Eelgrass Survey of South Discovery Bay
August 2010

by

James G. Norris and Ian E. Fraser

Submitted To:

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May 2, 2011

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James G. Norris
Signature (James G. Norris)

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Introduction

Eelgrass (*Zostera marina*) is a critical habitat for many marine species. The Washington State Department of Fish and Wildlife pursues a "no net loss" policy for eelgrass habitat through its Hydraulic Project Approval (HPA) process. Any nearshore marine project that might impact eelgrass beds (e.g., bulkhead, sewer outfall, dock) must first receive an HPA permit. Knowing the location of eelgrass beds helps cities and counties plan shoreline development.

The Washington State Department of Natural Resources (DNR) Submerged Vegetation Monitoring Project (SVMP) uses a rotational random sampling survey design to estimate the total amount of eelgrass in Puget Sound each year. The basic idea of the SVMP is to divide the Puget Sound shoreline into equal size units (1000 m long sections called "fringe" sites), randomly select about 100 of these sites each year (there are 2,188 total sites), measure the amount of eelgrass at each site (using underwater videography and line-intercept statistical methods), and expand the average of the 100 measured sites to a sound-wide estimate. Thus, the SVMP provides eelgrass maps only for the randomly selected sites.

The Jefferson County Marine Resources Committee contracted with Marine Resources Consultants to prepare a Geographic Information System (GIS) layer for Jefferson County showing eelgrass bed locations in Discovery Bay, Matts Matts Bay, and Port Ludlow during the summer of 2010. A secondary goal was to collect the data necessary to monitor changes in eelgrass parameters at three critical locations— the headwaters of Discovery Bay (mouths of Snow Creek and Salmon Creek), Matts Matts Bay, and Port Ludlow (including the inner harbor). This report summarizes the parameter estimates for DNR SVMP site sjs2634 located at the headwaters of Discovery Bay.

Methods

Overview

The DNR SVMP methods estimate five parameters: (1) eelgrass fraction (within a bed boundary, the fraction of the area that has eelgrass); (2) eelgrass areal extent (number of square meters of seabed that has at least one shoot of eelgrass growing on it); (3) patchiness index (the number of eelgrass presence/absence transitions along 100 m of transect length); (4) mean minimum eelgrass depth; and (5) mean maximum eelgrass depth (Berry et al. 2003; Dowty et al. 2005). These parameters describe in statistical terms the characteristics of each eelgrass bed and provide a means of tracking changes in a single bed over time or comparing different beds at the same time (see Dowty 2005 for a complete description and discussion of these parameters).

Fig. 1 illustrates the concepts of eelgrass areal extent, eelgrass fraction, and patchiness index. In this figure all three eelgrass beds have the same eelgrass area (i.e., number of square meters of seabed covered with eelgrass, shown in green) within the bed boundary (shown in red). The eelgrass fraction in bed "a" is 100% whereas the fractions in beds "b" and "c" are both 65%. Although beds "b" and "c" have the same eelgrass fraction, bed "c" has a much higher patchiness index.

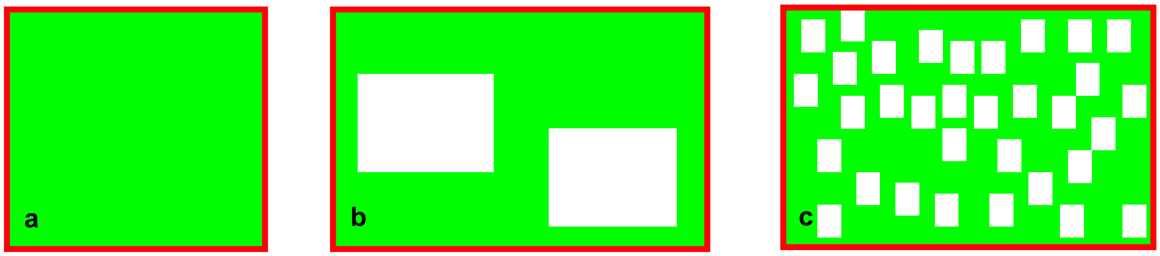

Figure 1. Illustration of eelgrass areal extent, eelgrass fraction, and patchiness.

Fig. 2 illustrates the concepts of mean minimum and maximum eelgrass depths. Each transect running perpendicular to the isobaths has a minimum and maximum eelgrass depth associated with it. If transects within a site are selected randomly, averaging the collection of minimum (or maximum) depth observations provides an estimate of mean minimum (or maximum) eelgrass depth for a site.

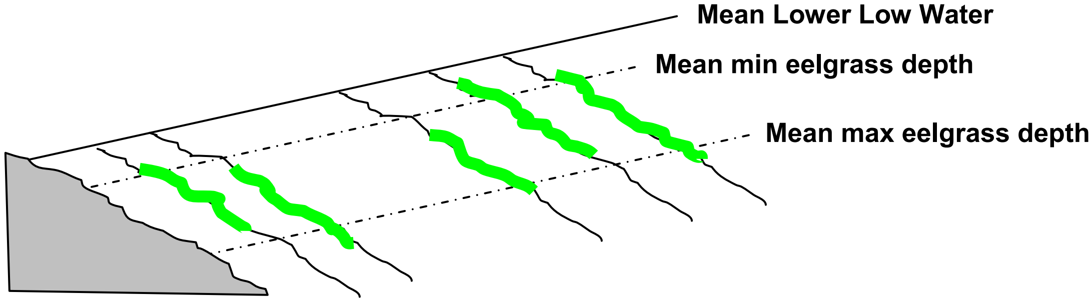

Figure 2. Illustration of mean minimum and maximum eelgrass depths.

To estimate eelgrass parameters we used line intercept sampling (Norris et al. 1997). First, a study region is delineated as a polygon and its area calculated analytically (e.g., using a Computer Aided Design or Graphical Information System computer program). Second, randomly selected linear transects are placed completely through the polygon and their lengths within the polygon computed. Third, the lengths of each transect that are touching the vegetation of interest are computed. Fourth, the sum of the vegetated transect portions is divided by the sum of the transect lengths within the polygon to get an unbiased estimate of the fraction of the polygon that has the vegetation of interest. This fraction estimate comes with variance estimates so confidence intervals and statistical tests can be computed. Finally, the area within the sample polygon with the target vegetation is estimated by multiplying the known area of the polygon by the estimated fraction. Orienting transects perpendicular to the isobaths makes it possible to estimate patchiness index and mean minimum and maximum eelgrass depths, also.

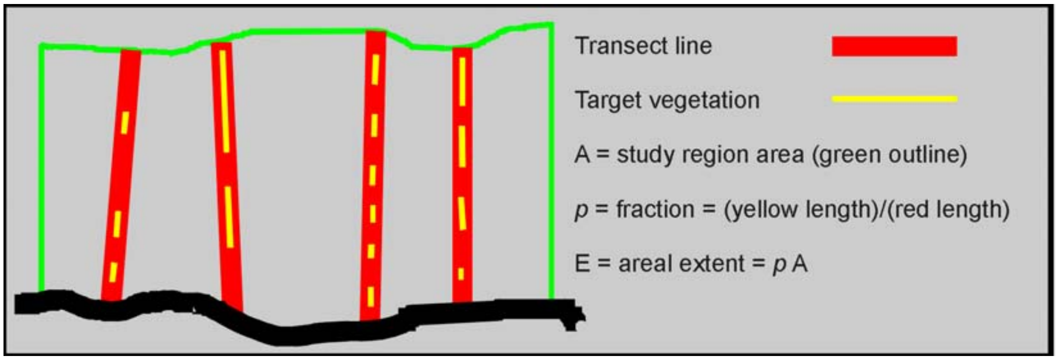

Figure 3. Illustration of the line intercept estimation method.

Personnel

For all field surveys Ian Fraser served as skipper and chief scientist while Ryan Charrier served as deckhand/engineer. James Norris performed all data analysis and report writing.

Site Description

There are 31 DNR SVMP fringe sites along the Jefferson County shoreline in Discovery Bay. Four of these sites were surveyed previously by the DNR SVMP: sjs2628 (2009; and planned through 2013); sjs2632 (2009; and planned through 2013); sjs2645 (2004 – 2008); and sjs2646 (2000 – 2004). On July 15 and 16, 2010 we conducted a reconnaissance survey using "zig-zag" transects along the entire shoreline (except sites sjs2628 and sjs2632 which were surveyed by DNR in 2010) to determine where eelgrass was present. There is a nearly continuous fringing bed of eelgrass from Cape George around the eastern shoreline and up the western shore to Contractor Point (Fig. 4). The 2010 DNR SVMP survey showed eelgrass located throughout sjs2628, but only one eelgrass plant was observed on 12 transects in sjs2632. Between Contractor Point and the Clallam County line there are large shoreline sections with no eelgrass. We selected site sjs2634 for more detailed study because it contains the mouths of Snow and Salmon Creeks, sites of extensive salmon enhancement work.

Figure 4. Eelgrass observations (orange) from a "zig-zag" reconnaissance survey conducted on July 15-16, 2010.

Sampling Plan

At site sjs2634 we conducted 13 straight-line underwater videographic transects perpendicular to the isobaths and added two meandering transects to help delineate the eelgrass bed boundaries. Straight-line transects started as shallow as possible (approximately +1.0 ft) and ran to depths between -16 and -21 ft. Note that all depths in this report are referenced to the Mean Lower Low Water datum (MLLW).

Survey Equipment and Methods

Vessel

We conducted sampling aboard the 36-ft *R/V Brendan D II* (Fig. 5). We acquired position data using a sub-meter differential global positioning system (DGPS) with the antenna located at the tip of the A-frame used to deploy the camera towfish. Differential corrections were received from the United States Coast Guard public DGPS network using the NAD 83 datum. A laptop computer running Hypack Max hydrographic survey software stored position data, depth data from one echosounder (Garmin), and user-supplied transect information onto its hard drive. Position data were stored in both latitude/longitude and State Plane coordinates (Washington North, US Survey Feet). All data were updated at 1 s intervals. Table 1 lists all the equipment used during this survey.

Figure 5. The *R/V Brendan D II*.

Table 1. Survey equipment used onboard the *R/V Brendan D II* during the 2010 eelgrass survey at Discovery Bay site sjs2634.

Item	Manufacturer/Model
Differential GPS	Trimble AgGPS 132 (sub-meter accuracy)
Depth Sounders	BioSonics DE4000 system (including Dell laptop computer with Submerged Aquatic Vegetation software)
	Garmin FishFinder 250
Underwater Cameras (2)	SplashCam Deep Blue Pro Color (Ocean Systems, Inc.)
Lasers	Deep Sea Power & Light
Underwater Light	Deep Sea Power & Light RiteLite (500 watt)
Navigation Software	Hypack Max
Video Overlay Controller	Intuitive Circuits TimeFrame
DVD Recorder	Sony RDR-GX7
Digital VideoTape Recorder	Sony digital tape deck GVD800

Video Data

We obtained underwater video images using an underwater camera mounted in a down-looking orientation on a weighted towfish. Two parallel red lasers mounted 10 cm apart created two red dots in the video images as a scaling reference. We mounted a second forward looking underwater camera on the towfish to give the winch operator a better view of the seabed. We deployed the towfish directly off the stern of the vessel using the A-frame and winch. Video monitors located in both the pilothouse and the work deck assisted the helmsman and winch operator control the speed and vertical position of the towfish. The weight of the towfish kept the camera positioned directly beneath the DGPS antenna, thus ensuring that the position data accurately reflected the geographic location of the camera. A video overlay controller integrated DGPS data (date, time) and user supplied transect information (transect number and site code) into the video signal. We stored video images directly onto a Sony Digital8 videotape and onto a DVD-R disk.

Depth Data

Our primary depth sounder was a BioSonics DE4000 system. The advantage of this system is its ability to accurately measure distance between the transducer and the seabed, even when the seabed is covered with dense vegetation (e.g., eelgrass and/or macroalgae). Other depth sounders often measure distance only to the top of the vegetation canopy. The BioSonics system does not produce depth readings in real time. Instead, it records on a laptop computer all of the returning raw signals in separate files for individual transects. During post-processing, individual transect files are combined into larger files and processed through EcoSAV software (part of the BioSonics system). The output is a single text file including time, depth, and position data. These data are then merged with the tide correction data to give corrected depths.

Our backup depth sounder was a Garmin FishFinder 250. Although this echosounder provided real-time estimates of depth (which were recorded by the Hypack Max program), it often estimated depth only to the top of the vegetation canopy rather than to the seabed.

For both echosounders, we mounted the portable transducers on poles attached to the starboard (Garmin) and port (BioSonics) corners of the transom. Since the DGPS antenna was mounted along the centerline of the vessel, each transducer was offset 1.5 m from the DGPS antenna. During analysis, we ignored this slight offset and assumed that depth readings from both depth sounders were taken at the location of the DGPS antenna.

Field Sampling Procedures

At the start of each transect the skipper backed the vessel close to the shoreline and the winch operator lowered the camera to just above the seabed. Visual references were noted and all video recorders and data loggers were started. As the vessel moved along the transect the winch operator viewed live video on a monitor and raised and lowered the camera towfish to follow the seabed contour (Fig. 6). The field of view changed with the height above the bottom. The vessel speed was held as constant as possible (about 0.8 m/sec). In addition to driving the vessel, the skipper watched a video monitor and used a real-time “clicker” to record preliminary eelgrass observations (i.e., clicker on/off when eelgrass was present/absent on the monitor). The preliminary observations were used to select non-random transects to better delineate eelgrass bed boundaries. At the end of the transect, we stopped the recorders, retrieved the camera towfish, and moved the vessel to the next sampling position.

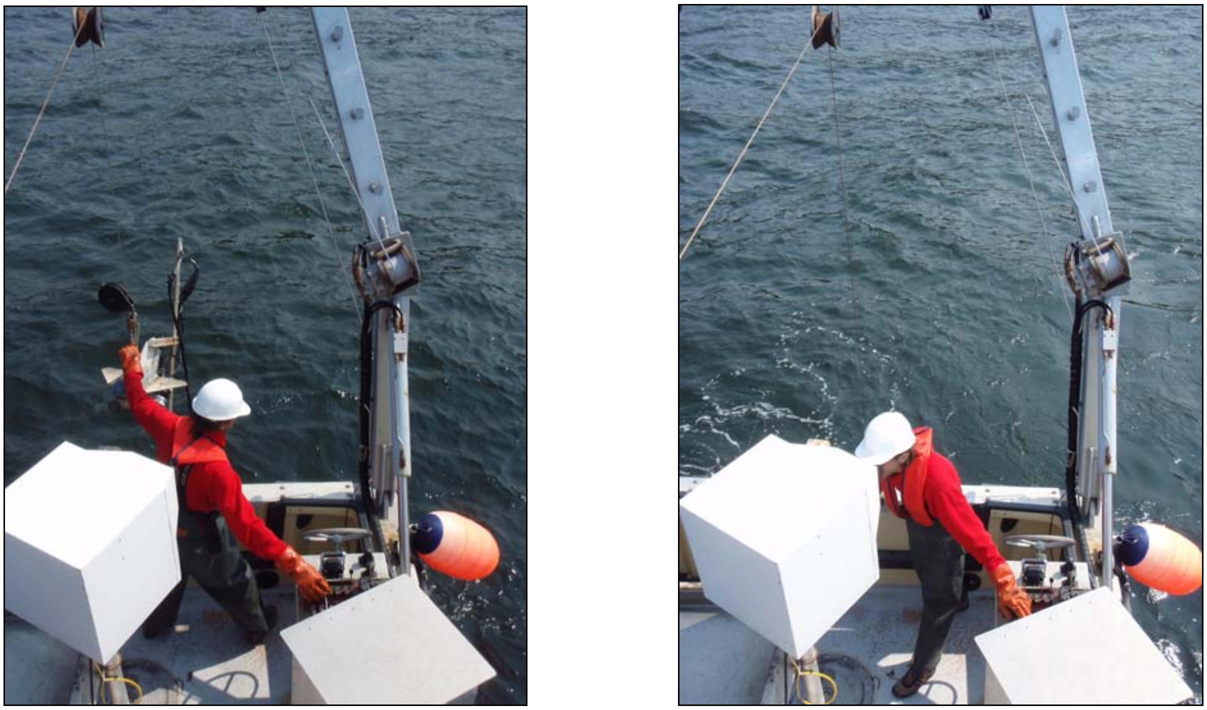

Figure 6. Launching the camera towfish and "flying" the towfish during a transect.

Underwater Video Data Post-Processing

Data stored on the laptop computer were downloaded and organized into a spreadsheet file including blank columns for video code (0 = cannot view the seabed; 1 = seabed in view) and eelgrass code (0 = absent; 1 = present). Digital8 tapes were reviewed using slow motion and stop action to assign codes to each 1 s data record.

Tide Heights

We used the BioSonics echosounder to gather bathymetry data. Raw depths collected from the echosounder measure the distance between the seabed and the transducer. We applied three factors to correct these depths to the MLLW vertical datum:

- transducer offset (i.e., distance between the transducer and the water surface);
- predicted tidal height (i.e., predicted distance between the surface and MLLW);
- tide prediction error (i.e., predicted tidal height minus the observed tidal height at a reference station).

Corrected depth equals depth below the transducer plus the transducer offset minus the predicted tidal height plus the tide prediction error. We measured the transducer offsets directly each day. To get predicted tide heights we used the computer program Tides and Currents Pro 3.0 (Nobletec Corporation) for the Gardiner, Discovery Bay station (ID 0987; 48 04.00 N, 122 55.00 W). We computed tide prediction errors by comparing the computer program predicted tide heights for the Port Townsend reference station (ID 0995; 48 6.90 N, 122 45.00 W) with actual observed tide heights published by the National Oceanic and Atmospheric Administration on their web site (http://tidesandcurrents.noaa.gov).

Parameter Estimation

Eelgrass Fraction and Areal Extent

We estimated the total eelgrass areal extent using methods described in Norris et al. (1997) and Dowty (2005). After video tape post-processing, we plotted the positions of all eelgrass observations in AutoCAD and drew a polygon around the observations following the -12 ft isobath at the deepwater edge. We calculated the area (*A*) of the polygon using AutoCAD tools. For each straight-line transect, we computed (using proprietary software) the length of the transect passing through the eelgrass polygon and the lengths associated with eelgrass presence. Table 2 lists the notation and formulae for estimating eelgrass fraction and areal extent at a single site.

Table 2. Notation and formulae for estimating eelgrass fraction and areal extent at a single site.

Parameter	Estimation formula	Definition
n		Number of transects passing through the sample polygon.
A		Area within the sample polygon. This value is determined after the sample polygon is drawn using AutoCAD or ArcGIS or some other analytical means.
l_i		Length of transect *i* that has eelgrass.
L_i		Length of transect *i* within the sample polygon.
$\hat{\rho}$	$\dfrac{\sum_i l_i}{\sum_i L_i}$	Estimated eelgrass fraction (i.e., fraction of sample area *A* that has eelgrass).
$Var(\hat{\rho})$	$\dfrac{1-f}{n\cdot \bar{L}^2}\dfrac{\sum_i l_i^2 - 2\hat{\rho}\sum_i L_i l_i + \hat{\rho}^2\sum_i L_i^2}{n-1}$	Estimated variance of $\hat{\rho}$.
$\hat{E}$	$\hat{\rho}A$	Estimated area of eelgrass within sample polygon.
$Var(\hat{E})$	$A^2Var(\hat{\rho})$	Estimated variance of $\hat{E}$.
CI	$CI = \hat{E} \pm 1.28\sqrt{Var(\hat{E})}$	Approximate 80% confidence interval around $\hat{E}$ assuming a normal distribution.

Since each video observation also has an associated depth observation, it is possible to estimate the eelgrass fraction within any given depth zone (see Table 3 for the notation and formulae). For depth zone estimates we used 1 ft wide depth zones centered around whole numbers (e.g., the -2 ft depth zone ranged from -1.50 ft to -2.49 ft).

Table 3. Notation and formulae for estimating eelgrass fraction within a given depth zone.

Parameter	Estimation formula	Definition
n_d		Number of transects passing through both the sample polygon and depth zone *d*.
$l_{i,d}$		Length of transect *i* that has eelgrass within depth zone *d*.
$L_{i,d}$		Length of transect *i* within the sample polygon and within depth zone *d*.
$\hat{\rho}_d$	$\dfrac{\sum_i l_{i,d}}{\sum_i L_{i,d}}$	Estimated eelgrass fraction (i.e., fraction of area within depth zone *d* that has eelgrass).
$Var(\hat{\rho}_d)$	$\dfrac{1-f}{n_d \cdot \overline{L}_d^{\,2}} \dfrac{\sum_i l_{i,d}^{\,2} - 2\hat{\rho}_d \sum_i L_{i,d} l_{i,d} + \hat{\rho}_d^{\,2} \sum_i L_{i,d}^{\,2}}{n_d - 1}$	Estimated variance of $\hat{\rho}_d$.

Mean Minimum and Maximum Eelgrass Depths

Minimum and maximum eelgrass depths refer to the shallow- and deepwater boundaries of eelgrass growth. Consider a straight-line transect oriented perpendicular to the isobaths (i.e., running shallow to deep) and passing through an eelgrass bed. If one records the depths at which eelgrass is observed at regular intervals along the transect, there will be both a minimum and a maximum depth observation. If measurements are taken along many such transects, one will have a collection of minimum and maximum depth measurements. Our parameters of interest are the averages of these collections of minimum and maximum depth measurements. We used depths from BioSonics echosounder to estimate these parameters.

Patchiness Index

Patchiness index was computed as the number of patch/gap transitions per 100 m of straight-line transect length. A gap was defined to be a transect section at least 1 m long with no eelgrass.

Results

Visibility during both the reconnaissance survey on July 15 and the intensive survey on August 31 was very poor at the north end of the site and did not improve until south of transect 8. It appeared that plankton was the primary cause of poor visibility, not suspended sediment. Visibility was much better throughout the rest of Discovery Bay (during the July 15 survey). Although we do not believe *Zostera japonica* was present in the shallow portions of the site, the poor visibility made it difficult to be certain.

Fig. 7 shows the locations of each transect and where eelgrass was observed. Transects 13 and 15 were meandering transects to delineate the bed boundaries. All other transects were used to estimate areal extent, fraction, and patchiness index. The zig-zag transect shown in Fig. 7 (from the July 15, 2010 reconnaissance survey) was used only to help delineate the eelgrass bed boundaries.

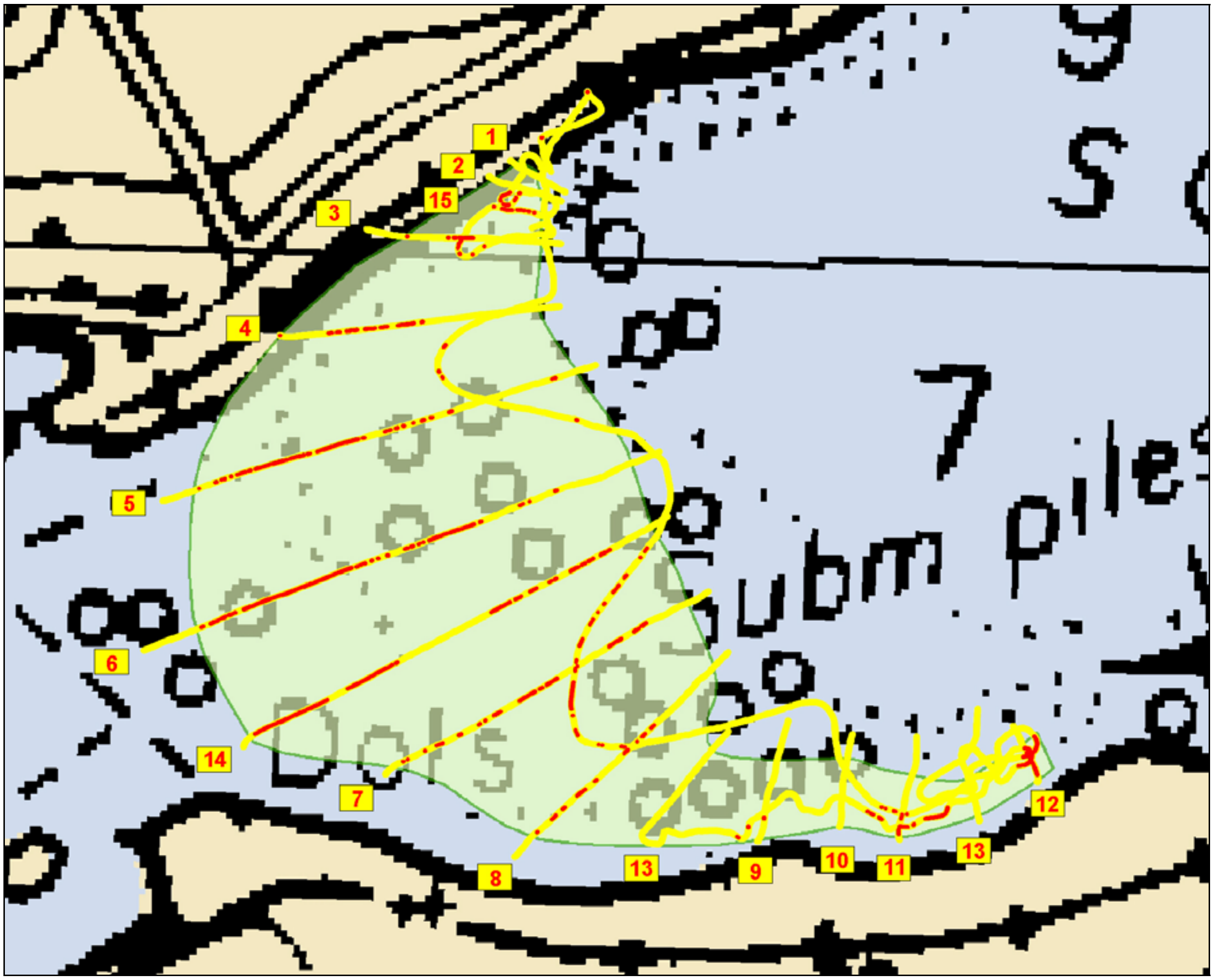

Figure 7. Numbered underwater videographic transects (yellow) and eelgrass observations (red) from the August 31, 2010 eelgrass survey at DNR SVMP site sjs2634.

Table 4 lists the parameter estimation results for areal extent, eelgrass fraction, and patchiness index. In Table 4 “Total Length” is the total length of the transect and “Sample Length” is the length of the transect passing through the sample polygon (shown in light green in Fig. 7). “Eelgrass Length” is the length of the transect where eelgrass was observed (shown in red in Fig. 7). We estimated a total of 11.2 ha of eelgrass habitat (28.7% of the total sample polygon). The coefficient of variation for the fraction estimate was 0.1656.

Table 4. Parameter estimation results for eelgrass fraction, areal extent, and patchiness index.

Transect	Total Length (m)	Sample Length (m)	Eelgrass Length (m)	Eelgrass Fraction	Avg Vessel Speed (m/s)	Eelgrass Patches
1	78.8	30.8	0.0	0.0000	0.59	0
2	84.5	61.6	0.0	0.0000	0.68	0
3	229.8	171.5	21.2	0.1234	0.84	5
4	337.6	321.9	59.4	0.1846	0.75	9
5	546.4	496.7	155.9	0.3138	0.81	21
6	671.9	574.9	258.4	0.4495	0.88	22
7	449.6	418.2	103.3	0.2469	0.77	13
8	359.3	305.8	45.0	0.1471	0.83	9
9	147.9	101.3	2.3	0.0227	0.81	1
10	113.7	85.9	0.0	0.0000	0.80	0
11	115.8	78.7	12.7	0.1614	0.72	2
12	74.8	49.0	31.2	0.6364	0.71	1
14	591.6	560.5	244.8	0.4368	0.89	15
Totals	3801.9	3256.8	934.1			98

Parameter	Estimate
Estimated mean eelgrass fraction:	0.2868
Estimated variance of eelgrass fraction:	0.0023
Estimated standard error of eelgrass fraction:	0.0475
Approximate lower 80% confidence limit:	0.2261
Approximate upper 80% confidence limit:	0.3476
Total sample area within perimeter (sq m):	389,170
Estimated areal extent (sq m):	111,624
Estimated variance of areal extent (sq m):	341,362,346
Estimated standard error of areal extent (sq m):	18,476
Approx. lower 80% confidence limit:	87,975
Approx. upper 80% confidence limit:	135,273
Minimum patch/gap length (m):	1.00
Patchiness Index:	5.72
Average vessel speed (m/s):	0.81

We observed no eelgrass on transects 1, 2, and 10, so they were not used in estimating mean minimum and maximum depths (Table 5). In Table 5 the “Max Eelgrass Depth” and “Min Eelgrass Depth” columns refer to the maximum and minimum depths at which eelgrass was observed on each transect. The mean minimum and maximum eelgrass depths were -0.5 ft and -4.7 ft, respectively. The highest eelgrass fractions were in the +1 ft to -2 ft range (Fig. 8; Table 6). Eelgrass distribution along the northernmost transects (3-7 and 14) was generally shallower than along the southernmost transects (Fig. 9). In Fig. 9, note that the transects are ordered north to south and are not in numerical order.

Table 5. Parameter estimation results for mean minimum and maximum eelgrass depths.

Transect	Max Track Depth (ft)	Max Eelgrass Depth (ft)	Min Eelgrass Depth (ft)	Min Track Depth (ft)
3	-21.1	-1.0	0.0	0.7
4	-19.2	-2.1	0.9	1.1
5	-17.8	-5.8	1.2	1.6
6	-19.8	-3.4	0.9	1.4
7	-16.8	-7.0	-0.2	1.4
8	-16.0	-6.5	-1.9	0.3
9	-17.1	-3.4	-3.1	0.9
11	-16.8	-3.5	-1.6	-0.3
12	-19.7	-10.6	-1.2	0.4
14	-16.6	-3.7	0.5	1.1

Number of observations		10	10	
minimum		-10.6	-3.1	
maximum		-1.0	1.2	
mean		-4.7	-0.5	
standard deviation		2.8	1.4	
standard error		0.9	0.5	
t stat (0.05)		2.2622	2.2622	
lower 95% limit		-6.7	-1.5	
upper 95% limit		-2.7	0.6	

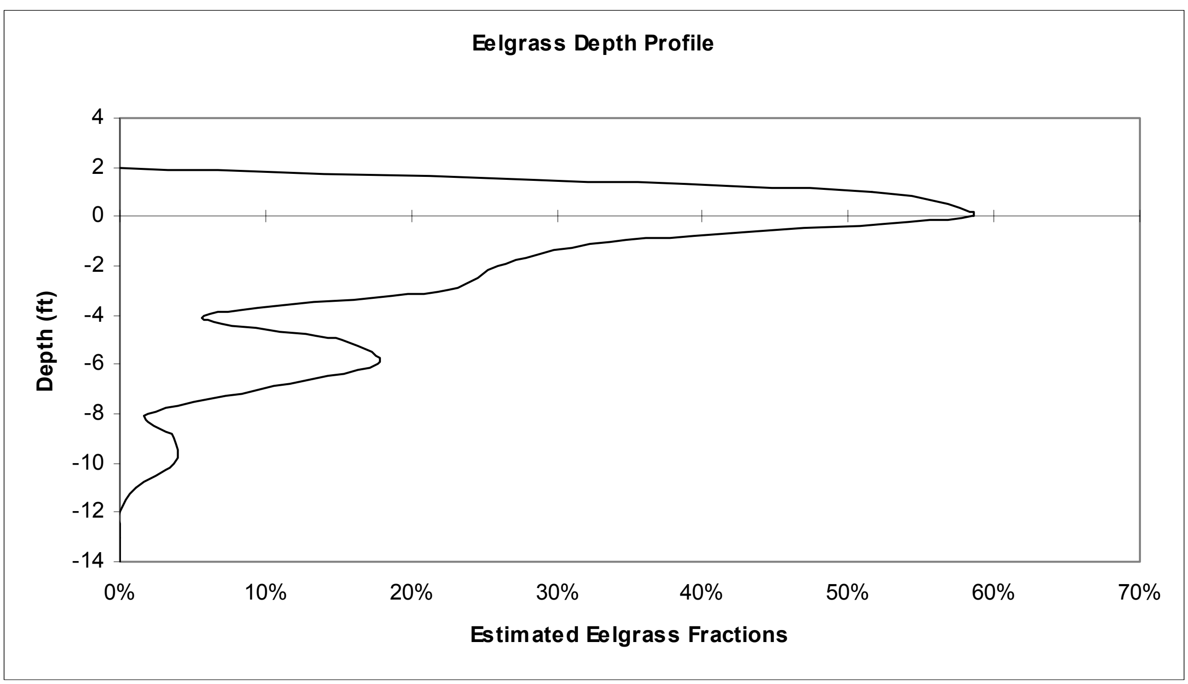

Figure 8. Estimated eelgrass fractions by depth.

Table 6. Estimated eelgrass fractions by depth zone.

Mid Depth Zone (ft)	Number of 1 s Video Observations Within the Depth Zone	Estimated Eelgrass Fraction Within the Depth Zone
2	0	0.0000
1	322	0.5164
0	686	0.5842
-1	773	0.3369
-2	508	0.2596
-3	523	0.2249
-4	252	0.0574
-5	195	0.1529
-6	164	0.1768
-7	156	0.0945
-8	122	0.0197
-9	114	0.0373
-10	70	0.0376
-11	66	0.0114
-12	30	0.0000
-13	3	0.0000
-14	5	0.0000
-15	3	0.0000

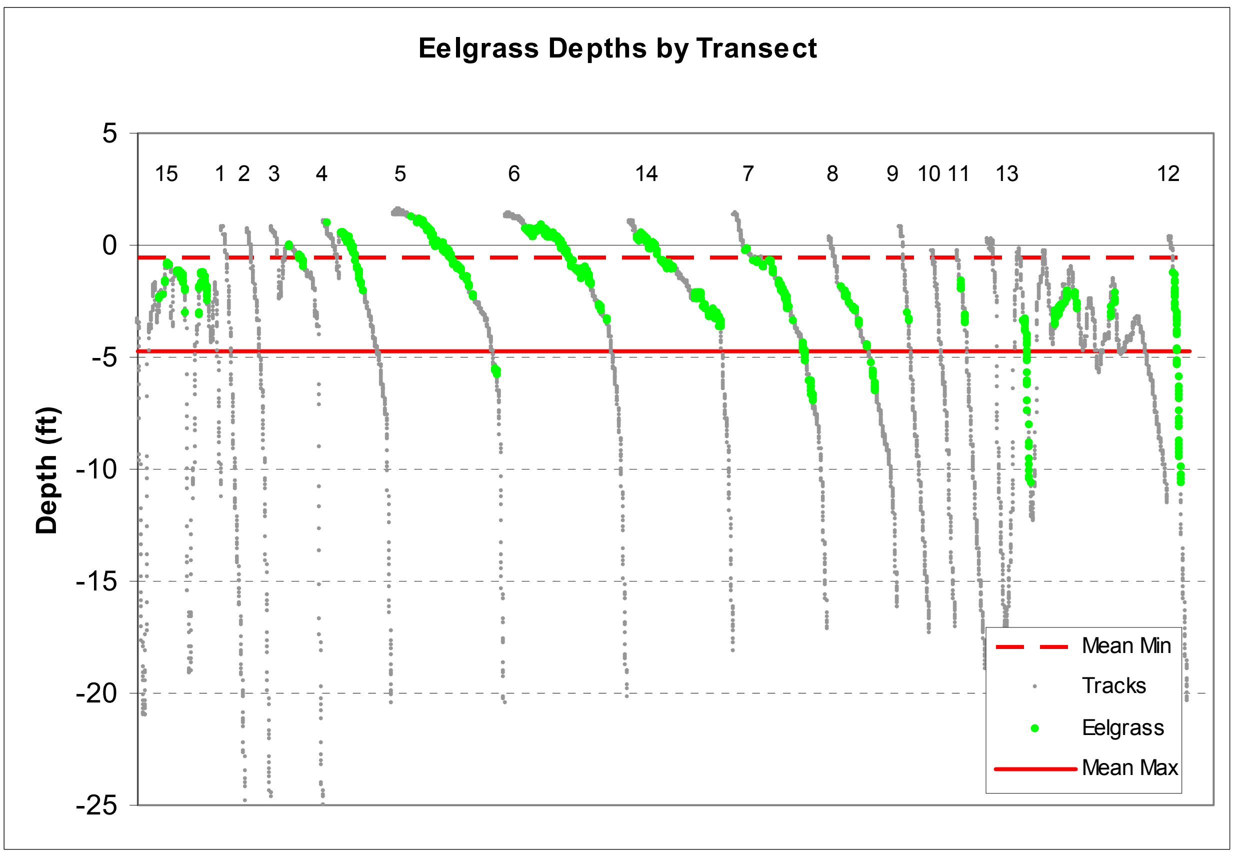

Figure 9. Eelgrass depth profiles by transect (ordered north to south).

Discussion

In previous work (Norris et al. 2007; Norris and Fraser 2009) we found that eelgrass beds in neighboring Clallam County could be divided into three categories based on their depth ranges (Fig. 10). Eelgrass beds in areas with good circulation and protected from high wave energy during the growing season (i.e., dominant westerly winds in spring and summer) tended to have the largest depth range (-2 ft to -22 ft). This category includes the western portions of Crescent and Freshwater Bays and the areas inside Ediz Hook and Dungeness Spit. Eelgrass growing in areas exposed to high wave energy tended to grow in a relatively narrow deep range (-15 ft to -22 ft). The eastern portions of Crescent and Freshwater Bays and the outer edges of Ediz Hook and Dungeness Spit were in this category. The eelgrass at the head of Discovery Bay is most similar to the third category—eelgrass growing in a relatively narrow shallow range (-1 ft to -7 ft). Port Angeles Harbor (the area just east of the City Dock) and inner Dungeness Bay were the only two sites in this category.

The poor visibility we experienced during our northernmost transects suggests that light penetration may be the limiting factor. We did not see any obvious sediment limitations. Transects furthest from the mouths of Salmon and Snow Creeks (i.e., transects 8-13) had the deepest growing eelgrass.

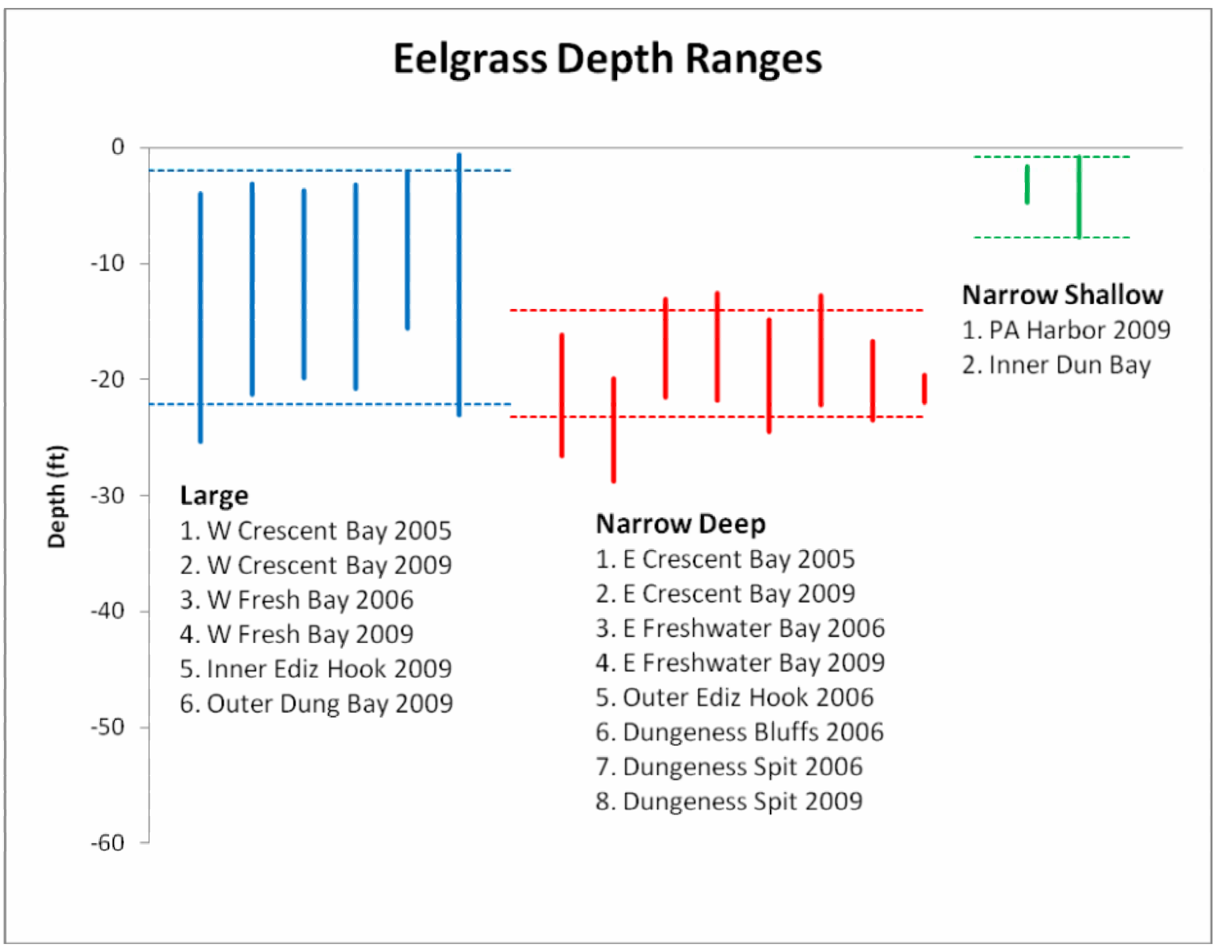

Figure 10. Eelgrass depth ranges (mean minimum depth to mean maximum depth) for all major eelgrass beds and years surveyed (from Norris and Fraser 2002).

Acknowledgments

The Jefferson County Marine Resources Committee funded this project. We thank Gabrielle LaRoche for administrative assistance.

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