions | polygon feature class | Polygons delineating the SVMP regions and the focus areas used for 2004-2012 focus area sampling. |
| | site_results_annual | geodatabase table | A table with annual estimates for sites sampled. |
| SVMP_transects_cps | transects_pt_cps | point feature class | Transect points for all transect surveyed within the Central Puget Sound region which includes a portion of southern Puget Sound where eelgrass is found. |
| SVMP_transects_hdc | transects_pt_hdc | point feature class | Transect points for all transect surveyed within the Hood Canal region. |
| SVMP_transects_nps | transects_pt_nps | point feature class | Transect points for all transect surveyed within the North Puget Sound region. |
| SVMP_transects_sjs | transects_pt_sjs | point feature class | Transect points for all transect surveyed within the San Juan Islands/Strait of Juan de Fuca region. |
| SVMP_transects_swh | transects_pt_swh | point feature class | Transect points for all transect surveyed within the Saratoga Passage/Whidbey Basin region. |

Table 3. Attributes of the site summary information table. This table is replicated in the attribute tables of three feature classes in the dataset: sites_poly, eelgrass_generalized_poly and sites_pt. For attributes with a limited domain of attribute values or an explicit missing data value, the attribute values are listed in bold font and defined in the attribute description.

| Field Name | Type | Description |
|---|---|---|
| SITE_CODE | Text | Unique site identifier (alpha numeric) |
| SITE_NAME | Text | Site name typically based on nearby community name or geographic landmark |
| REGION | Text | Region where site is located (3-letter code)<br>**cps** = Central Puget Sound (includes the central Puget Sound basin and the northeast portion of southern Puget Sound where eelgrass occurs)<br>**hdc** = Hood Canal<br>**nps** = North Puget Sound<br>**sjs** = San Juan Islands and Strait of Juan de Fuca<br>**sps** = South Puget Sound (extreme southern reaches of south Puget Sound basin where eelgrass is rare; excluded from SVMP sampling)<br>**swh** = Saratoga Passage and Whidbey Basin |
| YRS_SAMPLED | Integer | Count of years the site has been sampled |
| SAMP_STATUS | Text | Sampling status of the site<br>**sampled** = site has been visited and eelgrass area estimated. Either video transects were collected or eelgrass was assessed to be absent based on reconnaissance.<br>**unsampled** = site has not been visited<br>**obstructed** = site was visited but not sampled due to obstruction. |
| NATIVE_SG | Text | Presence of native seagrass in any of the sampling occasions at the site. Observations of native seagrass include eelgrass (*Zostera marina*) and surfgrass (*Phyllospadix* spp.).<br>**present** = native seagrass was observed to be present on one or more sampling occasions (includes sites of total loss and sites where field notes indicate presence even if not observed in transect data).<br>**absent** = the site has been visited but there were no observations of native seagrass.<br>**no_data** = the site has not been sampled. |
| EELGRASS | Text | Presence of eelgrass (*Zostera marina*) in any of the sampling occasions at the site.<br>**present** = eelgrass was observed to be present on one or more sampling occasions (includes sites of total loss and sites where field notes indicate presence even if not observed in transect data).<br>**absent** = the site has been visited but there were no observations of eelgrass.<br>**trace** = eelgrass was observed, either during reconnaissance or in transects, but the abundance was too low to allow meaningful estimates with transect sampling.<br>**no_data** = the site has not been sampled. |
| JAPONICA | Text | Presence of *Zostera japonica* in any of the sampling occasions at the site.<br>**present** = *Z. japonica* was observed to be present on one or more sampling occasions.<br>**absent** = the site has been visited but there were no observations of *Z. japonica*.<br>**no_data** = the site has not been sampled. |
| PHYLLOSPADIX | Text | Presence of surfgrass (*Phyllospadix* spp.) in any of the sampling occasions at the site.<br>**present** = surfgrass was observed to be present on one or more sampling occasions.<br>**absent** = the site has been visited but there were no observations of surfgrass.<br>**no_data** = the site has not been sampled. |
| NATIVE_UNDIFF | Text | Presence of native seagrass that could not be differentiated with certainty between eelgrass and surfgrass.<br>**present** = undifferentiated native seagrass was observed to be present on one or more sampling occasions.<br>**absent** = the site has been visited but there were no observations of undifferentiated native seagrass.<br>**no_data** = the site has not been sampled. |

| Field Name | Type | Description |
|---|---|---|
| VEG_CLASS | Text | A classification of seagrass species composition at the site.<br>Zm_mono = eelgrass (*Zostera marina*) in a monospecific stand<br>Zm_Ps_mix = eelgrass and surfgrass (*Phyllospadix* spp.) mixed<br>Zm_Zj_mix = eelgrass and *Z. japonica* mixed<br>Ps_mono = surfgrass in a monospecific stand<br>Zj_mono = *Z. japonica* in a monospecific stand<br>absent = no seagrass observed<br>no_data = site has not been sampled |
| LATEST_SRVY | Date | Most recent date of survey at the site.<br>Null = not sampled. |
| FIRST_SRVY | Date | First date of survey at the site.<br>Null = not sampled |
| MAX_ZMAREA_AC | Double | Maximum eelgrass area estimate from all survey dates in acres.<br>-9999 = not sampled. |
| MIN_ZMAREA_AC | Double | Minimum eelgrass area estimate from all survey dates in acres.<br>-9999 = not sampled. |
| SHALLOWEST_FT | Double | Shallowest depth of eelgrass observations from all survey dates in feet with respect to mean lower low water (MLLW).<br>-9999 = not sampled. |
| DEEPEST_FT | Double | Deepest depth of eelgrass observations from all survey dates in feet with respect to mean lower low water (MLLW).<br>-9999 = not sampled. |
| MAX_ZMAREA_HA | Double | Maximum eelgrass area estimate from all survey dates in hectares.<br>-9999 = not sampled. |
| MIN_ZMAREA_HA | Double | Minimum eelgrass area estimate from all survey dates in hectares.<br>-9999 = not sampled. |
| SHALLOWEST_M | Double | Shallowest depth of eelgrass observations from all survey dates in meters with respect to mean lower low water (MLLW).<br>-9999 = not sampled. |
| DEEPEST_M | Double | Deepest depth of eelgrass observations from all survey dates in meters with respect to mean lower low water (MLLW).<br>-9999 = not sampled. |
| SITE_CHG_CLASS | Text | Classification of the change in native seagrass estimated for the site.<br>decreasing = area of native seagrass is decreasing<br>increasing = area of native seagrass is increasing<br>no_change_detected = no change in the area of native seagrass was detected<br>absent = native seagrass not observed<br>insufficient = insufficient data to assess change<br>no_data = no data collected |
| STRATUM2004 | Text | Sampling stratum that the site is a member of based on stratification finalized in 2004.<br>core = core stratum<br>flp = persistent flats stratum<br>flr = rotational flats stratum<br>frn = narrow fringe stratum<br>frn_orphan = orphan associated with narrow fringe stratum<br>frw = wide fringe stratum<br>frw_orphan = orphan associated with wide fringe stratum |
| FOCUS_AREA | Text | Focus area where the site is located. The focus areas were part of a sampling design for supplementary sampling effort that rotated annually among five focus areas. Focus area sampling was conducted 2004-2012. |
| STRATUM_FOCUS | Text | Sampling stratum that the site is a member of for the purposes of 2004-2012 focus area sampling. |

## *3.3 Attributes for Transect Points Feature Classes*

The attribute tables for the five geodatabases with transect points (one geodatabase for each region) follow the format below in Table 4.

Table 4. Attributes of the transect point feature classes.

| Field Name | Type | Description |
|---|---|---|
| SITE_CODE | Text | Unique site identifier (alpha numeric) |
| TRAN_NUM | Text | Transect number assigned in the field. |
| DATE_SAMP | Date | Date on which transect video was collected. |
| TIME24HR | Text | Time at which video was collected for each transect point in a 12-hour HH:MM:SS AM/PM format (e.g., 10:08:18 AM). Time is local time which is Pacific Daylight Time with few exceptions where sampling took place under Pacific Standard Time. |
| NATIVE_SG | Integer | Presence of native seagrass within the sequence of video frames in a one-second time interval (i.e., video frames with the same time stamp). Native seagrass includes eelgrass (*Z. marina*) and surfgrass (*Phyllospadix* spp.).<br>1 = present.<br>0 = not present. |
| ZJ | Integer | Presence of *Z. japonica* within the sequence of video frames in a one-second time interval (i.e., video frames with the same time stamp).<br>1 = present.<br>0 = not present. |
| PHYLLO | Integer | Presence of surfgrass (*Phyllospadix* spp.) within the sequence of video frames in a one-second time interval (i.e., video frames with the same time stamp).<br>1 = present.<br>0 = not present. |
| ZM | Integer | Presence of eelgrass (*Z. marina*) within the sequence of video frames in a one-second time interval (i.e., video frames with the same time stamp).<br>1 = present.<br>0 = not present. |
| UNDIFF | Integer | Presence of native seagrass that could not be differentiated with certainty between eelgrass and surfgrass within the sequence of video frames in a one-second time interval (i.e., video frames with the same time stamp). Native seagrass includes eelgrass (*Z. marina*) and surfgrass (*Phyllospadix* spp.).<br>1 = present.<br>0 = not present. |
| VIDEO | Integer | Video quality in a one-second time interval (i.e., video frames with the same time stamp).<br>1 = good video quality.<br>0 = poor video quality due to turbidity or low light conditions. |
| TRKTYPE | Text | Type of transect.<br>SLPR = random transect oriented perpendicular to shoreline.<br>RECN = reconnaissance.<br>MEAN = meandering transect (reconnaissance).<br>ZZAG = zig-zag transect (reconnaissance).<br>BATH = transect collected for bathymetry data.<br>SLPL = transect oriented parallel to shoreline.<br>SLOB = obstructed transect.<br>ABRT = aborted transect.<br>-9999 = unspecified transect type. |

| Field Name | Type | Description |
|---|---|---|
| DEPTH_OBS_M | Double | Observed depth of transect points in meters (MLLW).<br>-9999 = missing data value |
| DEPTH_INTERP_M | Double | Interpolated depth of transect points in meters (MLLW). Where possible, missing depth values in the observations were replaced with interpolated values.<br>-9999 = missing data value. |
| DEPTH_OBS_FT | Double | Observed depth of transect points in feet (MLLW).<br>-9999 = missing data value |
| DEPTH_INTERP_FT | Double | Interpolated depth of transect points in feet (MLLW). Where possible, missing depth values in the observations were replaced with interpolated values.<br>-9999 = missing data value. |
| VEG_CLASS | Text | A classification of seagrass species composition within the transect point footprint.<br>Zm_mono = eelgrass (*Zostera marina*) in a monospecific stand<br>Zm_Ps_mix = eelgrass and surfgrass (*Phyllospadix* spp.) mixed<br>undiff_native = native seagrass that could not be differentiated with certainty between eelgrass and surfgrass.<br>Zm_Zj_mix = eelgrass and *Z. japonica* mixed<br>Ps_mono = surfgrass in a monospecific stand<br>Zj_mono = *Z. japonica* in a monospecific stand<br>absent = no seagrass observed<br>no_data = transect point not classified. |

### *3.4 Attributes of Annual Eelgrass Site Results Geodatabase Table*

Annual site results are included as a table named *site_results_annual* in the svmp_distribute geodatabase. The attributes of this table are shown in Table 5.

### *3.5 Metadata*

Metadata is included with each data element in the SVMP distribution dataset. These data elements are listed in Table 2 (p.16). Much of the information in this user manual is replicated in the metadata for easy access within GIS software. Metadata is commonly viewed using the ESRI ArcCatalog application.

In 2003, the Washington State Information Services Board (ISB) adopted the FGDC metadata standard[1] for datasets produced by state agencies (Office of the Chief Information Officer, 2012). As part of the state government transition from managing technology policy through the ISB to the new Office of the Chief Information Officer (created October 1, 2011), the metadata policy was reviewed but no policy changes were made. The state metadata standard is likely to change eventually given that the FGDC itself now encourages federal agencies to transition to ISO metadata standards (FGDC 2013). The metadata accompanying the SVMP dataset follows the FGDC standard but full compliance with the standard was not explicitly validated.

[1] The FGDC metadata standard is formally the Federal Geographic Data Committee FGDC-STD-001-1998 Content Standard for Digital Geospatial Metadata.

Table 5. Attributes in the annual site results geoatabase table.

| Field Name | Type | Description |
|---|---|---|
| SITE_CODE | Text | Unique site identifier (alpha numeric). |
| YEAR | Text | Year in which sampling took place. |
| DATE_SAMP_START | Date | Date on which transect sampling started. |
| ZM_AREA_N_TRAN | Integer | Number of transects used for site eelgrass area estimate. |
| ZM_AREA_AC | Double | Site eelgrass area estimate in acres. |
| ZM_AREA_SE_AC | Double | Standard error of site eelgrass area estimate in acres. |
| ZM_MIND_N_TRAN | Integer | Number of transects used for mean minimum depth estimate. |
| ZM_MIND_MEAN_FT | Double | Mean minimum eelgrass depth estimate in feet (MLLW). |
| ZM_MIND_SE_FT | Double | Standard error of mean minimum eelgrass depth estimate in feet (MLLW). |
| ZM_MIND_SHALLOWEST_FT | Double | Depth of shallowest observation of eelgrass in feet (MLLW). |
| ZM_MAXD_N_TRAN | Integer | Number of transects used for mean maximum depth estimate. |
| ZM_MAXD_MEAN_FT | Double | Mean maximum eelgrass depth estimate in feet (MLLW). |
| ZM_MAX_SE_FT | Double | Standard error of mean maximum eelgrass depth estimate in feet (MLLW). |
| ZM_MAXD_DEEPEST_FT | Double | Depth of deepest observation of eelgrass in feet (MLLW). |
| ZM_AREA_HA | Double | Site eelgrass area estimate in hectares. |
| ZM_AREA_SE_HA | Double | Standard error of site eelgrass area estimate in hectares. |
| ZM_MIND_MEAN_M | Double | Mean minimum eelgrass depth estimate in meters (MLLW). |
| ZM_MIND_SE_M | Double | Standard error of mean minimum eelgrass depth estimate in meters (MLLW). |
| ZM_MIND_SHALLOWEST_M | Double | Depth of shallowest observation of eelgrass in meters (MLLW). |
| ZM_MAXD_MEAN_M | Double | Mean maximum eelgrass depth estimate in meters (MLLW). |
| ZM_MAXD_SE_M | Double | Standard error of mean maximum eelgrass depth estimate in meters (MLLW). |
| ZM_MAXD_DEEPEST_M | Double | Depth of deepest observation of eelgrass in meters (MLLW). |
| SAMP_STATUS | Text | Sampling status for this sampling occasion.<br>sampled = site was visited and an eelgrass area estimate has been produced. Either video transects were collected or eelgrass was assessed to be absent or trace based on reconnaissance.<br>obstructed = site was visited but not sampled due to obstruction.<br>incomplete = site was visited but sampling was not completed due to early protocols in place at time of visit that did not prescribe transect sampling if eelgrass (*Z. marina*) was not present even if surfgrass (*Phyllospadix* spp.) was present. The current protocol calls for sampling if either surfgrass or eelgrass is present.<br>withdrawn = site was selected for sampling but removed from site list prior to fieldwork due to obstruction or limited access (e.g., naval facilities). |
| SOUNDWIDE_STUDY | Integer | Flag indicating whether site was selected for sampling as part of soundwide study design intended to contribute to estimate of soundwide eelgrass area.<br>1 = selected as part of soundwide study.<br>0 = not selected as part of soundwide study. |
| FOCUS_STUDY | Integer | Flag indicating whether site was selected for sampling as part of focus study.<br>1 = selected as part of focus study.<br>0 = not selected as part of focus study. |
| SPECIAL_STUDY | Integer | Flag indicating whether site was selected for sampling as part of a special study.<br>1 = selected as part of special study.<br>0 = not selected as part of special study. |

# 4 Map Document

An ArcGIS map document (.mxd) is distributed with the SVMP database to facilitate browsing of symbolized data. All the spatial data layers and the geodatabase table described in this user manual are included in the map document.

The map document is included with the zip archive *SVMP_distribution.zip* which is one of the six zip files in the distribution dataset that can be downloaded (see section 1.3 Online Access on p.5). There are data links in the map document to transect data distributed in the other five zip archives. Data links to transects in a particular SVMP region will only function properly if the transect zip archive for that region has been downloaded, uncompressed and in the same location as the map document.

When using this map document to browse the dataset, it is important to be cognizant of three ways in which the presentation of the data diverges from the descriptions given in the previous section (section 3. Geospatial Database).

1. *Use of Definition Queries*.
   In some cases, an SQL query is used to filter the features in a data layer so that not all features are presented. For example, in the transect data a query can be seen in the Definition Query tab of the layer properties window (in ArcGIS software) that restricts visible transects to particulars years.

2. *Use of Field Aliases*.
   When the attribute tables are viewed in ArcGIS using the map document, aliases are seen instead of the field names presented in the previous section. These aliases are intended to be more easily understood without reference to the user manual.

3. *Hidden Fields*.
   When the attribute tables are viewed in ArcGIS using the map document, some fields that may not be of general interest (e.g., sampling stratum) are not visible. The visibility of fields can be seen on the Fields tab of the layer properties window in ArcMap.

Only a simple basemap is included in the SVMP map document and the download data. The basemap includes a simple polygon representation of Washington State and the adjacent area of Canada without any labeling of landmarks. This basemap is included for convenience and may not be suitable for many mapping needs. The Washington State

boundary was derived from data maintained by the Washington Department of Natural Resources. The Canadian boundary was derived from data distributed without restriction by the Humanitarian Information Unit of the Office of the Geographer in the U.S. Department of State.

# 5 References


Ardizzone, G., Belluscio A. & Maiorano, L. 2006. Long-Term Change in the Structure of a *Posidonia oceanica* Landscape and its Reference for a Monitoring Plan. *Marine Ecology* 27:299-309.

Bando, K.J. 2006. The roles of competition and disturbance in a marine invasion. *Biological Invasions* 8:755-763.

Berry, H.D., J.R. Harper, T.F. Mumford, Jr., B.E. Bookheim, A.T. Sewell and L.J. Tarrayo. 2001. *The Washington State ShoreZone Inventory User Manual*. Nearshore Habitat Program, Washington Department of Natural Resources. Olympia, WA. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_szusermanual.pdf

Berry, H. and R. Ritter. 1997. Puget Sound Intertidal Habitat Inventory 1995: Vegetation and Shoreline Characteristics Classification Methods. Nearshore Habitat Program, Washington Department of Natural Resources. Olympia, WA. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_methods.pdf

Berry, H.D., A.T. Sewell, S. Wyllie-Echeverria, B.R. Reeves, T.F. Mumford, Jr., J.R., Skalski, R.C. Zimmerman and J. Archer. 2003. *Puget Sound Submerged Vegetation Monitoring Project: 2000-2002 Monitoring Report*. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. 60pp. plus appendices. Available online: http://www2.wadnr.gov/nearshore.

Bulthuis, D.A. 1995. Distribution of Seagrasses in a North Puget Sound Estuary: Padilla Bay. Washington, USA. *Aquatic Botany* 50:99-105.

Cunha, A.H., Santos, R.P., Gaspar, A.P. & Bairros, M.F. 2005. Seagrass Landscape-Scale Changes in Response to Disturbance Created by the Dynamics of Barrier-Islands: A Case Study from Ria Formosa (Southern Portugal). *Estuarine, Coastal and Shelf Science*, 64:636-644.

Dowty, P. 2010. Initial assessment of SVMP focus area sampling. Unpublished report. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA. 59 pp.

Dowty, P. 2009. Significance of the comparison of increasing/decreasing SVMP site. Unpublished report. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA. 6 pp.

Dowty, P. 2006a. SVMP sampling frames and strata. Unpublished report. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA. 20 pp.

Dowty, P. 2006b. Reconstruction of original 2000 SVMP results, revised 2000 – 2005 results and new bonus material. Unpublished report. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA. 36 pp.

Dowty, P. 2005. *A Study of Sampling and Analysis Methods: Submerged Vegetation Monitoring Project at Year 4.* Nearshore Habitat Program, Washington Department of Natural Resources, Olympia, Washington. 133 pp. Available online: http://www2.wadnr.gov/nearshore.

Dowty, P., B. Reeves, H. Berry, S. Wyllie-Echeverria, T. Mumford, A. Sewell, P. Milos and R. Wright. 2005. *Puget Sound Submerged vegetation Monitoring Project: 2003-2004 Monitoring Report.* Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. 95 pp.

Ferguson, R.L. & Korfmacher, K. 1997. Remote Sensing and GIS Analysis of Seagrass Meadows in North Carolina, USA. *Aquatic Botany* 58:241-258.

FGDC. 2013. *Geospatial Metadata Standards*. Web page, accessed 11/29/13. http://www.fgdc.gov/metadata/geospatial-metadata-standards.

Fletcher, R.S., Pulich, Jr., W. & Hardegree, B. 2009. A Semiautomated Approach for Monitoring Landscape Changes in Texas Seagrass Beds from Aerial Photography. *Journal of Coastal Research* 25(2):500-506.

Gaeckle, J. 2009. SVMP_QA_QC_update_22Oct09. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. 6 pp.

Gaeckle, J., P. Dowty, B. Berry, L. Ferrier. 2009. *Puget Sound Submerged Vegetation Monitoring Project 2008 Monitoring Report.* Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. 57 pp.

Gaeckle, J., P. Dowty, B. Berry, S. Wyllie-Echeverria and T. Mumford. 2008. *Puget Sound Submerged Vegetation Monitoring Project 2006-2007 Monitoring Report*. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. 89 pp.

Gaeckle, J., P. Dowty, B. Reeves, H. Berry, S. Wyllie-Echeverria and T. Mumford. 2007. *Puget Sound Submerged Vegetation Monitoring Project 2005 Monitoring Report*. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. 93 pp.

Grizzle, R.E., Brodeur, M.A., Abeels, H.A. & Greene, J.K. 2008. Bottom Habitat Mapping Using Towed Underwater Videography: Subtidal Oyster Reefs as an Example Application. *Journal of Coastal Research* 24(1):103-109.

Hernández-Cruz, L.R, Purkis, S.J. & Riegl, B.M. 2006. Documenting Decadal Spatial Changes in Seagrass and *Acropora palmata* Cover by Aerial Photography Analysis in Vieques, Puerto Rico: 1937-2000. *Bulletin of Marine Science* 79(2):401-414.

Kendrick, G.A., Hegge, B.J., Wyllie, A., Davidson, A. & Lord D.A. 2000. Changes in Seagrass Cover on Success and Parmelia Banks, Western Australia Between 1965 and 1995. *Estuarine, Coastal and Shelf Science* 50:341-353.

Lirman, D., Deangelo, G., Serafy, J.E., Hazra, A., Hazra, D.S. & Brown, A. 2008. Geospatial Video Monitoring of Nearshore Benthic Habitats of Western Biscayne Bay (Florida) Using the Shallow-Water Positioning System (SWaPS). *Journal of Coastal Research* 24(1A):135-145.

Mach, M.E., S. Wyllie-Echeverria, and J.R. Ward. 2010. *Distribution and potential effects of a non-native seagrass in Washington State – Zostera japonica workshop*. Friday Harbor Laboratories, University of Washington. WA Department of Natural Resources and WA Sea Grant.

McDonald, J.I., Coupland, G.T. & Kendrick, G.A. 2006. Underwater Video as a Monitoring Tool to Detect Change in Seagrass Cover. *Journal of Environmental Management* 80:148-155.

Moore, K.A., Wilcox, D.J., & Orth, R.J. 2000. Analysis of the Abundance of Submersed Aquatic Vegetation Communities in the Chesapeake Bay. *Estuaries* 23(1):115-127.

Mumby, P.J., Green, E.P., Edwards, A.J. & Clark, C.D. 1997. Measurement of Seagrass Standing Crop Using Satellite and Digital Airborne Remote Sensing. *Marine Ecology Progress Series* 159:51-60.

Norris, J.G., Wyllie-Echeverria, S., Mumford, T., Bailey, A. & Turner, T. 1997. Estimating Basal Area Coverage of Subtidal Seagrass Beds Using Underwater Videography. *Aquatic Botany* 58:269-287.

Nysewander, D.R., Evenson, J.R., Murphie, B.L. & Cyra, T.A. 2005. *Report of Marine Bird and Marine Mammal Component, Puget Sound Ambient Monitoring Program, for July 1992 to December 1999 Period*. Washington State Department of Fish and Wildlife. Olympia, Washington.

Office of the Chief Information Officer. 2012. *Geographic Information Systems (GIS) Geospatial Metadata Policy No. 602-S1*. Adopted Feb. 06, 2003 and Revised April 20, 2012. http://www.ofm.wa.gov/ocio/policies/documents/161.11.pdf

Pasqualini, V., Pergent-Martini, C. & Pergent, G. 1999. Environmental Impact Identification along the Corsican Coast (Mediterranean Sea) using Image Processing. *Aquatic Botany* 65:311-320.

Phillips, R.C. 1974. Temperate Grass Flats. In H.T. Odum, B.J. Copeland & E.A. McMahan (Eds), *Coastal Ecological Systems of the United States* (pp.244-299). Washington DC: The Conservation Foundation.

Puget Sound Action Team. 2007. *State of the Sound 2007*. Publication No. PSAT 07-01. Puget Sound Action Team, Olympia, WA. http://www.psparchives.com/puget_sound/sos.htm

Puget Sound Action Team. 2005. *State of the Sound 2004*. Publication No. PSAT 05-01. Puget Sound Action Team, Olympia, WA. http://www.psparchives.com/publications/puget_sound/sos/04sos/PSATSOS2004.pdf

Puget Sound Action Team. 2002. *Puget Sound's Health 2002*. Puget Sound Action Team, Olympia, WA. http://www.psparchives.com/publications/puget_sound/sos/2002health/pshealth_2002.pdf

Puget Sound Water Quality Action Team. 2000. *Puget Sound's Health 2000*. Olympia, WA. http://www.psparchives.com/publications/puget_sound/sos/2000health/PSWQAT_PSHealth2000.pdf

Puget Sound Partnership. 2013a. *2013 State of the Sound: A Biennial Report on the Recovery of Puget Sound*. Tacoma, WA. http://www.psp.wa.gov/SOS_download.php

Puget Sound Partnership. 2013b. *Puget Sound Vital Signs*. Web resource. http://www.psp.wa.gov/vitalsigns/

Puget Sound Partnership. 2012. *2012 State of the Sound: A Biennual Report on the Recovery of Puget Sound*. Tacoma, WA. http://www.psp.wa.gov/downloads/SOS2012/sos2012_110812pdfs/SOS2012_ALL_110812.pdf

Puget Sound Partnership. 2010. *2009 State of the Sound Report*. Puget Sound Partnership, Olympia, WA. http://www.psp.wa.gov/sos2009.php

Puget Sound Partnership. 2009. *Puget Sound Action Agenda: Protecting and Restoring the Puget Sound Ecosystem by 2020*. Olympia, WA. Version 01 December 2008.

Reeves, B.R., Dowty, P.R., Wyllie-Echeverria, S. & Berry, H.D. 2007. Classifying the Seagrass *Zostera marina* L. from Underwater Video: An Assessment of Sampling Variation. Journal of Marine *Environmental Engineering* 9:1-15.

Ritter, R.A., H.D. Berry, B.E. Bookheim and A.T. Sewell. 1999. Puget Sound Intertidal Habitat Inventory 1996: Vegetation and Shoreline Characteristics Classification Methods. Nearshore Habitat Program, Washington Department of Natural Resources. Olympia, WA. Available online: http://www.dnr.wa.gov/Publications/aqr_nrsh_skagit_inv_methods.pdf

Shafer, D.J., J.E. Kaldy and J.L. Gaeckle. 2013. Science and Management of the Introduced Seagrass *Zostera japonica* in North America. *Environmental Management*. DOI 10.1007/s00267-013-0172-z. Published online 08 October 2013.

ShoreZone Inventory. 2001. The Washington State ShoreZone Inventory. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Skalski, J.R. 2003. Statistical Framework for Monitoring *Zostera marina* (Eelgrass) Area in Puget Sound. *In*: Berry et al. 2003. *Puget Sound Submerged Vegetation Monitoring Project: 2000-2002 Monitoring Report*. Appendix L. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, Washington. Available online: http://www2.wadnr.gov/nearshore.

Ward, D.H., Markon, C.J. & Douglas, D.C. 1997. Distribution and Stability of Eelgrass Beds at Izembek Lagoon, Alaska. *Aquatic Botany* 58:229-240.

Ward, D.H., Morton, A., Tibbitts, T.L., Douglas, D.C. & Carrera-González, E. 2004. Long-term Change in Eelgrass Distribution at Bahía San Quintín, Baja California, Mexico, Using Satellite Imagery. *Estuaries* 26(6):1529-1539.

Young, D.R., Clinton, P.J., Specht, D.T., DeWitt, T.H. & Lee, II, H. 2008. Monitoring the Expanding Distribution of Nonindigenous Dwarf Eelgrass *Zostera japonica* in a Pacific Northwest USA Estuary using High Resolution Digital Aerial Orthophography. *Spatial Science* 53(1):87-97.