Whatcom County
Submerged Aquatic Vegetation
Survey Methods

August 2004

This report was funded in part through a cooperative agreement with the National Oceanic and Atmospheric Administration.

The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA or any of it sub-agencies.

Whatcom County
Submerged Aquatic Vegetation
Survey Methods

Prepared for:

Whatcom County Public Works
Water Resources Division and,
Whatcom County Marine Resources Committee
322 North Commercial Street
Bellingham, WA 98225

Prepared by:

Chris Fairbanks
Fairbanks Environmental Services, Inc.
517 Briar Road
Bellingham, WA 98225

James G. Norris
Marine Resources Consultants
P.O. Box 816
Port Townsend, WA 98368

August 2004

Table of Contents

Appendix

1.0 INTRODUCTION

Submerged aquatic vegetation (SAV) in the marine environment is an important component of the nearshore ecosystem. SAV includes eelgrass (*Zostera marina* and *Z. japonica*) and attached macroalgae such as kelps (brown algae), red algae such as Turkish towel (*Chondracanthus exasperatus*), and green algae such as sea lettuce (*Ulva fenestrate*). SAV functions as rearing and forage habitat for many commercially important species such as juvenile salmon (*Oncorhynchus* spp.) and Dungeness crab (*Cancer magister*). The Cherry Point area is of particular interest partly because the Washington State Department of Natural Resources (DNR) has selected this area as a potential Aquatic Reserve and because of a stock of Pacific herring (*Clupea harengus pallasi*) that spawns exclusively along this shoreline. The Cherry Point herring stock is severely depressed and a petition for listing this stock under the Endangered Species Act is pending review by NOAA Fisheries. Pacific herring spawn on SAV in the nearshore and juvenile salmon prey on the eggs and larvae of herring and other forage fish.

SAV occupies the space that is "in the middle," between the terrestrial and marine environments and responds to forces originating both from onshore and offshore. Increased development along the shoreline of Whatcom County and Puget Sound threaten the health of SAV and the nearshore environment (Berry et al. 2003).

2.0 MAPPING METHODS

SAV has been assessed at many locations in Whatcom County using a variety of methods. These assessments range from efforts to comprehensively map the nearshore vegetation over a large area to mapping a very narrow study area with high resolution as part of project design and permitting. Each survey effort has used methodologies to meet their specific objectives. The survey methods used in Whatcom County and elsewhere can be categorized into three groups: (1) physical; (2) off-water-remote; and (3) on-water remote (Sabol et al. 2002). Table 1 summarizes the advantages and limitations of each general method described below.

Physical methods include direct observation and measurement by divers or beach walkers. Several of the proposed projects along the Cherry Point shoreline, for example the Georgia Strait Crossing (GSX) project and Gateway Pacific project, have used divers to map and assess the SAV within the project boundaries. WDFW has responsibility for issuing Hydraulic Project Approvals (HPA) for such projects, and provides recommended guidelines for eelgrass/macro algae habitat surveys at four levels:

1. Preliminary surveys to determine eelgrass presence/absence;
2. Intermediate surveys provide higher resolution are required if eelgrass is present;
3. Intensive surveys must be conducted if the area is a known herring spawning site; and,
4. Monitoring surveys must be conducted if mitigation was required.

Table 1. Comparison of methodologies

METHOD	EXAMPLES	ADVANTAGES	DISADVANTAGES	COST
Physical survey Direct physical sampling	WDFW eelgrass guidelines conducted by divers or beachwalkers	Precise mapping of a relatively small study area, Precise identification of vegetation and habitat characteristics	Labor-intensive fieldwork. Limited working time for divers and beachwalking is limited by tidal events. Divers observe a small portion of the survey area and results are interpolated between transects.	Moderately high; cost effective for site specific assessment and mapping
Off-water remote Aerial photo interpretation Satellite photo interpretation	WDNR ShoreZone survey. FREMP habitat mapping	Large area can be surveyed with less field labor.	Restricted to intertidal zone and to a shallow depth of water if clarity is sufficient. Identification of vegetation species must be done by ground truthing. Density and general health of plants cannot be discerned. Labor intensive for human interpretation of photos	High; cost for aerial photography is high and interpretation by qualified scientist is labor intensive.
On-water remote Underwater videography and Hydroacoustics	Friends of the San Juans and San Juan County MRC SAV mapping WDNR SAV Monitoring Project. Island County MRC	Precise mapping of moderately large areas using GPS technology. Precise identification of vegetation, density and general health. Data is stored digitally and can easily be reviewed for post processing. Digital data can be easily transferred into GIS tools.	Video camera and viewer observe a small portion of the survey area and results are interpolated between transects.	Moderate; cost effective for mapping moderately large areas.

Preliminary surveys may be conducted at any time of the year; all other surveys must be conducted between June 1 and September 30. These surveys are usually conducted by divers with transects set at 20 to 40 ft intervals. These methods provide the greatest level of resolution and generally can identify eelgrass to species and macroalgae to genus levels. Diving surveys are cost effective for discrete project areas; however, they are labor intensive and not cost effective for comprehensive mapping.

Off-water remote sensing methods interpret aerial photography (still or video) or satellite imagery by either a human interpreter or by a computer algorithm. The Washington State Department of Natural Resources (DNR) used aerial video photography from a helicopter to survey the entire shoreline of Washington State in 1995 and published the ShoreZone survey (Berry et al. 1997). The results of the ShoreZone survey were presented as linear shoreline segments having patchy, continuous, or no eelgrass. A limitation of the DNR ShoreZone survey was its inability to adequately identify subtidal resources. In general, off-water remote sensing methods work well when the water is clear and calm; the vegetation is easily identifiable and has a shallow distribution. For example, vertical true-color aerial photography has been used successfully to monitor eelgrass in Padilla Bay where conditions are near ideal (Bulthuis et al. 2003). Off-water remote sensing methods are limited because the vegetation types cannot be distinguished between eelgrasses or between eelgrass and macroalgae without extensive field truthing. In addition, macroalgae can grow to depths of -30 ft relative to Mean Lower Low Water (MLLW), which is too deep to be recorded from an aerial platform.

Improvements to the aerial remote sensing methods have been made through the Fraser River Estuary Management Program (FREMP). Habitat mapping was accomplished using three-dimensional surface modeling supplemented with Digital Elevation Model (DEM) data based on color aerial photos at 1:20,000 scale. After polygons were distinguished from adjacent polygons a field team visited the site to collect data to characterize the habitat. This methodology requires extensive post-processing and field visits to ground truth the results of interpretation and to identify the vegetation to species and genus. This method provides good resolution for vegetation observable from aerial photos but, as discussed above, aerial photography cannot penetrate the water beyond one meter (www.bieapfremp.org).

On-water remote sensing methods interpret georeferenced underwater videographic or hydroacoustic images. Norris et al. (1997) describe an underwater videographic technique for estimating the basal area coverage of submerged aquatic vegetation. Their sampling design is statistically motivated and involves randomly placed transects through a study area. Thus, their methods are not specifically designed to create a detailed map of the aerial extent of eelgrass. Sabol et al. (2002) evaluated the effectiveness of an unsupervised interpretation (i.e., computer interpretation without human intervention) of signals from a BioSonics DT4000 digital echosounder. Although they recommended the technique, they noted that it could not identify sparse or short vegetation and it could not predict plant biomass from echo integration. They did not attempt to differentiate species of SAV. Norris et al. (2003) evaluated the effectiveness of both an unsupervised and a supervised classification of signals from a BioSonics system collected from 10 locations in Puget Sound. They found that the unsupervised classification method was unusable as an eelgrass detection tool because it could not reliably distinguish between eelgrass and macroalgae. However, the supervised classification method (i.e., echograms interpreted by a scientist instead of a computer) was acceptable at seven of the ten sites considered.

Hydroacoustic systems use either vertical oriented acoustic signals or horizontal oriented signals. Vertical oriented systems such as the BioSonics DT 4000 can provide information to determine the height of the plant canopy above the seabed (plant height) and density of the vegetation bed. When interfaced with underwater video and GPS receivers, the vegetation can be accurately identified and mapped. This data can be stored digitally for post processing and direct transfer to GIS tools. Side scanning sonar uses a horizontally directed acoustic signal to delineate seagrass beds. This technique is an effective tool especially for delineating the margin of SAV as the boat travels parallel to the shore. This method is limited because the return signal requires subjective interpretation and vegetation height and density cannot easily be determined (Sabol et al. 2002).

In 2000, DNR initiated the Submerged Vegetation Monitoring Project (SVMP) to monitor eelgrass resources throughout Puget Sound and its bathymetric range (Berry et al. 2003). The SVMP approach is to divide Puget Sound into discrete sampling units, conduct detailed sampling (line transects) to estimate critical parameters (e.g., aerial extent, average maximum depth) at a few randomly selected units each year, and extrapolate the results to all of Puget Sound. DNR selected underwater videographic methods to conduct line transects for the SVMP because those methods appeared to be more cost effective than diver transects and more accurate (in terms of species identification and positioning) than other remote sensing methods, such as aerial photography and hydroacoustics.

The DNR SVMP stratifies the Puget Sound shoreline and associated SAV resources into two types: “Flats” and “Fringe.” The same field sampling methods are used at each type of site, but the statistics for parameter estimation are slightly different. Flats are broad areas in which the lengths of the shoreline and the -20 ft isobath are of much different length for example, Birch Bay and Lummi Bay. Fringe sites are defined to be 1,000 meters of shoreline in which the shoreline and the -20 ft isobath lengths are approximately equal. These sites are characterized by a relatively narrow band of eelgrass along a well defined shoreline. The Cherry Point shoreline from Pt. Whitehorn to Sandy Point would be considered a narrow fringe sites.

Multispectral Imagery

The Whatcom County shoreline from Pt. Whitehorn through Chuckanut Bay including Lummi Island (Figure 1) was extensively mapped in 1995 by the DNR using multispectral imagery from aerial photography, an off-water remote sensing method. This study classified SAV by the color spectral analysis of the types of vegetation (Berry and Ritter 1997) and is considered moderate resolution of the vegetation that was observed during low tide events. Floating algae such as bull kelp (*Nereocystis luetkeana*) could be delineated, but vegetation below approximately one meter depth could not be observed. A comparison of the estimates of vegetation based on the multispectral data compared to the SVMP method using underwater videography and hydroacoustics found that at six sites the area with *Z. marina* was substantially underestimated by the 1995 study by 13% to 66% and at one site, the area of *Z. marina* was overestimated by multispectral methods by 147 % to 271% (Berry et al. 2003). Underwater videography provides a greater resolution and can detect SAV at very low densities and at depth that could not be distinguished by aerial photographs (Berry et al. 2003).

3.0 RECOMMENDATIONS

To accurately map the vegetation along the Cherry Point shoreline from Pt. Whitehorn to the northern boundary of the Lummi Nation, a combination of two methods is recommended. These recommendations are based on two issues, navigation and resolution. Many large boulders are present in the intertidal and subtidal along the study area that are a hazard to navigating a boat and underwater equipment close to shore. Selecting mapping resolution is a balance between the project budget and size of the study area. To avoid the navigation hazards and to provide a high resolution for accurate mapping, the inner margin of vegetation can be mapped by walking the beach during an extreme low tide when the line of vegetation is exposed. The inner margin of the vegetation can be delineated using a map-grade GPS receiver as the beach walker travels along the beach.

Two technicians will walk the beach together. One will carry the GPS receiver and data logger and will walk along the shoreward edge of the SAV vegetation. The second technician will provide information of vegetation type, density, substrate, and offset measurements. Offset measurements will be used to map widths of vegetated or bare areas and will be measured with a resolution of at least 25 meters depending on length and width of feature. Attributes of intertidal vegetation, habitat characteristics, and offset measurements will be stored with the location points using the Trimble data logger. These attributes will include:

- Vegetation type; *Z. marina*, *Z. japonica*, macroalgae type.
- Density; high, low or absent.
- Substrate

The outer margin and body of the SAV band can be delineated using underwater videography and hydroacoustic sonar interfaced with a GPS receiver. This method was used to map eelgrass beds in Island County and San Juan County (Friends of the San Juans, 2004). The boat will travel at a speed of 0.5 to 2 knots (0.5 –1 meter per second) on zig-zag transects along the deepwater edge of vegetation where navigation is unimpeded. In areas where obstructions may occur such as large boulders or extensive beds of bull kelp (*Nereocystic luetkeana*) the boat operator may choose to back in toward the shore on a transect perpendicular to the shoreline, deploy the camera and recorded data as the boat moves seaward on the transect The zig-zag pattern is more time efficient than a series of transects perpendicular to the shoreline because the camera is continuously deployed along the entire length of a site (i.e., there is no setup time between transects). A critical advantage of surveying only along the deepwater edge is that surveying can be conducted during any tide stage, thus increasing the number of working hours each day. Where possible, the inner apex of the zig-zag or transect line will be at a depth appropriate for eelgrass (approximately -10 ft or less) so that the outer margins of eelgrass can be accurately mapped. Attributes of the subtidal vegetation and habitat characteristics will include:

- Vegetation type; eelgrass, macroalgae type.
- Density; high, low or absent.
- Substrate
- Depth

Locations of previous study such as the proposed GSX landing, and pipestring launch site at Gulf Road, BP Cherry Point pier, the proposed Gateway Pacific and Cherry Point Industrial Park will be included on the transect for comparison of results. The comparison of results from surveys conducted with differing methodologies will provide insight into consistency of data.

Accuracy and Resolution

Both the beach walk and boat-based surveys will have geo-referenced location data and therefore one single map can be created that will accurately plot both data sets. GPS receivers with sub-meter accuracy will be used to map SAV during both surveys. During the beach walk, a Trimble Pathfinder Pro XRS will be used to collect GPS locations and store attribute data entered into the data logger. A Trimble AgGPS 132 will be used for the boat-based survey and location data will be stored on a laptop computer. Both of these GPS receivers are rated as sub-meter accuracy by the manufacturer (Appendix A).

During the beach walk, the GPS receiver will record location at 5 second intervals. Attributes will be entered when a significant change of vegetation or substrate is encountered along the inner margin of the vegetation line. If a break in the vegetation is encountered, a straight line will be traveled to the inner margin of the next patch of vegetation.

Data collected during the boat-based survey will be stored at one second intervals on a laptop computer equipped with a video overlay controller and data logger software integrated GPS data (date, time, latitude, longitude), user supplied transect information (transect number and site code), and the video signal. Video images will be stored directly onto a VHS videotape, a video compact disk, and onto a digital videotape. Date, time, position, and transect information will also be stored on a floppy disk at one second intervals.

The boat-based survey will have transects spaced at approximately 50 to 100 meters apart depending on:

- Difficulty of navigation;
- Consistency of bottom features and vegetation;
- Areas of interest.

Where navigation is difficult due to a high density of intertidal boulders, kelp beds or other obstacles, transects may be spaced further apart to avoid damage to equipment. Where bottom features, vegetation type and vegetation density is consistent between transects the distance between the transects can be expanded. Transects and the apex of the zigzag pattern will not exceed 100 meters. Conversely, where bottom features and vegetation parameters are variable, the distance between transects will be reduced. Three locations that have been surveyed by divers within the past ten years will also have transects set with more narrow resolution. These locations are:

- Georgia Strait Crossing Landfall;
- Gateway Pacific Terminal;
- Gulf Road.

Vegetation and Substrate Classification

Both Island County and San Juan County choose to map eelgrass only without mapping macroalgae beds. Eelgrass and macroalgae grow in similar habitat and provide much of the same functions. Excluding macroalgae, especially at Cherry Point, would underestimate the SAV habitat area. Macroalgae observed on the boat-based survey will be classified from the video imaging during the post-processing phase. To balance the post-processing effort with the survey budget, macroalgae will be categorized as turf algae or canopy algae. Turf algae are dense mixed beds of algae that generally less than 0.5 meter in length and grow in the intertidal zone and canopy algae are taller less dense and grow in the lower intertidal and subtidal zones (O'Clair and Lindstrom 2000). Bull kelp (*Nereocystis luetkeana*) Sargassum (*Sargassum muticum*) would be classified as canopy algae but these two species are of particular interest because of their extensive beds at Cherry Point. The video image will be a permanent record and can be reanalyzed to document a more refined set of attributes at a later date. This survey will classify the SAV as:

- Absent
- Eelgrass; *Z. japonica*, *Z. marina*, (differentiating when possible)
- Turf algae (<0.5 m height dense beds of mixed algae types)
- Canopy algae (>0.5 m height beds of mixed algae dominated by Laminarias)
- Bull kelp (*Nereocystis luetkeana*)
- Sargassum (*Sargassum muticum*)

Density of vegetation will be categorized by the percentage of cover over the substrate with three categories:

- Absent
- Low density; 1% to 50% cover
- High density; 51% to 100% cover

Substrates will be classified using Washington State Classification System for marine and estuarine habitats (Dethier 1990) and summarized below:

Substrate	Size Class (mm)	Description
Rock, hardpan	>256	Boulder, bedrock, and consolidated clays
Cobble	64 – 256	Baseball to bowling ball sized rounded rock
Mixed coarse	38 – 304	Rock and cobble mixed with gravel, sand and shell (no component exceeds 70% of surface area)
Gravel	4 – 64	Washed and sorted pebbles to small rock.

Sand	0.06 – 4	Washed medium to coarse sand.
Mixed fines		Unwashed sand and mud with some gravel and organic material
Mud	<0.06	Very fine clay and organic material

4.0 SUMMARY OF FINDINGS

A summary of the methods and findings will be submitted to Whatcom County with a map of the SAV community of the Cherry Point area. The report and map will be submitted as both printed material and electronic media. The map will be in a GIS format consistent with Department of Ecology and Whatcom County's shoreline master plan program.

LITERATURE CITED

Berry, H.D., A.T. Sewell, S. Wyllie-Echeverria, B.R. Reeves, T.F. Mumford, J.R. Skalski, R.C. Zimmerman, and J. Archer. 2003. Puget Sound Submerged Vegetation Monitoring Porject: 2000-2002 Monitoring Report. Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA. 60 pp. plus appendices.

Berry, H.D. and B. Ritter. 1997. Puget Sound Intertidal Habitat Inventory 1995: Vegetation and Shoreline Characteristics. . Nearshore Habitat Program, Washington State Department of Natural Resources, Olympia, WA.

Bulthuis, D.A., S. Shull. 2003. Eelgrass distribution in Padilla Bay, Washington in 2000: gains and losses over a decade. Oral presentation at the 2003 annual meeting of the Pacific Estuarine Research Society, Vancouver, Canada.

Cochran, W.G. 1977. Sampling techniques. John Wiley and Sons, Inc.

Dethier, M.N., 1990. A marine and estuarine habitat classification system for Washington State. Washington Natural Heritage Program, Dept. Natural Resoures. 56 pp. Olympia, WA.

Friends of the San Juans. 2004. Eelgrass survey and mapping in San Juan County. Friends of the the San Juans. Friday Harbor, WA.

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

Norris, J.G., S. Wyllie-Echeverria, T. Mumford, A. Bailey, and T. Turner. 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquatic Botany 58: 269–287.

Norris, J.G., I.E. Fraser, H. Berry, A. Sewell, B. Reeves, and S. Wyllie-Echeverria. 2003. Comparison of acoustic and underwater videographic methods for mapping and monitoring eelgrass (*Zostera marina*). Poster presentation at the 2003 Biennial Conference of the Estuarine Research Federation, Seattle, WA.

O'Clair, R.M. and S.C. Lindstrom. 2000. North Pacific seaweeds. Plant Press. Auke Bay, AK.

Sabol, B.M., R.E. Melton, Jr., R. Chamberlain, P. Doering, and K. Haunter. 2002. Evaluation of a digital echo sounder system for detection of submersed aquatic vegetation. Estuaries.

Thom, R. M., and L. Hallum. 1991. Long-term changes in the areal extent of tidal marshes, eelgrass meadows and kelp forests of Puget Sound. U.S. Environmental Protection Agency, Seattle, WA. EPA910-91-005. 55 pp.

Woodruff, D., P. Farley, A. Borde, J. Southard, R. Thom, J. Norris, S. Wyllie-Echeverria, D. MacLellan, and R. Shuman. 2001. Nearshore habitat mapping in Puget Sound using side scan sonar and underwater videography. Oral presentation at the Puget Sound Research 2001 Conference, Bellevue, WA.

Appendix A

Trimble GPS
Receiver Specifications