

November 30 2012

Eelgrass Boundary Workshop Participants,

The attached technical memo is updated to incorporate additional feedback and information gathered from the past field season when implementation of the definition criteria were tested in the Puget Sound and outer coast estuaries.

Concerns persisted about the use of the term “bed,” not only from workshop participants, and memo reviewers but also from the DNR science staff attempting to implement the criteria. It became clear from our field sampling and interpretation of the criteria, that our goal was not to define a minimum presence of eelgrass, but rather to define when to stop surveying along a transect at an area where eelgrass was present. In fact, the project started to be referred to as the “eelgrass boundary project” because everyone involved was uncomfortable with the term “bed.”

Below is the memo from last spring with revisions that reflect changes in the use of the term that more accurately reflect how the criteria are being applied.

Please feel free to contact me if you have questions or comments at 360-902-1718 or cinde.donoghue@dnr.wa.gov.

Sincerely,

Cinde Donoghue
Aquatics Program
Washington Department of Natural Resources

Technical Memorandum:

Operational Definition for Determining Edge of Eelgrass (*Zostera marina*) Presence

A Summary of Workgroup Discussions and Related Analysis
November 2012

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Introduction

Proposed habitat conservation measures aimed to minimize or avoid impacts to eelgrass (*Zostera marina*) are currently being discussed among representatives of the Washington shellfish aquaculture industry, Washington Department of Natural Resources (DNR) management, and DNR aquatics program staff. Questions have emerged from these discussions regarding what constitutes an edge of eelgrass bed: What minimum presence of

eelgrass shoots comprise the edge of a bed? Are groups of non-contiguous eelgrass presence considered the edge of one larger bed, or are they treated as independent bed edges? Is there a minimum time that observable shoots must persist in an area to be considered a bed? The answers specified for these questions will have direct effects on activities that are constrained by proximity to eelgrass beds.

In an effort to address these questions, a technical workgroup was convened with the goal of establishing criteria for defining an eelgrass bed. Workgroup participants included scientists and technical representatives from DNR Aquatics Program, U.S. Fish and Wildlife, NOAA Fisheries, University of Washington, Northwest Indian Fisheries Commission, Point-No-Point Treaty Council, the Squaxin Island Tribe and the shellfish aquaculture industry. This technical memorandum provides a review of the information discussed at the meetings, steps through analyses of available data, proposes criteria for defining an eelgrass bed, and recommends metrics to consider for developing conservation measures with the intent to minimize and avoid impacts to eelgrass beds.

Goal

The overall goal is to determine the criteria for an operational definition for minimal presence of eelgrass necessary to be considered bed edge. The definition must be sufficient for site-level application for the sustainable management of eelgrass. It must allow for repeatable delineation of the beds so impacts from DNR authorized activities in marine tidelands can be avoided or minimized with application of appropriate conservation measures.

Objectives and Constraints

- The eelgrass edge criteria must be applicable at the project or site scale (on the order of 0.1-10 acres). This definition must be precise enough to provide a basis for siting of projects on state owned aquatic land parcels where eelgrass is present.
- The criteria must be feasible to apply using common survey methods and equipment by experienced environmental scientists.
- While a definition based on ecological principles is preferable, in the absence of conclusive scientific evidence, an operational definition based on best available scientific information will suffice so long as it is understood that this will be adaptively managed as information is gathered through implementation and monitoring.

Background

Currently used or proposed criteria for eelgrass presence and edge

As scientific evidence demonstrating the importance of eelgrass to nearshore ecological function has accumulated (Phillips 1984, Orth et al. 2006), entities tasked with sustainable

stewardship of coastal habitats are striving to maintain and restore eelgrass (Thom et al. 2008). This challenge requires the ability to delineate beds and to measure current status and change in the edge over time. Table 1 summarizes various eelgrass bed and edge criteria and the agency or entity that has implemented or proposed each. Some of these definitions are proposed based on some local empirical data, others are based on knowledge of the specific ecological function the eelgrass provides that is of concern (e.g. fish refugia),. Some were developed for research or resource management purposes while others were developed for regulatory implementation.

Table 1. Existing criteria for defining eelgrass presence and bed edge

IMPLEMENTATION AGENCY, ENTITY, RULE OR POLICY	CONTIGUOUS BED and BED EDGE CRITERIA
DNR Habitat Stewardship eelgrass surveying criteria	Contiguous separation distance ≤ 1 m Minimum shoot density 3 shoots/m ²
DNR Submerged Vegetation Monitoring Program (SVMP)	Any eelgrass presence within a 1m ² area along the length of a video transect that is continuously sampled at approximately 1 meter intervals until no presence is detected. A single shoot within a 0.1 m ² grab sample.
U.S. Corps of Engineers Regional General Permit -6	An area of tidal substrate supporting eelgrass covering a minimum of 25% of the substrate
Tampa Bay Estuary Program-proposed definition	A "seagrass bed" is $\geq 10\%$ cover within a 10-30 m long transect line. The "zone of eelgrass occurrence" is defined as 1 shoot/m ² for at least 10 m along a line transect (Virnstein et al. 1998)
Alaska Sea Grant	A "persistent patch" of eelgrass from qualitative observations requires ≥ 50 shoots/m ² (Wyllie-Echeverria and Thom 1994)
Massachusetts Division of Marine Fisheries	The "edge of the bed" is defined as having two points; 1) the distance to the end of the continuous meadow, and 2) the distance to the last shoot (Evans and Leschen 2010).
Seagrass Net	To be considered within the same bed, any eelgrass present within a 1 m ² quadrat must be within ≤ 1 m distance of a nearby eelgrass presence. The edge or transition area is indicated by the distance of the furthest eelgrass shoot that is beyond this 1m contiguous bed from a fixed point along a fixed transect. Eelgrass shoot counts (within 0.0625 m ²) and percent cover (in 0.25m ²) is estimated in 12 randomly pre-selected quadrats along a 50 m transect (Short et al. 2006)
Seagrass Watch	A single shoot within a 1 m ² quadrat along a 50 m long transect constitutes presence. Both shoot counts and an estimate of percent cover are recorded (McKenzie et al. 2003).

Ospar Commission

A "seagrass meadow" is defined as an area of at least 2x2 meters covered in seagrass. If < 10 meters exists between patches, they are considered of the same meadow. A distance > 10 meters exists between patches they are of separate meadows (MARBIPP 2006).

Scientific literature relevant to minimal eelgrass presence definition

Listed below are ecological functions and attributes that should be considered when developing a scientifically based definition for minimal eelgrass presence constituting an edge.

- In many areas eelgrass occurs as a 'compound' grouping of non-contiguous areas. (Fonseca and Bell. 1998). A separation distance criterion must be established to determine how to group these non-contiguous areas.
- The minimum detectable quantity of eelgrass depends on the sampling method used, but most site-scale sampling methods are able to detect eelgrass to the individual shoot. A minimum threshold that constitutes an accepted eelgrass presence (e.g. single shoot, area of specified shoot density or percent cover) must be defined.
- Eelgrass morphological structure consists of above-ground shoots as well as below-ground rhizomes. The below-ground portion of the plant is often of larger dimension and mass than the visible, above-ground portion.
- How eelgrass presence affects the scope of habitat provision (benthic invertebrates, fish, or birds) (Hirst and Atrill 2008).
- How eelgrass presence parameters (area and density) affects the ability of eelgrass to stabilize sediment and trap suspended particulates (Koch 2001).
- How eelgrass biomass, area and density affects the level of primary productivity and contribution to the detrital food web.
- Persistence of vegetated area – a minimum eelgrass presence may be needed for an eelgrass unit to remain present year after year. Interannual cross- and long-shore variability of seagrass bed edges has been documented (Frederiksen et al. 2004; Marbà and Duarte 1995, Grette Associates 2005, 2008, and 2009).
- Resilience of vegetated area – a minimum residual eelgrass presence or density may be required to re-establish an area after experiencing disturbance (natural or anthropogenic)
- Distances between eelgrass shoots affect seed dispersal and successful gene flow.

Scientific studies with specific metrics regarding the ecological attributes listed above are summarized below. This information was reviewed and discussed in the workgroup meetings

when considering development of minimum size, density and persistence eelgrass bed edge criteria.

Habitat

- Fonseca et al. (1998) observed that eelgrass present in areas as small as 1-2 m² had greater numbers of fish, shrimp, and crab compared with adjacent unvegetated areas.
- A study comparing benthic infaunal biodiversity of *Zostera* vegetated patches (ranging in size from 0.24 m² to 17 m²) and non-vegetated intertidal substrate areas found that all *Zostera* patches supported a higher level of biodiversity than bare sand, and neither the patch size or mean shoot density had any impact on the level of diversity (Hirst and Attrill 2008).
- Eelgrass fragmentation was examined for its role in benthic infauna community composition in the United Kingdom by comparing infaunal communities in a continuous 2.3 ha meadow versus the composition in patches 6-9 m² (Frost et al. 1999). Communities differed as a result of small changes in species abundance, but not in diversity. However, polychaetes generally associated with unvegetated habitats (e.g. *Magelona mirabilis*) were found to be more common in the fragmented bed than in continuous beds.
- Neither patch size, nor location of sampling within patches (edge or central) exerted as much influence on the infaunal community as sediment composition (Frost et al. 1999). Total abundance did not differ between patch sizes in univariate analyses, but multivariate analyses showed that the species that contributed most to the difference in assemblage composition between patches were more abundant at the edge. In particular the nematodes *Capitella capitata* and *Spio filicornis*, species tolerant of random disturbance (stochastic events) were more abundant at the edge of beds relative to samples collected from the interior of the beds.
- An examination of fish and amphipod abundance across seagrass areas (*Halodule wrightii*) ranging 5-93 m² in size suggested no consistent relationship between faunal abundance and patch size (Bell et al. 2001).
- Based on a study of varying eelgrass densities (140 to 660 shoots/m²), no significant differences in the number of fishes sampled were detected between eelgrass plots (Wyllie-Echeverria et al. 2002 as cited in Blackmon et al. 2006).
- Throughout the Puget Sound, eelgrass habitat has been shown to be utilized by juvenile salmonids, but no indication of how this habitat is used based on the density and structure of the eelgrass beds has been provided (Blackmon et al. 2006).
- Epibenthic faunal abundance was closely related to eelgrass presence and shoot development when comparing unvegetated, transplanted, recently seed-colonized, and mature eelgrass habitats in North Carolina (Fonseca et al. 1990).

- Blue crab survival in the Chesapeake Bay was found to vary with eelgrass patch size and complexity (Hovel and Lipcius 2001 as cited in Blackmon et al. 2006). Juvenile blue crab density decreased as patch size increased, and increased habitat fragmentation increased blue crab survival due to the increase in seagrass edge habitat. However, density was significantly lower in isolated patches separated by large areas of unvegetated habitats.
- In a New Zealand study, seagrass patch variables (patch size, % cover and biomass) explained only 3-4% of the variation in benthic community, while landscape variables (fractal geometry, patch isolation) and wave exposure explained 62.5% of the variation in faunal abundance data (Turner, et al. 1999).

Sediment characteristics

- Both above and below ground eelgrass structure contributes to sediment stabilization; above-ground shoots have the capacity to reduce water flow which results in lowering the velocity of the flow on the sediment substrate, thus reducing the amount of sediment that can be entrained and transported (Fonseca et al. 2006).
- Eelgrass acts as a sediment sink with above-ground shoots trapping sediment and particulates from the water column and below ground rhizomes and roots anchoring sediment. This can result in sediment accretion that changes the bathymetry – causing mounding in areas around seagrass (Walker 1999).
- The capacity of eelgrass to accrete sediment increases with increasing patch size. The magnitude of slowing current velocity and accreting sediment is based on the density of the eelgrass shoots, hydrodynamic conditions of the area, and the depth of the water column above the plants (Koch 2001). Changes in physical conditions trap nutrients and stabilize habitats that are necessary for seagrass growth and recruitment. Elimination of newly developed small patches will slow or entirely inhibit larger, more extensive patch development (Kendrick et al. 2005)
- Patches as small as 0.3 m and 1.0 m along the axis of current flow were capable of significantly reducing current velocity relative to bare mud flat habitat (Fonseca and Koehl 2006). Eelgrass has been shown to attenuate 43% of wave energy in a 1 m long vegetated transects (Fonseca and Cahalan 1992).
- A significant difference in median grain size and sorting coefficient was observed in contiguous versus fragmented eelgrass areas, and median grain size was found to be the variable best explaining multivariate community patterns (Frost et al. 1999).

Primary Productivity/contribution to food web

- Seagrasses can act as short-term sinks for refractory carbon; 1-2 years for above-ground biomass and 4-6 years for below ground biomass (Mateo 2006). Eelgrass has the capacity to survive and maintain actively growing perennial populations even in

its northern-most limit by storing excess carbohydrates in the rhizomes during the dark winter. There is, therefore, important ecological function being provided by below-ground structure that may be laterally distant from the visible above ground shoots (Duarte et al. 2002).

Persistence

- In plots established outside a continuous vegetated meadow, patch mortality was observed to decrease with increasing patch size (area) and age, and only patches >32 shoots survived. The critical minimum patch area required for survivorship varied seasonally (Olesen and Sand-Jensen 1994).
- Fonseca and Bell (1998) found that eelgrass areas with <50% cover were less stable than those with greater percent cover.

Resilience

- Compared with seedlings, surviving adult plants and small patches may contribute considerably to recolonization of a dieback area as these plants have faster elongation and branching rates and lower mortality than seedlings (Greve et al. 2005).

Reproduction

There are differences in the relative importance of sexual and clonal portions of eelgrass life history that must be considered when attempting to set management standards for protection and maintenance of genetic structure.

Seed dispersal distance and transport time

- 95% of pollination occurs within 15 m of source. 83% of seeds are dispersed within 5 m of the source and 100% within 50 m (Ruckelshaus 1996).
- Pollen is viable for only 7-48 hours (de Cock 1980; Cox et al. 1992).
- Once buried in sediment, seeds of *eelgrass* can remain dormant for 1-2 months (Moore et al. 1993).
- Reproductive shoots carrying maturing seeds can be carried by currents or consumed by water fowl and transported long distances (kilometers).
- Germination rates range between 5-20%, with 80% of the seedlings germination within 5 m diameter of source (Orth et al. 1994). Germination rates were found to not be seed-density dependent, but were patch size dependent (Orth et al. 2003).

Genetic Neighborhood

- In a study of genetic diversity and patch size with patches ranging from 0.25m² to 440m², Ruckelshaus (1996) found genetic diversity was inversely related to patch

size. Genetic diversity tended to be higher in intertidal areas that had smaller patch sizes and were more prone to disturbance.

- Ruckelshaus (1994) found that a distance of 4 m around a plant was adequate to genetically separate individual plants.

Table 2. Summary Table: values of eelgrass metrics associated with ecological attributes from the review of literature

ECOLOGICAL ATTRIBUTE	EELGRASS METRIC	VALUE
Benthic habitat	Minimum area of eelgrass presence that affects habitat value	1-2 m ² (Fonseca et al. 1998)
		0.24 m ² (Hirst and Attrill 2008)
Sediment stability	Minimum area of eelgrass to significantly reduce current velocity	0.3 m ² (Fonseca and Koehl 2006)
Seed dispersal	Seed dispersal distance	5m (Ruckelshaus 1996)
Genetic diversity	Distance at which plants can be genetically distinguished	4m (Ruckelshaus 1994)
Vegetative reproduction	Mean rhizome growth rate	26 cm/yr (Marbà and Duarte 1998, Sintes et al, 2006))
Persistence	Minimum eelgrass density associated with persistence	>32 shoots per patch area (Olesen and Sand-Jensen, 1994)
	Eelgrass cover associated with greater persistence	>50% cover (Fonseca and Bell 1998)

Summary of available data relevant definition of eelgrass edge

Existing eelgrass data available to DNR staff were evaluated to see if any patterns in eelgrass density, patchiness or persistence emerged, or if perhaps there was any indication that further investigation of this data might be useful in developing eelgrass bed criteria. The four data sources described below include the Dumas Bay SeagrassNet site, the Submerged Vegetation Monitoring Program density grab samples, mitigation monitoring data from a Maury Island site and plant morphology data from the DNR Stressor Project.

Dumas Bay SeagrassNet Site

SeagrassNet is a worldwide ecological monitoring program that documents the status of seagrass resources. The program started in 2001 in the Western Pacific and now includes 115 sites in 32 countries with a global monitoring protocol and web-based data reporting system. A SeagrassNet site was established in Dumas Bay in Washington’s Puget Sound in May 2008. SeagrassNet sampling protocol requires that three fixed transects be established in an area of seagrass presence that is representative or “typical” for the area. The fixed transects run alongshore, parallel to the beach. Transect A is located approximately 1 m into the contiguous eelgrass from the shoreward edge. Transect C is 1 m into the contiguous eelgrass from waterward edge. Transect B runs through the center of the contiguous eelgrass.

Contiguous is defined as any eelgrass shoot that is within ≤ 1 meter of another eelgrass shoot. Furthest shoot data was compiled and analyzed from the Dumas Bay SeagrassNet site. The furthest (last, terminal) shoot is measured from three points (0, 25 and 50 m) perpendicular from the shallow (transect A) shoreward and deep (transect C) seaward transect. The distance to the edge of the area of contiguous eelgrass (≤ 1 meter shoot spacing) is also measured from these points. Data is collected quarterly.

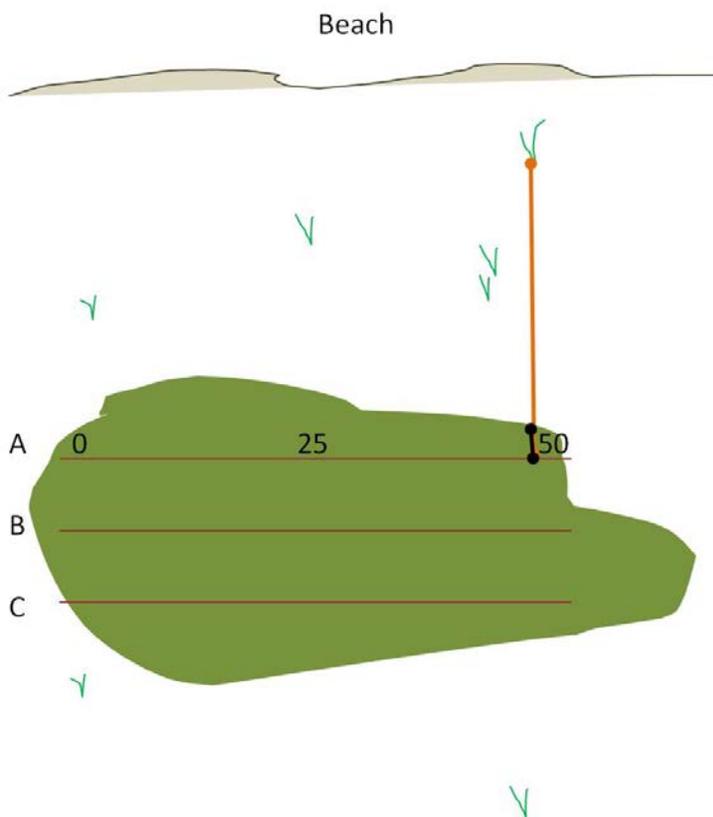


Figure 1 illustrates SeagrassNet transect placement, measurement to bed edge and furthest shoot distance.

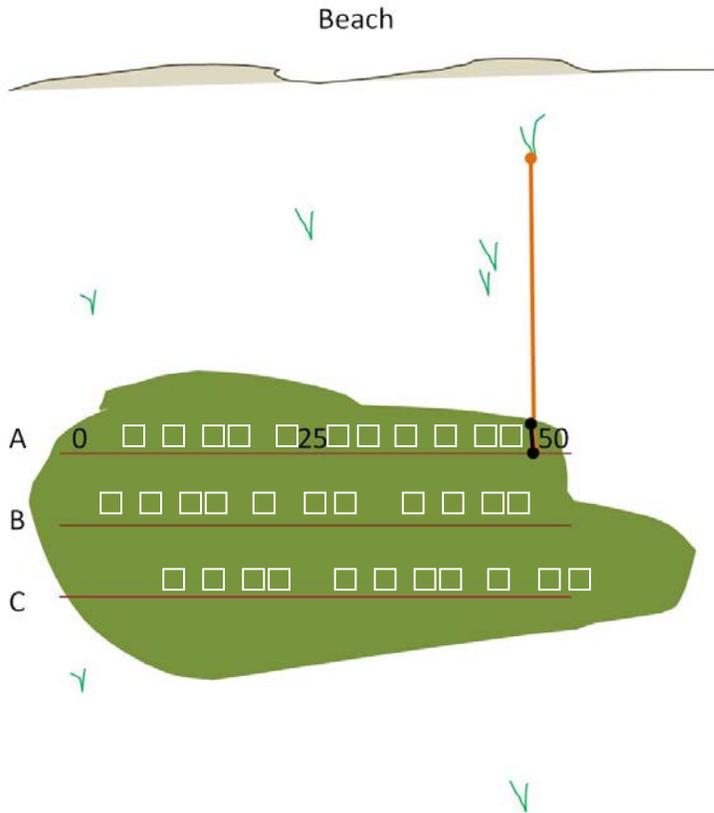


Figure 1. Schematic of SeagrassNet site and distance to edge of bed (black line) and furthest shoot distance (orange line) (diagram not to scale)

From May 2008 through January 2011, thirteen sampling events occurred. There were not enough sample times where furthest shoot data was collected from the deep transect (transect C) to provide any meaningful information for the analysis. A basic evaluation of the furthest shoot data collected from the shallow transect (transect A) revealed:

Furthest shoot distance- Dumas Bay

Sparse, patchy eelgrass along the intertidal edge of larger contiguous eelgrass areas had been observed in the field by many of the workgroup participants. From the discussion, it seems the size, distance from the contiguous eelgrass, and ephemeral nature of this eelgrass varies considerably. This prompted an examination of the available data to see whether any of these parameters might be quantified. Here, the furthest shoot refers to the single furthest shoot from the central area of the eelgrass.

- 1) Furthest shoots were not present throughout the year; they were only present in the spring and summer sample times.

2) When furthest shoots were present, they were located near where they had been previously detected (maximum change in furthest shoot distance was 5.3 m).

3) The maximum distance of a furthest shoot from the contiguous edge was 8.9 m. 4) The change in contiguous edge location over all sampling times (through all seasons) ranged from 0.4m at the center position to 11.3 m at the left position. 5) Net change from the first spring sampling (May '08) to the most recent spring sampling (Apr '10) was much smaller, ranging from 0.1 m at the center position to 1.7 m at the left position. The results are summarized in Table 3 and Table 4.

Table 3. Furthest shoot distance, Dumas Bay, SeagrassNet site.

	SHALLOW TRANSECT FURTHEST SHOOT DISTANCE (M)				n (# times furthest shoots present)	n (# times bed examined for furthest shoot)
	Max	Min	Mean	Std dev		
SeagrassNet site, Dumas Bay May '08-Jan '11	8.9	1.8	6.6	2.3	7	34

Table 4. Change in edge and furthest shoot location Dumas Bay, SeagrassNet site

Position on Transect A	Max seasonal change in edge distance (m)	Max annual change in edge distance	Max change in furthest shoot distance(m)
center	+0.4	+0.3	+1.5
left	-11.3	-3.4	-1.7
right	-6.1	+2.2	+5.3

This analysis provided some insight into the magnitude of changes in the edge and furthest shoot location, as well as the seasonality in the expansion/contraction of the edge and furthest shoot presence at this site. In addition, a pilot investigation of the DNR Submerged Vegetation Monitoring Program (SVMP) data was conducted to see what information about furthest shoot distance from contiguous bed edge might be learned and what comparisons could be made among the different areas of Puget Sound. This preliminary analysis indicated the furthest shoot distance could not be estimated using the SVMP data. The SVMP data did not distinguish between a single blade in a square meter and thousands of shoots per meter. Further analysis of the SVMP data was abandoned.

Eelgrass Density- Dumas Bay

Eelgrass density and percent cover estimates were conducted at fixed random sites along three 50m longshore transects at +1, 0 and -1.6 MLLW tidal elevations. Seasonal variability is apparent in density and percent cover, with maximum values observed in the spring and summer (data not shown). Interannual variability is also observed. This is apparent from the range in density and the standard errors reported for just the July samplings (the SeagrassNet site is sampled quarterly) 2008-2011, documented in Table 5 below.

Table 5. Shoot density and percent cover at Dumas Bay, SeagrassNet site

Transect & elevation (MLLW)	Date	Average density (shoots/m ²)	SE(n)	Average % cover	SE (n)
A, +1	July '08	597.3	277.7 (12)	28	12 (12)
A, +1	July '09	292.0	206.7 (12)	16	9 (12)
A, +1	July '10	184.0	97.9 (12)	12	6.8 (12)
A, +1	July '11	109.3	76.8 (12)	8	5 (12)
B, 0	July '08	769.6	175 (12)	46	6.6 (12)
B, 0	July '09	878.7	192.4 (12)	61	7.9 (12)
B, 0	July '10	892.0	135.6 (12)	72	9.7 (12)
B, 0	July '11	841.3	148 (12)	62	9.1 (12)
C, -1.6	July '08	210.7	32 (12)	46	6.2 (12)
C, -1.6	July '09	280.0	33 (12)	38	4.1 (12)
C, -1.6	July '10	186.7	29.6 (12)	28	4.9 (12)
C, -1.6	July '11	130.7	10.9 (12)	26	4.3 (12)

SVMP Eelgrass Shoot Density

Environmental parameters influencing eelgrass plant structure and eelgrass density have been reported in scientific literature (Boese et al. 2003; Turner et al. 1999). Workgroup participants have also cited field observations of geographic differences in plant structure and density. This encouraged an examination of the available data on eelgrass shoot density, specifically to see if regional differences or variability in eelgrass density over time might be quantified.

DNR grab sample density counts

Initial sampling for the SVMP included shoot density counts of grab samples collected with a van Veen sampler. An average of 23.9 shoots /sample with a minimum of 1 shoot per unit area was reported from 1020 samples collected from 2000-2003. Sites sampled within each region were not necessarily sampled each year, though some sites were sampled in consecutive years. Sampling did not fall in the same period for each year either. While the absolute density numbers differed each year, visual observation of the data (see plots in figure 2 below) does

indicate a fairly consistent pattern of relative difference in shoot density among the five regions sampled, with Hood Canal (hdc) having the highest density, Central Puget Sound (cps) and North Puget Sound (nps) competing for second highest, then South Whidbey (swh), and San Juan Island (sjs) with the lowest density.

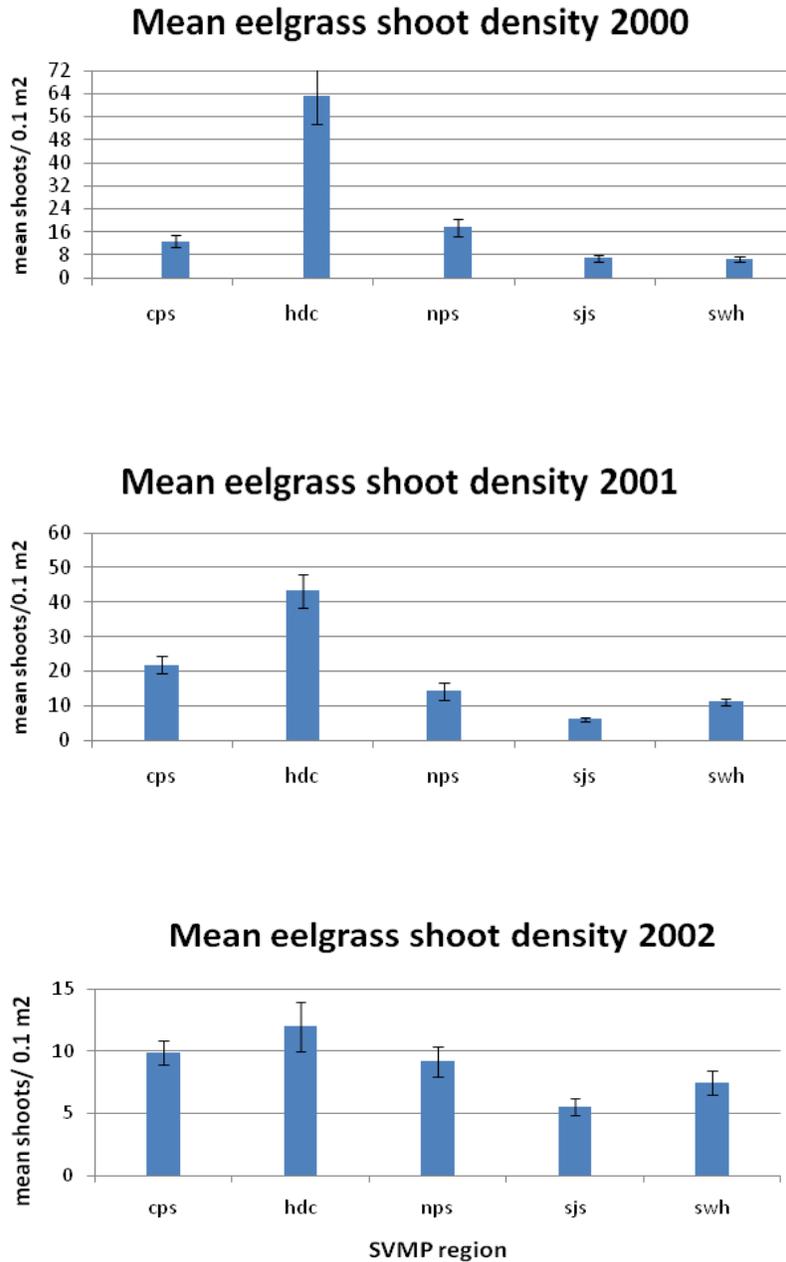


Figure 2 Mean eelgrass shoot density from annual grab sampling by region, 2000-2002. Error bars are standard errors of the means.

Mitigation monitoring data- Maury Island

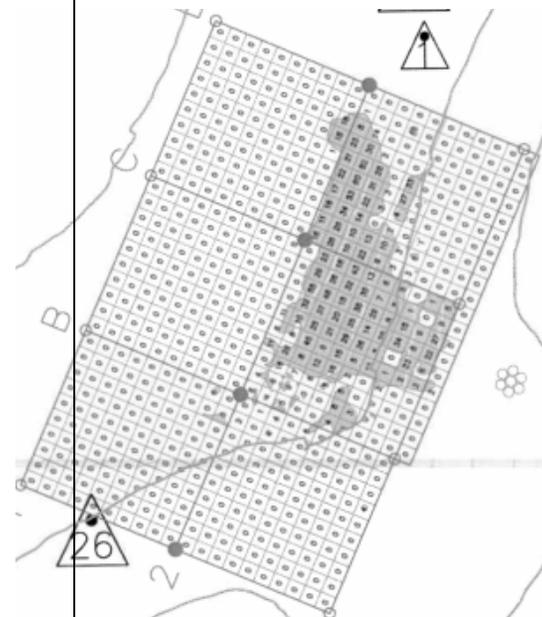
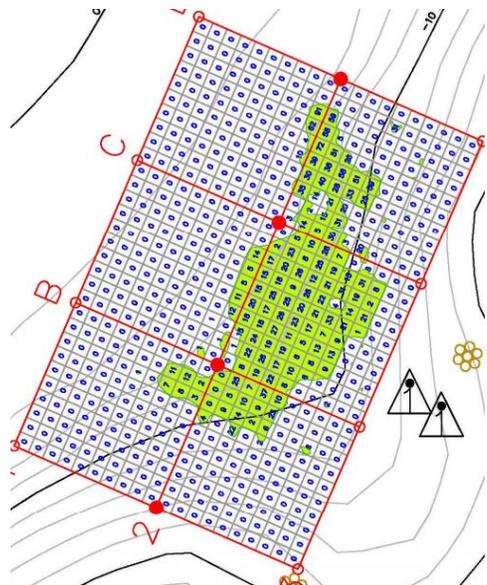
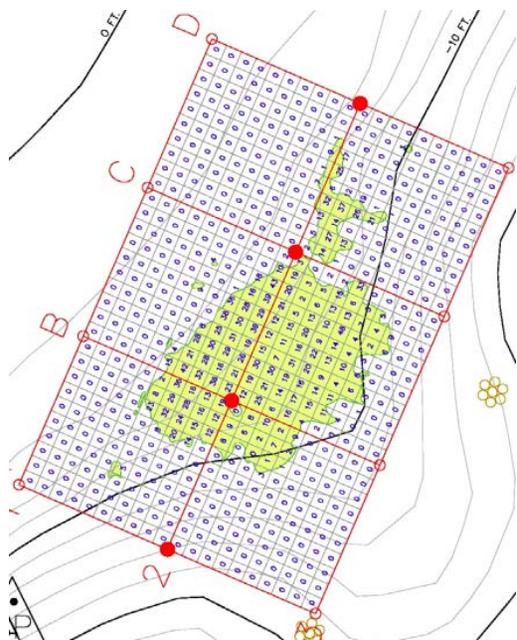
Eelgrass at a proposed project site on Maury Island was monitored intensely in 2005 and 2008 and 2009 by the consulting firm Grette Associates LLC. Fixed grids with grid cell size of 1 x 1 meter were established to encompass all the eelgrass area. Dive survey sampling included eelgrass percent cover estimates within each square meter grid cell, eelgrass density shoot counts within a 0.25 m² portion of each grid cell, and delineation of eelgrass presence in each square meter. Eelgrass survey maps from sample years 2005, 2008 and 2009 are reproduced in figures 3-5 below with eelgrass presence delineated and the density counts/0.25 m² indicated within each grid cell. Sampling occurred during July for 2005 and 2008, then in August for 2009. The images are from Northwest Aggregates: Maury Island Gravel Dock Annual Eelgrass Survey Reports, December 19, 2005, September 19, 2008, and December 15, 2009 prepared for Northwest Aggregates by Grette Associates LLC.

Eelgrass Density–Maury Island

Close examination of the data from eelgrass monitoring of the North, South and Control patches (figures 3-5 below) indicated differences in the stability of the three eelgrass areas. These findings are summarized in Table 5.

Table 6. Eelgrass area and mean density at Maury Island Gravel site

Patch name	Year	Area (m ²)	Net change in area (m ²) from '05 to '09	Average density (shoots/m ²)	Net change in avg. density (shoots/0.25m ²) from '05 to '09
North	2005	126		77	
	2008	127		72	
	2009	85	-41	13	-64
South	2005	148		54	
	2008	152		56	
	2009	218	+70	28	-26
Control	2005	261		30	
	2008	256		37	
	2009	265	+4	26	-4



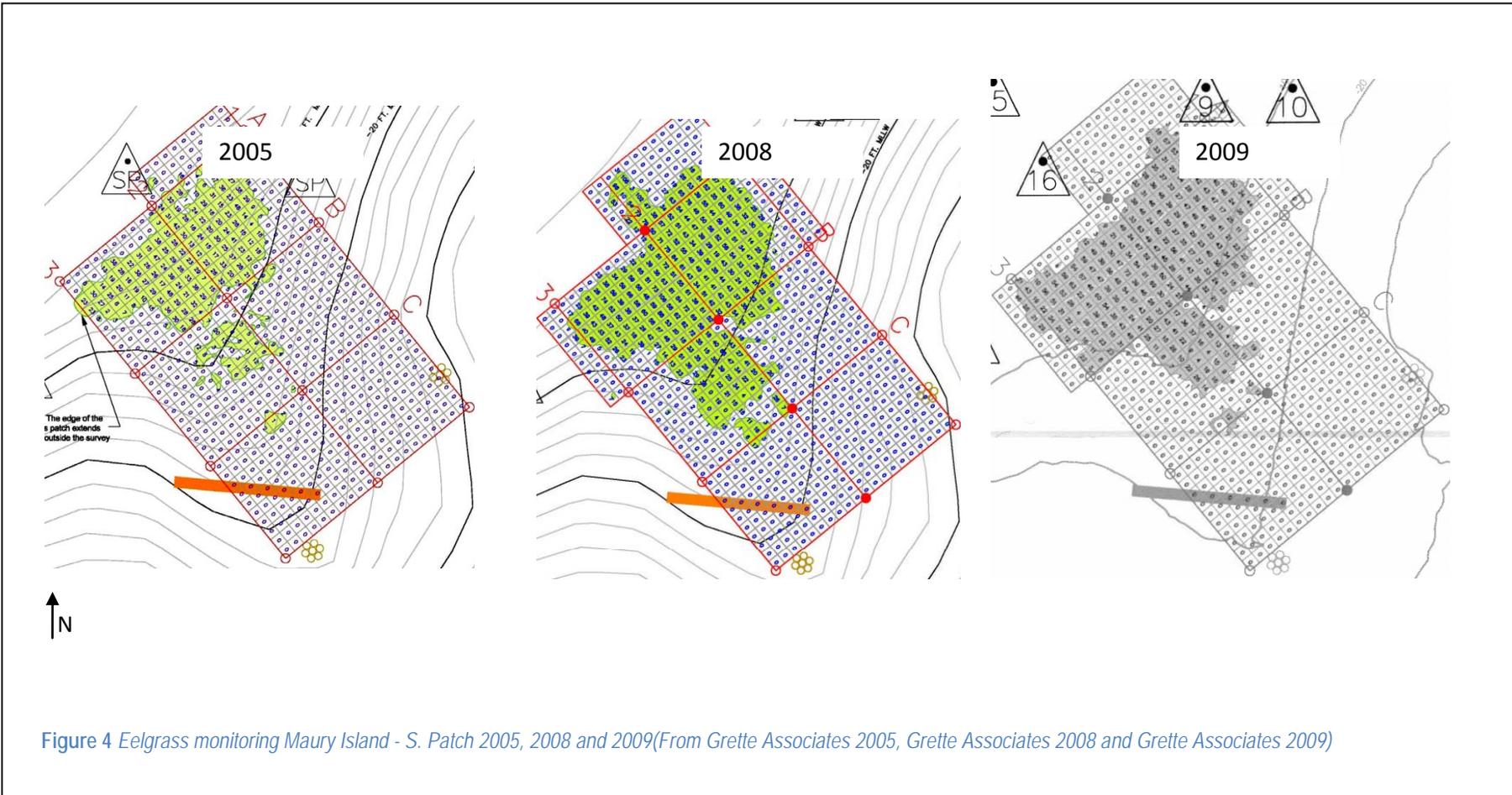
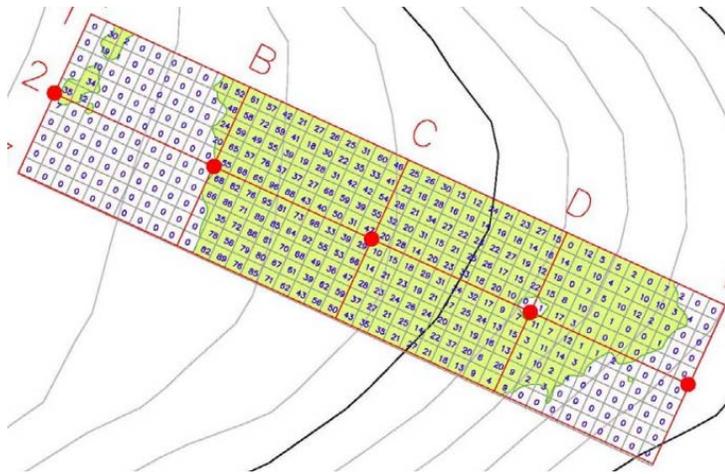
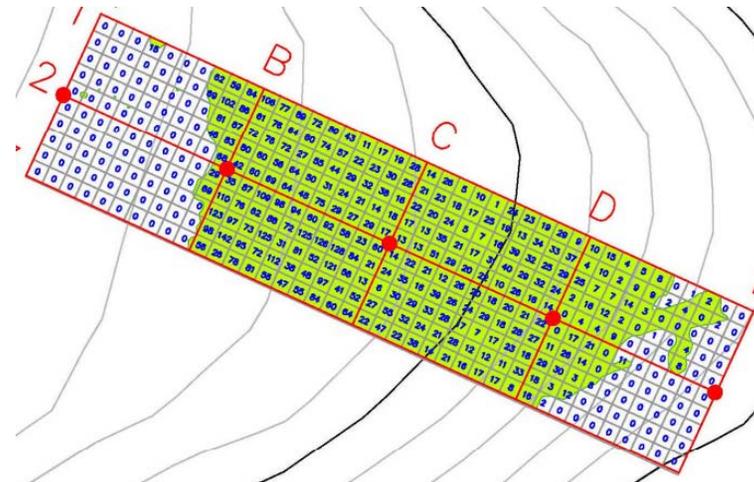


Figure 4 Eelgrass monitoring Maury Island - S. Patch 2005, 2008 and 2009 (From Grette Associates 2005, Grette Associates 2008 and Grette Associates 2009)



2005



2008

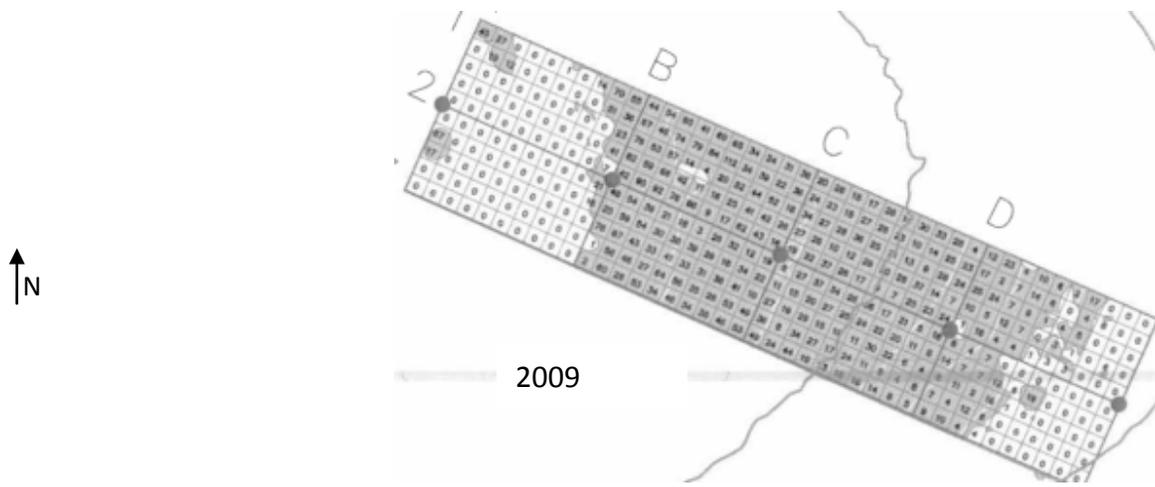


Figure 5 Eelgrass monitoring Maury Island - Control. Patch 2005, 2008 and 2009 (From Grette Associates 2005, Grette Associates 2008 and Grette Associates 2009)

Apparent differences in contiguous eelgrass stability from comparison of the Control site to the other two eelgrass areas may be an artifact of differences in the survey limits for Control site versus the North and South sites. The Control site survey was limited to a swath from a larger contiguous area, while the survey extents for the North and South sites contained the entire eelgrass presence in each case, and surveys increased if necessary to capture edge migration. Assessment of comparison between the North and South sites, and relative change for each of these two areas over time is not affected by this survey limitation.

The eelgrass area and average shoot density remained relatively stable at the Control site (again this may be an artifact of the survey extent for this site). The eelgrass area increased in the South site and decreased in the North site, while the average shoot density decreased in both North and South patches.

The North site eelgrass edge moved approximately 2 meters east between 2005 and 2008 (spreading out both north and south). The northward edge contracted approximately 5 meters from 2008 through 2009.

The western South site eelgrass edge migrated approximately 2 meters east (filling in the patchier northern portion) from 2005-2008. It continued to migrate another approximate 4 meters east between 2008 and 2009.

Migration of the Control site edges cannot be accurately assessed because the monitoring area does not contain the long-shore edges of that eelgrass area. It is apparent that smaller areas of eelgrass along the shoreward edge were ephemeral in size and shape.

Furthest shoot-Maury Island

When looking at the pattern of density in all sites for three years, gradual tapering off of the density toward the shallow edge is never observed. In fact, some of the highest density grid cells are located directly on the shallow edge. The decrease in density is slightly more gradual on the deeper edge but only 1 to 2 meters before complete drop-off.

In the North, South and Control sites, furthest shoots were documented (shoots located beyond a meter distance of the contiguous eelgrass area) off the shallow and deep edges. A furthest shoot was not always present. When present, furthest shoot distances on the shoreward edges ranged from 1.1m to 8.0m. The Furthest shoot distances on the seaward edges (when present) ranged from 2.1 m to 3.5m. Below is a table summarizing the furthest shoot distances measured at these sites.

While eelgrass presence did not migrate beyond the location a furthest shoot was found (shoreward or seaward) eelgrass did migrate along-shore to areas where no eelgrass was found at the previous sample time.

Table 7. Edge migration and shoot distance in eelgrass patches at Maury Island Gravel site

Patch name	Year sampled	Edge migration: expansion, +,	Shoreward furthest shoot distance (m)	Seaward furthest shoot distance (m)
North patch	2005		1.7	
	2008	+2 east	2.0	2.1
	2009	-5 north		
South patch	2005		1.1	3.5
	2008	+ 2 east		
	2009	+4 east		
Control patch	2005			
	2008		8.0	
	2009			

Eelgrass persistence–Maury Island

Persistence for eelgrass area and density was evaluated in the Maury Island data for comparison with the estimates provided in the literature. Only eelgrass presence that were a maximum of 2m x 2m were included in the analysis. Eelgrass that persisted beyond a season were larger in area and had a higher average shoot density compared with eelgrass that did not persist. Eelgrass that persisted were at least 0.3 m² in area with minimum density of 3 shoots/0.25m².

Table 8. Minimum area and shoot density for eelgrass persistence at Maury Island Gravel site

Patch persistence	Shoot density (shoots/0.25m ²)				Patch area (m ²)			n
	average	min	max	SE(n)	average	min	max	
>1 season	54.4	3	124	2.44	0.9	0.3	4.0	10
<1 season	13.7	1	36	0.76	0.6	0.1	1.0	14

Plant morphology data- DNR eelgrass stressor project

Plant structure provides important ecological functions. Above ground shoots can provide three-dimensional structure for fish refugia, epiphyte and invertebrate attachment. Below ground structure provides habitat for macroinvertebrate attachment and sediment stabilization. Morphology of the above and below ground structure of *Z. marina* has been documented to differ with environmental factors (Turner et al, 1999, Frederiksen, et al 2004). Plant structure is relevant in developing bed criteria because distance between plants and bed edge is influenced by shoot and rhizome length. Plant morphology data from the DNR eelgrass stressor project was analyzed and the results are presented below.

53.1 cm was the average shoot length at four sites (SE= 1.4, n=180) in Puget Sound, with an average maximum shoot length of 89.7 cm (SE=6.5, n=45)(DNR unpublished data). Average rhizome length at these sites was 33.3 cm (SE=2.9, n=169), with an average maximum rhizome length of 68.4 cm (SE=4.4, n=43).

Table 9. Eelgrass morphology metrics.

ECOLOGICAL ATTRIBUTE	EELGRASS METRIC	VALUE
Eelgrass morphology	Shoot length	Average shoot lengths ranged from 53.1 cm to 89.7 cm (DNR unpublished data)
	Rhizome length	Average rhizome length ranged from 33.3 cm to 68.4 cm (DNR unpublished data)

Index of eelgrass densities in Puget Sound and Willapa Bay

Eelgrass densities measured throughout Puget Sound and Willapa are compiled and presented in the table below. In the Workshops it was suggested that it may be possible to begin developing a spatially explicit index of patch densities for comparison when pre-construction eelgrass surveys are conducted for proposed projects. A preliminary compilation of eelgrass density data is presented in Table 8 below, with sample size and standard error presented when known. The bulk of this data is from published scientific publications, but there are also data from DNR Aquatics Program field collection, as well

as data from required environmental evaluation reports for proposed projects on state owned aquatic lands. These data may be helpful in developing mitigation performance standards and selecting reference sites. However, these data are not useful in determining minimum patch size as they are reported as means, most often with very large variation in the mean, or ranges of densities with limited or no information on sample size.

Table 10. Compilation of eelgrass densities measured throughout WA

Location (elevation)	Date	Average or range of densities (shoots/m²)	SE	n	reference
<i>Puget Sound</i>					
Lummi Bay	Apr-May 2007	160.7		20	Yang (2011)
North Samish Bay	Apr-May 2007	157.0		20	Yang (2011)
South Samish Bay	Apr-May 2007	177.1		20	Yang (2011)
Padilla Bay	Apr-May 2007	207.8		20	Yang (2011)
Similk Bay	Apr-May 2007	78.0		20	Yang (2011)
Kayak Point	Apr-May 2007	50.7		20	Yang (2011)
North Hood Canal	Apr-May 2007	137.8		20	Yang (2011)
Dabob Bay, Hood Canal	Apr-May 2007	155.9		20	Yang (2011)

Location (elevation)	Date	Average or range of densities (shoots/m ²)	SE	n	reference
Edmonds	Apr-May 2007	89.1		20	Yang (2011)
Carkeek Park	Apr-May 2007	212.2		20	Yang (2011)
Golden Gardens	Apr-May 2007	156.4		20	Yang (2011)
Seabeck, Hood Canal	Apr-May 2007	277.1		20	Yang (2011)
Lynch Cove, Hood Canal	Apr-May 2007	76.2		20	Yang (2011)
Purdy Spit, Car Inlet	Apr-May 2007	260		20	Yang (2011)
Rocky Point, Case Inlet	April 2007	150		20	Yang (2011)
	May 2007	89		20	Yang (2011)
Union, Hood Canal	Apr-May 2007	81.5		20	Yang (2011)
Dumas Bay	Apr-May 2007	141.8		20	Yang (2011)
Dumas Bay – DNR SeagrassNet Site. (-1.6 to +1 MLLW)	April 2008	464.9	77.5	36	DNR unpublished data
	July 2008	525.9	87.6	36	DNR unpublished data
	April 2009	479.5	79.9	36	DNR unpublished data

Location (elevation)	Date	Average or range of densities (shoots/m ²)	SE	n	reference
	July 2009	483.6	80.6	36	DNR unpublished data
	April 2010	352.4	58.7	36	DNR unpublished data
	July 2010	420.9	70.2	36	DNR unpublished data
	Apr 2011	392.2	66.4	36	DNR unpublished data
	July 2011	360.4	60.1	36	DNR unpublished data
Post Point Outfall, Bellingham	2005	22-61			City of Bellingham (2005)
Golden Tides, Bellingham	June 2006	28-39			Geomatrix (2007)
	July 2008	29-88			Geomatrix (2008)
Taylor Ave Dock, Bellingham	July 1998	42-238		30	Talyor Assoc. (1998)
	2004	49-235			Anchor Env. (2004)
Shannon Pt, Bellingham	2009	5-50			ATSI (2010)
Maury Island gravel site - North	July 2005	77			Grette Assoc. (2005)
	July 2008	72			Grette Assoc (2008)
	August 2009	13			Grette Assoc (2009)
Maury Island gravel site - South	July 2005	54			Grette Assoc. (2005)
	July 2008	56			Grette Assoc (2008)
	August 2009	28			Grette Assoc (2009)

Location (elevation)	Date	Average or range of densities (shoots/m ²)	SE	n	reference
Maury Island gravel site - Control	July 2005	30			Grette Assoc. (2005)
	July 2008	37			Grette Assoc (2008)
	August 2009	26			Grette Assoc (2009)
<i>Willapa Bay</i>					
Oysterville	Apr-May 2007	114.4		20	Yang (2011)
Oysterville (-0.5 to +1.5 MLLW)	July 2007	290	14	20	Ruesink et al (2010)
Stackpole (-0.5 to +1.5 MLLW)	July 2007	353	39	20	Ruesink et al (2010)
Stackpole Flats	2007	22.8	5.3	44	Ruesink et al (2010)
Nahcotta (-0.5 to +1.5 MLLW)	July 2007	69	7	20	Ruesink et al (2010)
Parcel A., Willapa	Apr-May 2007	100.3		20	Yang (2011)
Willapa Bay-7 locations	July 2004	159.5	33.9	7	Ruesink et al (2006)

Summary of relevant findings

- Changes in ecological function have been observed by the presence of a very small area of eelgrass; differences in benthic community diversity were observed in a 0.24 m² sized area of eelgrass vegetated substrate versus unvegetated substrate. An eelgrass area of 0.3m² was documented to have increased sediment trapping function when compared with unvegetated bottom.
- A minimum density of 3 shoots/0.25 m² was necessary for an area of eelgrass to persist from one season to the next at a Puget Sound site.
- With reported rhizome growth of 0.3 m per year, and observed average rhizome lengths ranging from 0.3 to 0.7 m , a distance of 1 m would be necessary to ensure that the below ground biomass of two adjacent shoots are captured when delineating a bed.
- Eelgrass edges at a site in Puget Sound were documented to migrate seasonally and annually. Maximum annual expansion to areas beyond the previous was documented at 4 m, and maximum annual contraction to areas previous bed interior up to 5 m.
- Edge migration shoreward or seaward always was within the distance defined by the furthest shoot, however, edges also migrate longshore where furthest shoot is not defined.
- Shoots >1m from a contiguous eelgrass area have been documented to appear and disappear seasonally and interannually.

Proposed Criteria

Based on information learned from review of the scientific literature considering minimum eelgrass presence criteria for delineating a vegetated edge that demonstrate ecological function, and examination of available field data (from Puget Sound sites), the proposed criteria listed in Table 11 emerged. Note that these criteria emerged from the limited data and information available regarding ecological function of *Zostera marina* characteristics and dynamics and are meant to provide for an operational definition. Future sampling and further analysis may indicate that an adaption or refinement of these criteria is necessary. In particular, field data from WA outer coast estuaries may provide scientific support for establishing separate criteria for those estuaries..

Table 11. Criteria for eelgrass bed edge and beyond

TERMS	CRITERIA	Bed edge or beyond?	RATIONALE
<i>persistent bed edge</i>	<p>Begin at a point within the interior of the bed (where ≥ 3 shoots/0.25m^2 within 1 m of adjacent shoots) move along any radial transect. Find the last shoot that is within 1 m of an adjacent shoot along that transect.</p> <p>Continue 0.5 m beyond this shoot, this is the bed edge. Both exterior and interior edges of bed can exist.</p>	Bed edge	<ul style="list-style-type: none"> • Vegetated areas as small as 0.24 m^2 demonstrated different ecological function from unvegetated substrate. • 3 shoots per 0.25 m^2 was the minimum density necessary for an eelgrass patch to persist from one season to the next in Puget Sound. • Observed average rhizome lengths ranged from 0.3 to 0.7 m and rhizome growth rates of approximately 0.3m per year have been documented. Average shoot lengths observed ranged from 0.5 to 0.9 m. • Two adjacent shoots would require a minimum distance of 1.0 m to accommodate above and below ground plant. • A distance of 0.5 m beyond last shoot is needed to accommodate below ground rhizome of edge shoot.
<i>shoots or patches</i>	Single shoot or patches <3shoots/ 0.25m^2 , that are >1m from adjacent shoot	Beyond	<ul style="list-style-type: none"> • Patches below this size and density have not been documented to provide ecological functions. • Patches below this size and density have been documented as ephemeral.
<i>Ephemeral shoots and patches</i>	Shoots or patches that may disappear then reappear from one season or year to the next	Beyond	<ul style="list-style-type: none"> • The ecological function of shoots and patches with limited temporal consistency has not been documented. • Ephemeral shoots and patches cannot feasibly be monitored for before-after effects analysis.

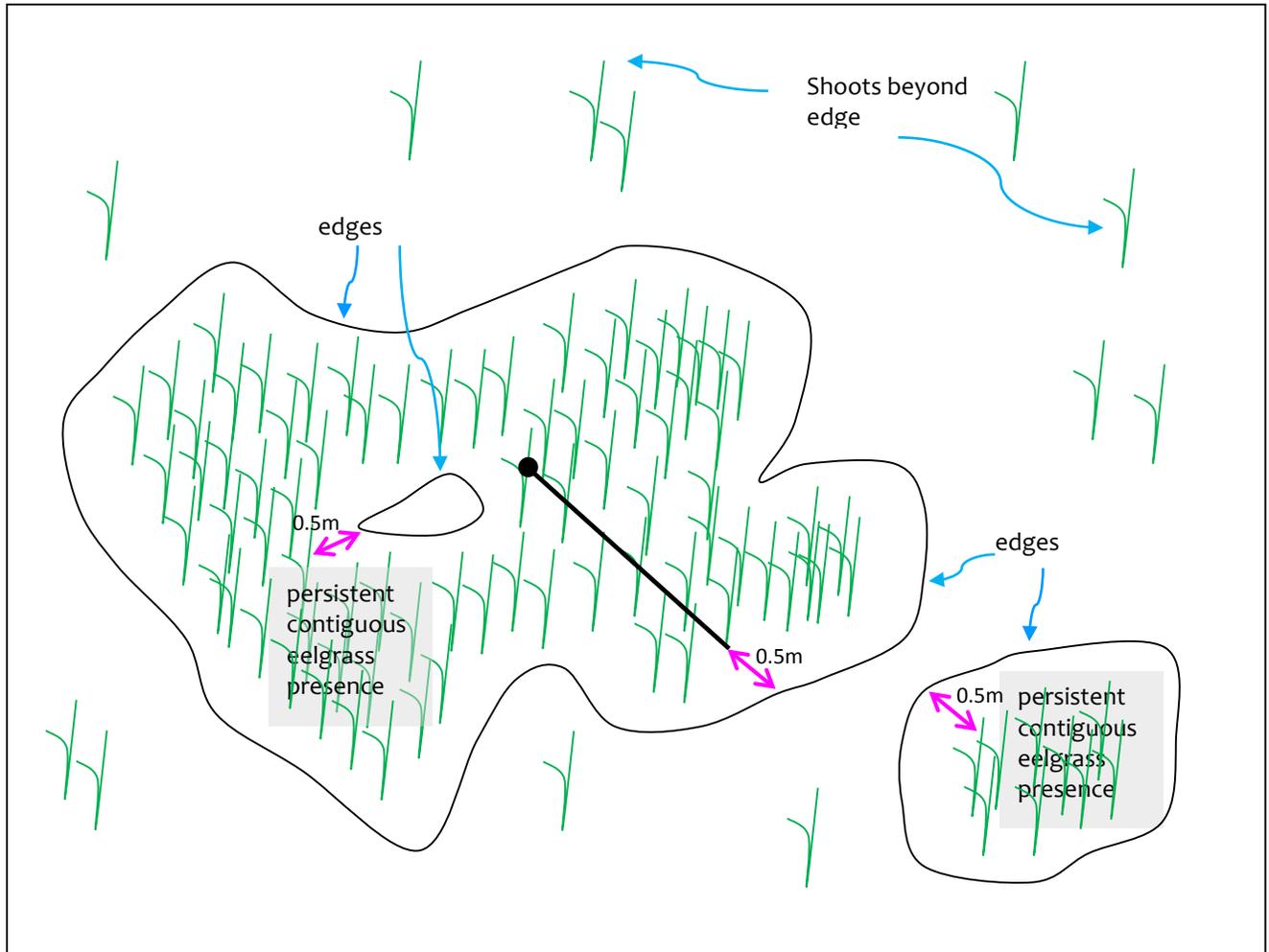


Figure 6 Schematic depicting two distinct, intact contiguous eelgrass areas. Edges are 0.5 m beyond the last shoot found within 1m of an adjacent shoot.

Conservation Approaches

The ephemeral nature of eelgrass, particularly the edges of eelgrass presence, has been documented in the scientific literature, in data analyzed from Puget Sound, in data from Willapa Bay, and has been anecdotally observed in the field by shellfish growers and scientists. SeagrassNet protocol acknowledges it by requiring measurement from a fixed transect to the edge and to the furthest shoot. Eelgrass at the edge is less persistent than eelgrass near the center of a contiguous area. This migratory characteristic of eelgrass makes it challenging to specify protocols for detecting change effected from a specific activity. It is also problematic in determining management decisions such as what distances from the eelgrass might be appropriate to encourage use and access of the tidelands, while protecting sustainable eelgrass functions. Below are some metrics from published literature and the recent data analysis that may be relevant in determining these distances.

Table 12. Metrics relevant for developing buffers

RELEVANT ECOLOGICAL ATTRIBUTE	EELGRASS METRIC	VALUE
Potential migration zone	Expansion (+) or contraction (-) distance	Maximum documented annual bed expansion of +4m, and contraction of -5 m (DNR unpublished data- 2 different sites sampled over 4 year
Seed dispersal	Seed dispersal distance	5m (Ruckelshaus 1996)
Genetic diversity	Distance at which plants can be genetically distinguished	4m (Ruckelshaus 1994)

Recommendations

The revised goal described in the introduction of this memo was to “determine the criteria for defining an eelgrass bed edge. The definition should allow for repeatable delineation of the edge so impacts from DNR authorized activities in marine tidelands can be avoided or minimized with application of appropriate conservation measures.” There was consensus early on among the workshop participants that the purpose of this effort was to apply scientific evidence to distinguish between an intact, persistent and functioning eelgrass area from sparse individual blades of eelgrass, or ephemeral eelgrass areas, or ‘potential’ eelgrass habitat. After a comprehensive review of scientific literature and analysis of available data we recommend the following:

- Apply the proposed criteria listed in Table 11 to delineate an edge around eelgrass presence. This distinguishes between contiguous eelgrass presence from sparse shoots of eelgrass that may be present at a site, but are not contained in a contiguous area..
- Consider the values provided in Table 12 as the uncertainty distance around an intact, persistent eelgrass area. It is only through siting activities within this expansion, contraction and seed dispersal distance that positive or negative changes to eelgrass can be effectively monitored for adaptive management.

Next Steps

It was suggested that further examination of the available data might be used to develop some “indices” of bed characteristics from different areas of the State. Various seagrass attributes (e.g. shoot density, plant architecture and colonization rates) have been shown to have a strong

relationship to the physical setting of an area (Robbins and Bell 1994, Frederiksen et al., 2004, Turner et al., 1999). Monitoring interannual variability in shoot density and the edge location in different areas would provide information on how to best site uses so they do not conflict with sustainable ecological function of eelgrass habitat.

If our intent is to develop the most effective operational definition possible, it will be useful to design initial baseline and adaptive management sampling on evaluating the practicability of the bed criteria and some of the eelgrass metrics listed in Table 2. Data relevant to longshore dynamics of *Zostera marina* is limited (Frederiksen et al., 2004), therefore, DNR adaptive management monitoring should include baseline sampling designed to explore interannual edge migration in both the cross and longshore.

These proposed edge criteria, delineation methods, and conservation approaches are the outcome of a series of technical workgroup discussions. This information can serve as a starting point for future policy deliberations on developing effective conservation measures that will allow for management of resources while encouraging sustainable uses on state owned aquatic lands.

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