Underwater Videographic and Hydroacoustic Eelgrass Survey
Chimacum/Irondale Beach Restoration Site
September 12, 2006

by

James G. Norris and Ian E. Fraser

Submitted To:

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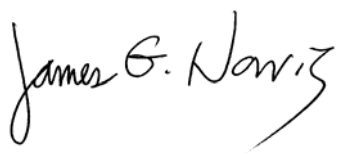

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Introduction

In 2004 the North Olympic Salmon Coalition (NOSC) contracted with Marine Resources Consultants to conduct a survey of eelgrass (*Zostera marina*) resources in the vicinity of the proposed Chimacum/Irondale Beach Restoration project located just south of the mouth of Chimacum Creek in Port Townsend Bay. Although all of the proposed work for this restoration project would occur above the mean higher high water level, it was possible inter-tidal and sub-tidal eelgrass resources might be affected. The purpose of that eelgrass survey was to gather pre-restoration baseline data that could be compared to post-restoration data collected in the future.

The restoration work was completed in the spring of 2006, after which NOSC contracted with Marine Resources Consultants to conduct a post-restoration survey of eelgrass resources. The post-restoration survey was conducted at the same time of year (early September) using identical methods. This report summarizes the findings of the 2006 survey and compares them with the 2004 survey.

Methods

Personnel

Table 1 lists the personnel on board the vessel during the survey.

Table 1. Personnel list.

Date	Name	Position
September 12, 2006	Frank Converse	Skipper
September 12, 2006	Ian E. Fraser	Scientist

Site Description

The restoration site includes approximately 620 m of shoreline just south of the mouth of Chimacum Creek. To be consistent with Washington State Department of Natural Resources (DNR) Submerged Vegetation Monitoring Project (SVMP) survey methods (Dowty et al. 2005), we surveyed in their entirety the two "fringe" sites (cps2585 and cps2586) encompassing the restoration area (Fig. 1). SVMP fringe sites are 1000 m sections of shoreline as measured by the –20 ft isobath. Site cps2584, located just south of the restoration area, was sampled during the 2000-2002 DNR annual surveys, but not during this survey. The depth range of the study site was defined to be from mean lower low water (MLLW) to approximately –20 ft MLLW. Fig. 2 shows aerial photographs of the site taken on July 12, 1994 at a tide stage of -0.4 ft. Fig. 3 shows photographs taken during and after the restoration work.

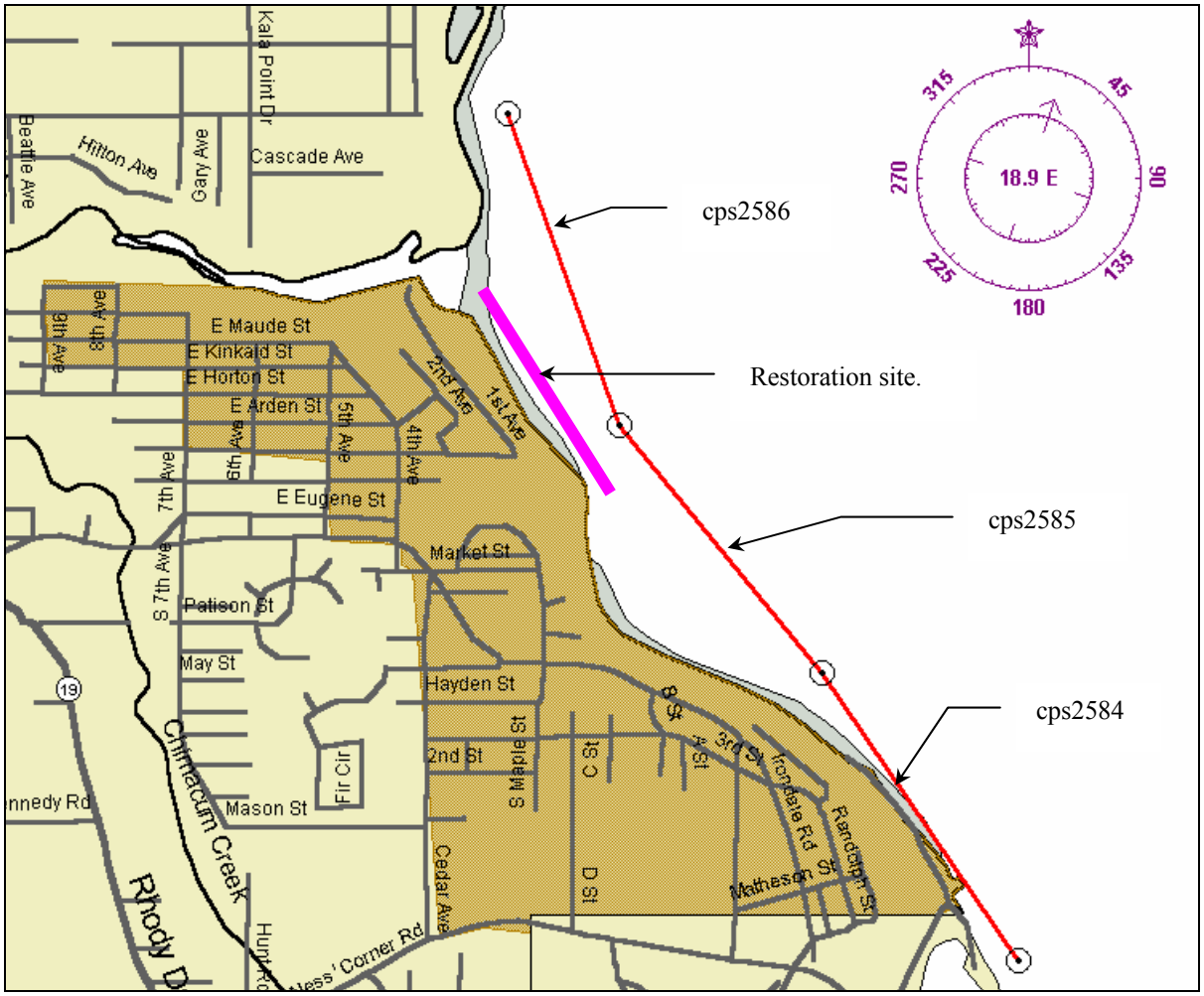


Figure 1. Site map. Washington State Department of Natural Resources (DNR) "fringe" sites cps2585 and cps2586 were included in this survey. Site cps2584 was surveyed by DNR during 2000-2002.

Figure 2. Aerial photographs of the study area taken on July 12, 1994 at 12:19 pm (tide stage: -0.4 ft). (Source: Washington State Department of Ecology web site at http://apps.ecy.wa.gov/shorephotos.)

Figure 3. Photographs during and after work at the Chimacum/Irondale beach restoration site.

Sampling Plan

The post-restoration survey was conducted on September 12, 2006. The sampling plan was designed to (1) map the geographic position of any eelgrass beds as accurately as

possible during one high tide cycle; and (2) estimate the following parameters: eelgrass basal area coverage (i.e., number of square meters of the seabed with at least one shoot of eelgrass); mean maximum and minimum eelgrass depths; and patchiness index.

Our survey methods were consistent with those of the DNR SVMP (Dowty 2005; Dowty et al. 2005). At each site we conducted straight-line underwater videographic transects perpendicular to the shoreline beginning as shallow as possible (to ensure that we captured the nearshore edge of any eelgrass beds) and continuing to a depth we were certain had no eelgrass. Transects were spaced approximately 50 m apart. We conducted 20 transects at each site (Fig. 4).

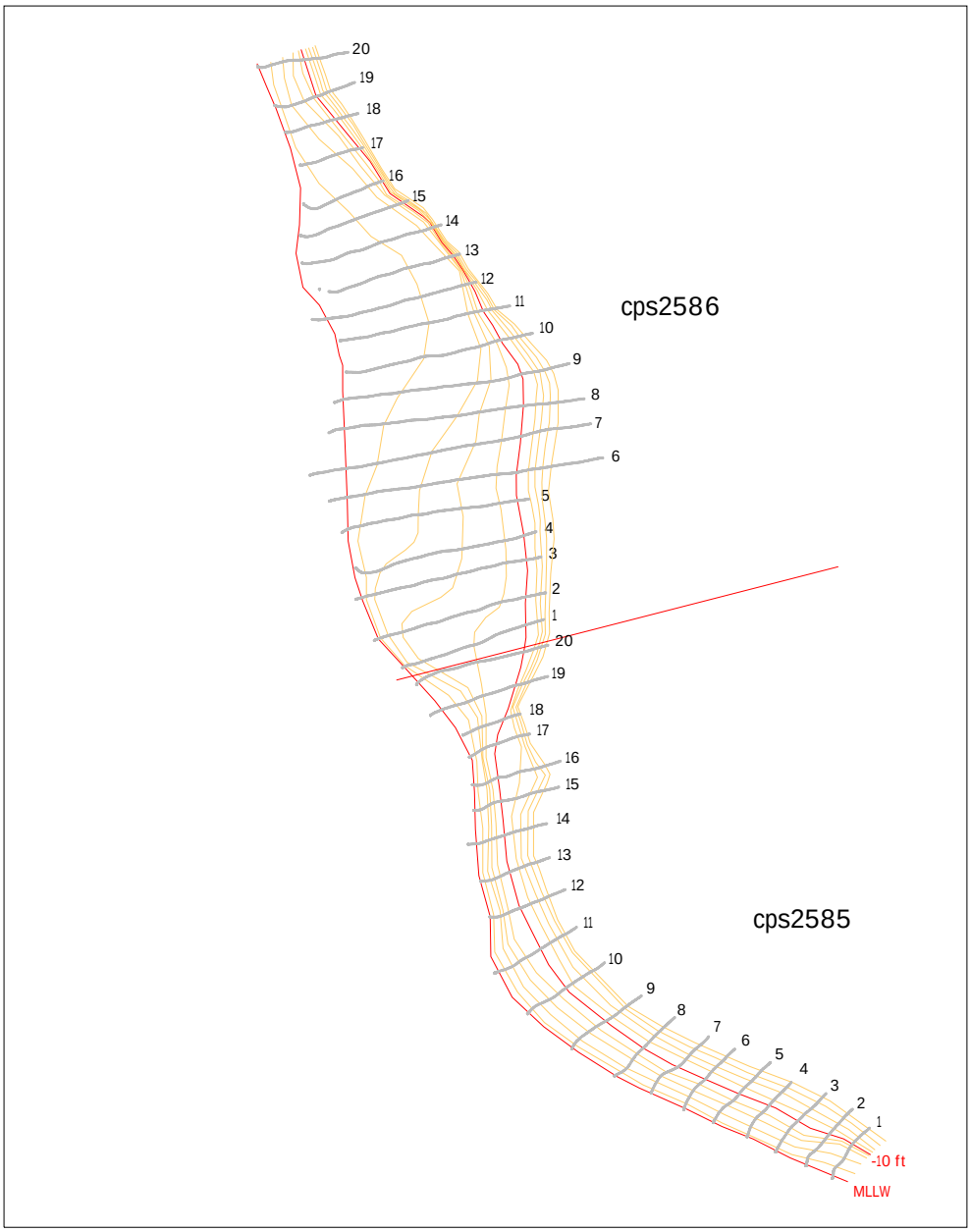


Figure 4. Map showing locations of the underwater video transects conducted on September 12, 2006. Isobaths are at 2 ft intervals.

Survey Equipment and Field 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 meters). All data were updated at 1 s intervals. Table 2 lists the equipment used during this survey.

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

Table 2. Survey equipment used onboard the *R/V Brendan D II* during the 2006 Chimacum/Irondale Beach Restoration Site eelgrass survey.

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 DVR-TRV310 Digital8 Camcorder

Video Data

We obtained underwater video images using an underwater camera mounted in a down-looking orientation on a heavy 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 Sony Digital8 videotapes and onto DVD-R disks.

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 were combined into larger files and processed through EcoSAV software (part of the BioSonics system). The output was a single text file with time, depth, and position data. These data were then merged with the tide correction data (see sub-section below) to give corrected depths.

Our secondary 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 estimates 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 raised and lowered the camera towfish to follow the seabed contour. The field of view changed with the height above the bottom. The vessel speed was held as constant as possible (about 1 m/sec). At the end of the transect, we stopped the recorders, retrieved the camera towfish, and moved the vessel to the next sampling position. We maintained field notes for each transect (Appendix A).

Data Analysis

Underwater Video Data Post-Processing

Data stored on floppy disks and hard drives were downloaded and organized into spreadsheet files including blank columns for “video code” and “eelgrass code.” Videotapes were reviewed in the laboratory to assign video codes (0 = cannot view the seabed; 1 = seabed in view) and eelgrass codes (0 = eelgrass absent; 1 = eelgrass present) to each position record. The resulting data were plotted in AutoCAD. Polygons were drawn around eelgrass observations to define the eelgrass bed outlines.

Tide Heights and Corrected Depth Data

Raw depths collected from the echosounders measured the distance between the seabed and the transducer. To correct these depths to the mean lower low water (MLLW) vertical datum, three corrections were applied:

1. transducer offset (i.e., distance between the transducer and the surface);
2. predicted tidal height (i.e., predicted distance between the surface and MLLW);
3. tide prediction error (i.e., difference between the predicted and 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. The transducer offsets were measured just prior to the survey (1.36 ft Garmin; 1.17 ft Biosonics). We used the computer program Tides and Currents Pro 3.0 (Nobletec Corporation) to get predicted tide heights (at 6 min intervals) for the tide prediction station closest to the survey site, in this case Port Townsend (station ID 0995; 48 06.90 N 122 45.00 W). We computed tide prediction errors at the reference station by comparing the computer program predicted tide heights with actual observed tide heights published by the National Oceanic and Atmospheric Administration on their web site (http://tidesandcurrents.noaa.gov/). The tide prediction errors during the time of the survey ranged from –0.4 ft to +0.2 ft (Fig. 6).

The BioSonics system often does not provide a depth estimate for every one second interval. For these records we estimated depths by using a linear interpolation between depth estimates immediately before and after the missing data. For example, if the recorded depths immediately before and after a missing depth were -3.6 ft and -3.8 ft, our estimate for the missing depth would be the average, or -3.7 ft.

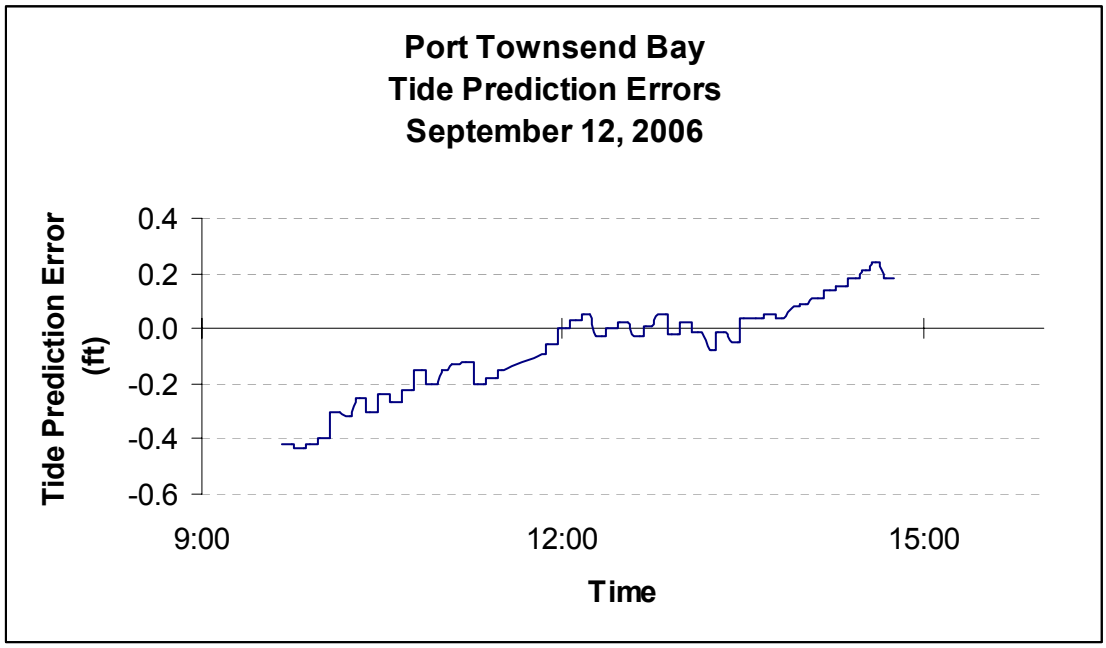


Figure 6. Tide prediction errors for Port Townsend Bay on September 12, 2006.

Basal Area Coverage

We estimated the total basal area coverage of eelgrass at each fringe site using methods described in Norris et al. (1997) and Dowty (2005). Some eelgrass observations from the

2006 survey were located just outside the eelgrass polygons used to analyze the 2004 data. To make valid comparisons between years we drew new, slightly larger polygons surrounding eelgrass observations from both surveys and re-estimated parameters from the 2004 survey. We used AutoCAD to compute the total area of the eelgrass polygons (A).

For each straight-line transect, we computed the length of the transect passing through the eelgrass polygon and the lengths associated with eelgrass. Once all transects were analyzed, the proportion of the polygon having eelgrass (p) was estimated by (Cochran 1977; eq. 3.31):

$$\hat{p} = \frac{\sum a_i}{\sum m_i}$$

where m_i = length (m) of transect i passing through the polygon and a_i = length (m) of transect i with eelgrass. An approximate estimated variance is (Cochran 1977; eq. 3.34):

$$v(\hat{p}) = \frac{1-f}{n\overline{m}^2} \frac{\sum a_i^2 - 2p\sum a_i m_i + p^2 \sum m_i^2}{n-1}$$

where n is the number of transects, $f = n/N$ is the sampling fraction, and $\overline{m} = \sum m_i / n$ is the average length of the transects passing through the polygon. The estimated total number of square meters covered by seagrass ($\hat{E}$) is given by:

$$\hat{E} = A \cdot \hat{p}$$

where A is the area of the eelgrass polygons.

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.

Isobaths

We used the isobaths estimated for the 2004 report. We estimated those isobaths by plotting the positions of equal depths and drawing each isobath line by hand. For example, to create the -6 ft isobath, we plotted all the positions where the BioSonics corrected depth was between -5.8 ft and -6.2 ft. The result was a series of points along each transect. We then drew the isobath line by connecting the centers of the series of points for each transect.

Mean Minimum and Maximum Eelgrass Depth

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

Results

Eelgrass Distribution

As with the 2004 pre-restoration survey, we observed three eelgrass beds (Fig. 7). The northernmost bed was largest and extended across the delta at the mouth of Chimacum Creek. The southern edge of this bed was located in the northern portion of the restoration site. No eelgrass was observed near the center of the restoration site. A smaller and narrower eelgrass bed was located near the southern edge of the restoration site. The third eelgrass bed was located about 800 m south of the restoration site. Note that the eelgrass beds depicted in Fig. 7 outline the limits of the eelgrass distribution and do not imply that eelgrass was located continuously throughout the beds.

Eelgrass Basal Area Coverage and Patchiness

As mentioned earlier, the eelgrass polygons shown in Fig. 7 are slightly larger than those shown in our report from the 2004 survey. Tables 5 - 8 in Appendix B list the 2004 and 2006 transect data and parameter estimates from both sites based on the polygons drawn in 2006. Note that the revised 2004 basal area coverage estimates were 6.3% and 1.1% higher than the original (i.e., reported in 2004) estimates for cps2585 and cps2586, respectively.

Between 2004 and 2006 the estimated eelgrass fractions dropped significantly at both sites—from 0.6191 to 0.2913 at cps2585 and from 0.5850 to 0.4012 at cps2586 (Table 3; Fig. 8). Fig. 9 provides a closer examination of the eelgrass observations in both 2004 and 2006 and illustrates the eelgrass loss. We estimated that the eelgrass area at cps2585 declined from 11,832 m^2 to 5,567 m^2—a 53% decline (Table 3; Fig. 8). At cps2586 the eelgrass area declined from 47,507 m^2 to 32,582 m^2—a 31% decline (Table 3; Fig. 8). Our estimated combined loss from both sites was 21,190 m^2 (2.119 hectares or 5.24 acres).

Patchiness indices declined at both sites—from 2.91 to 2.18 at cps2585 and from 9.39 to 5.24 at cps2586 (Table 3).

Eelgrass Depth

Tables 9 – 12 in Appendix B list depth data for individual transects and parameter estimates for each site based on the polygons drawn in 2006. There was no significant change between years in mean minimum or maximum eelgrass depths at either site (Table 3; Figs. 10 and 11). Ninety-seven percent of the eelgrass in both years was located between 0.5 ft and -6.5 ft isobaths; and sixty-seven percent was located between the -0.5 ft and -2.5 ft isobaths (Table 4; Fig. 12). Eelgrass fractions declined in all depth zones (Table 5: Fig. 13).

Discussion

Our results indicate that between 2004 and 2006 eelgrass beds did not significantly change shape or location. Polygons outlining beds were nearly identical, and there was no significant change in mean minimum and maximum eelgrass depths. However, basal area coverage declined significantly within the bed boundaries. It appears that losses occurred at all depth ranges. The decline in patchiness indices suggests that small patches of eelgrass within the beds were completely lost. Further analysis of the factors causing the eelgrass losses is beyond the scope of this report.

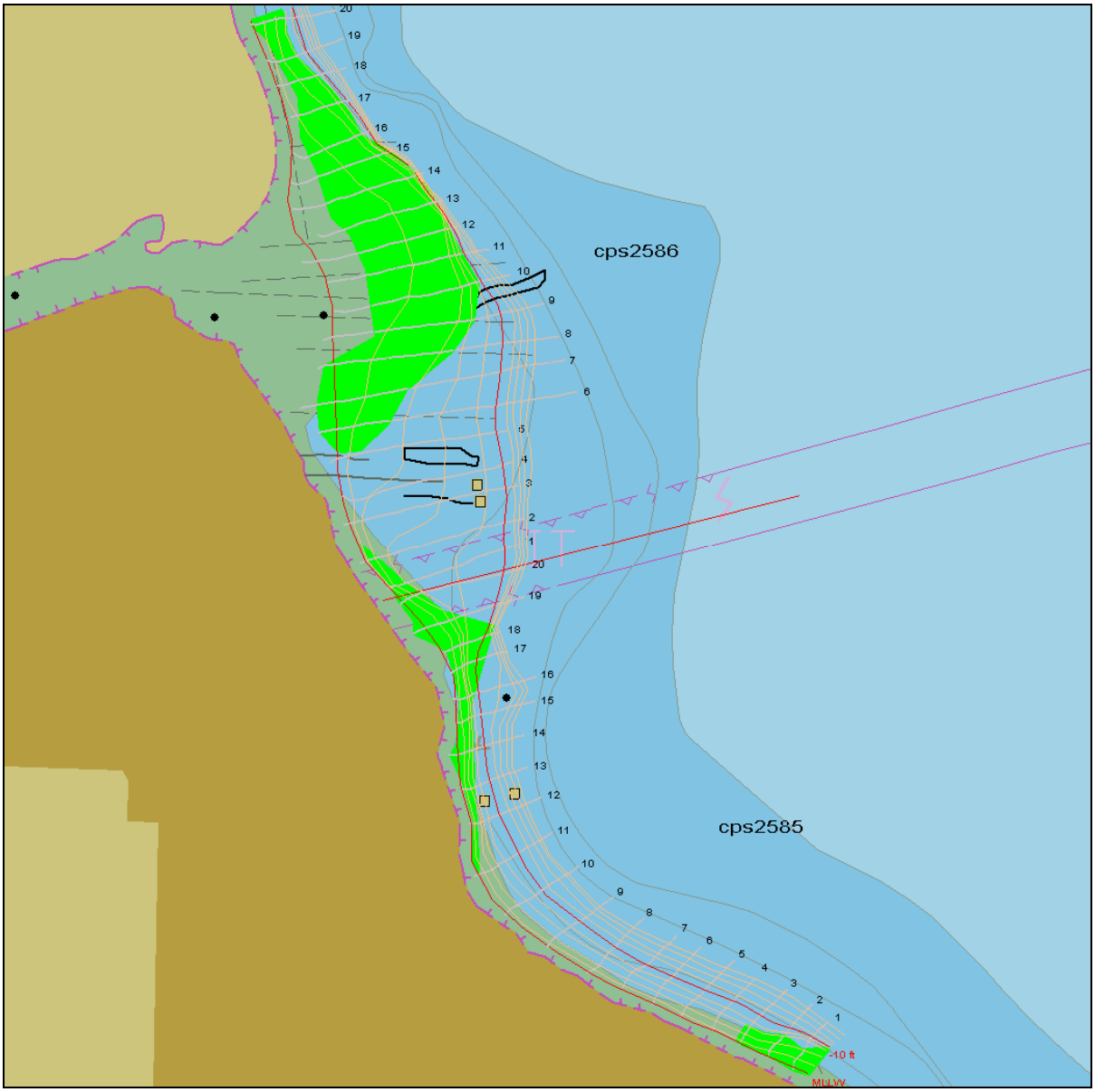


Figure 7. Map of the survey results.

Note: This map is superimposed over National Oceanic and Atmospheric Administration S57 format nautical chart number US5WA16M (Approaches to Admiralty Inlet—Dungeness to Oak Bay). Light colored lines perpendicular to the shoreline are the underwater video transects (numbered 1 through 20 for both cps2585 and cps2586). Light colored lines parallel to the shoreline are isobaths at 2 ft intervals (the 0 ft and -10 ft isobaths are colored red). The three green polygons identify the regions where eelgrass was observed. Eelgrass was patchily distributed within the polygons (about 29% of the area within the southernmost polygons contained eelgrass and about 40% of the northernmost polygon contained eelgrass).

Table 3. Parameter estimate comparisons between the 2004 and 2006 surveys.

	cps2585		cps2586	
Parameter	**2004**	**2006**	**2004**	**2006**
Upper 80% limit	.7627	.4123	.6372	.4697
Eelgrass fraction	.6191	.2913	.5850	.4012
Lower 80% limit	.4755	.1702	.5327	.3327
Upper 80% limit	14,576	7,880	51,752	38,148
Basal area coverage (m^2)	11,832	5,567	47,507	32,582
Lower 80% limit	9,088	3,254	43,261	27,016
Patchiness Index	2.91	2.18	9.39	5.24
Upper 95% limit	0.3	1.5	-1.2	-0.9
Mean minimum eelgrass depth	-0.5	0.3	-1.6	-1.4
Lower 95% limit	-1.3	-0.8	-2.0	-1.9
Upper 95% limit	-3.0	-2.4	-4.7	-4.2
Mean maximum eelgrass depth	-5.8	-5.5	-6.2	-5.4
Lower 95% limit	-8.6	-8.7	-7.7	-6.6

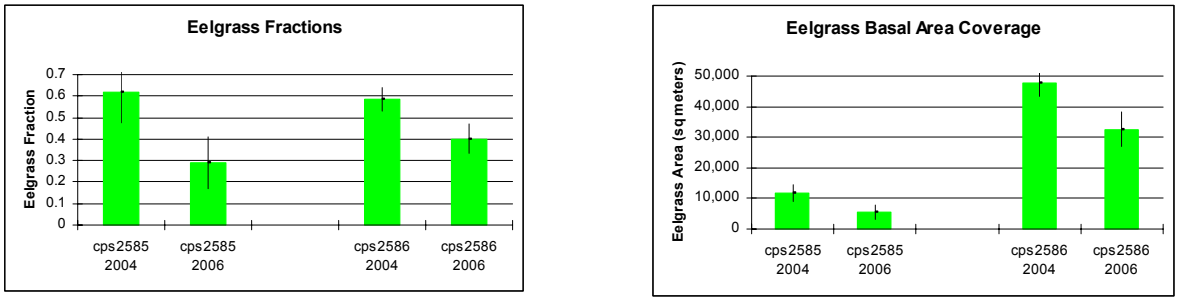


Figure 8. Comparison of estimated eelgrass fraction and basal area coverage from the 2004 and 2006 surveys.

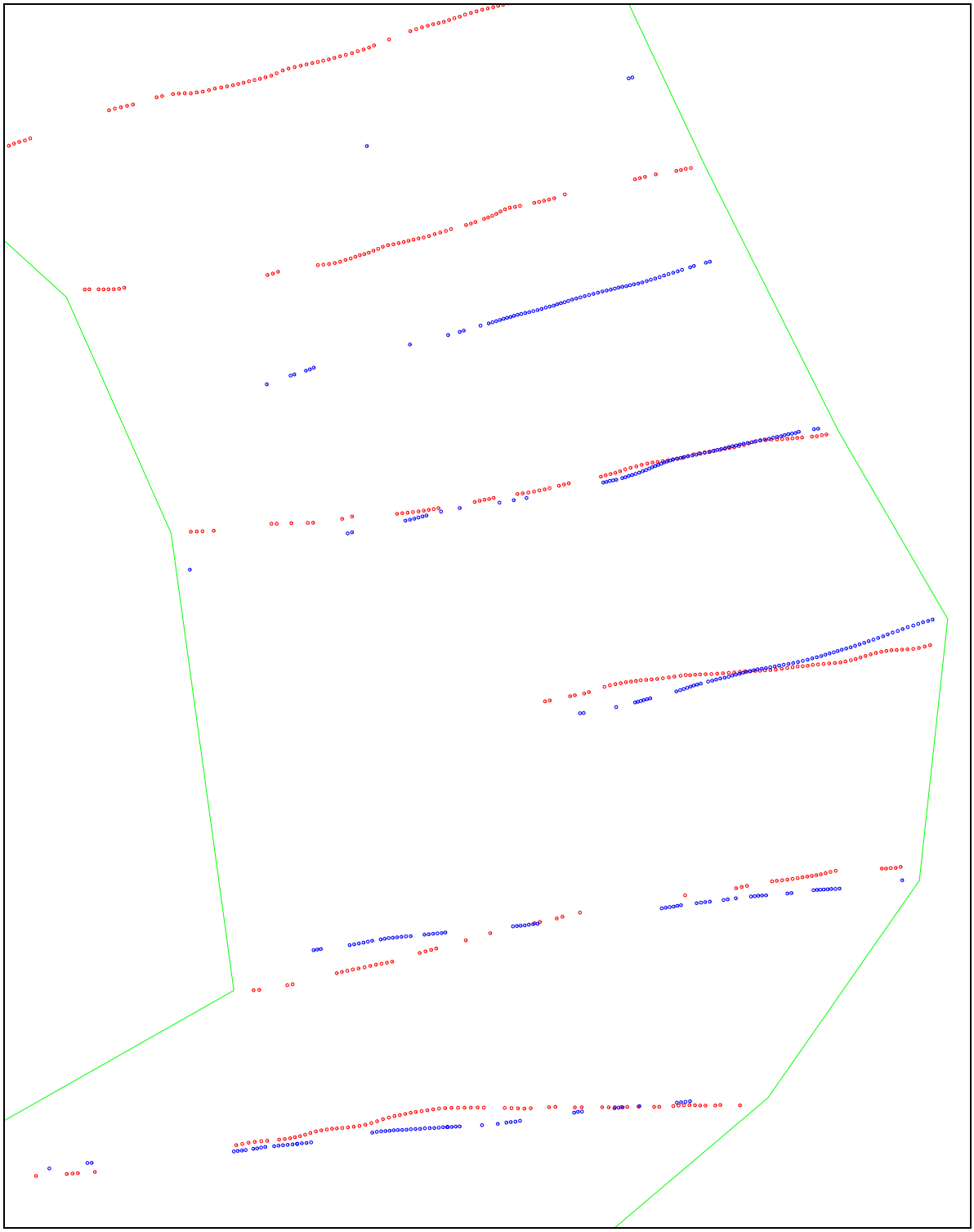
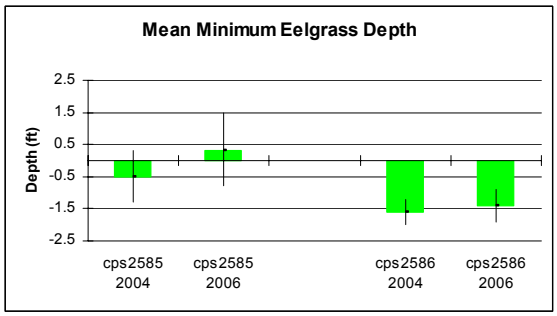


Figure 9. Comparison of selected eelgrass observations from the 2004 (red) and 2006 (blue) eelgrass surveys at the cps2586 site.



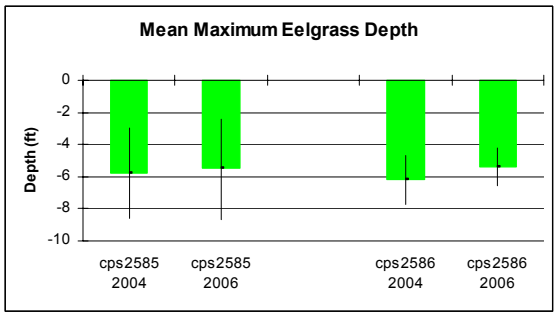


Figure 10. Comparison of estimated mean maximum and minimum eelgrass depths from the 2004 and 2006 surveys.

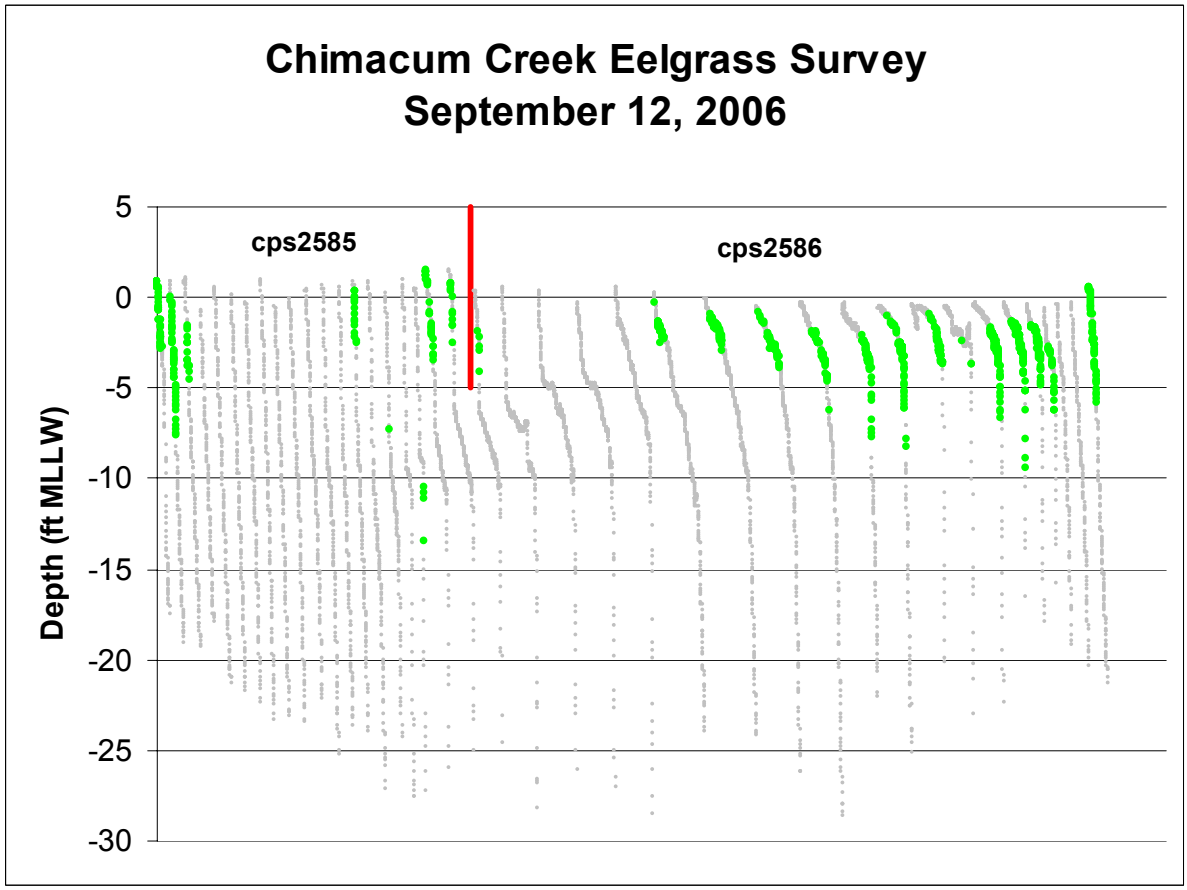


Figure 11. Eelgrass observations by depth from the 2006 survey.

Table 4. Estimated eelgrass areas by year, site, and depth zone.

Depth Zone Mid-Pt (ft)	2004			2006			Total Change	Percent Total Change
	cps2585	cps2586	Total	cps2585	cps2586	Total		
2	0	0	0	1	0	1	1	
1	60	0	60	231	6	237	177	295%
0	1,445	11	1,456	721	63	784	-672	-46%
-1	2,190	3,593	5,783	901	2,826	3,727	-2,056	-36%
-2	2,428	20,816	23,244	1,490	12,587	14,077	-9,167	-39%
-3	2,089	13,339	15,428	896	10,621	11,517	-3,911	-25%
-4	1,618	5,108	6,726	547	3,974	4,521	-2,205	-33%
-5	766	2,663	3,429	196	1,314	1,510	-1,919	-56%
-6	583	1,165	1,748	184	733	917	-831	-48%
-7	0	159	159	188	134	322	163	103%
-8	0	314	314	41	228	269	-45	-14%
-9	304	117	421	0	94	94	-327	-78%
-10	93	60	153	42	0	42	-111	-73%
-11	50	56	106	86	0	86	-20	-19%
-12	107	0	107	0	0	0	-107	-100%
-13	0	0	0	41	0	41	41	
-14	50	54	104	0	0	0	-104	-100%
-15	50	51	101	0	0	0	-101	-100%
Total	11,833	47,506	59,339	5,565	32,580	38,145	-21,194	-36%

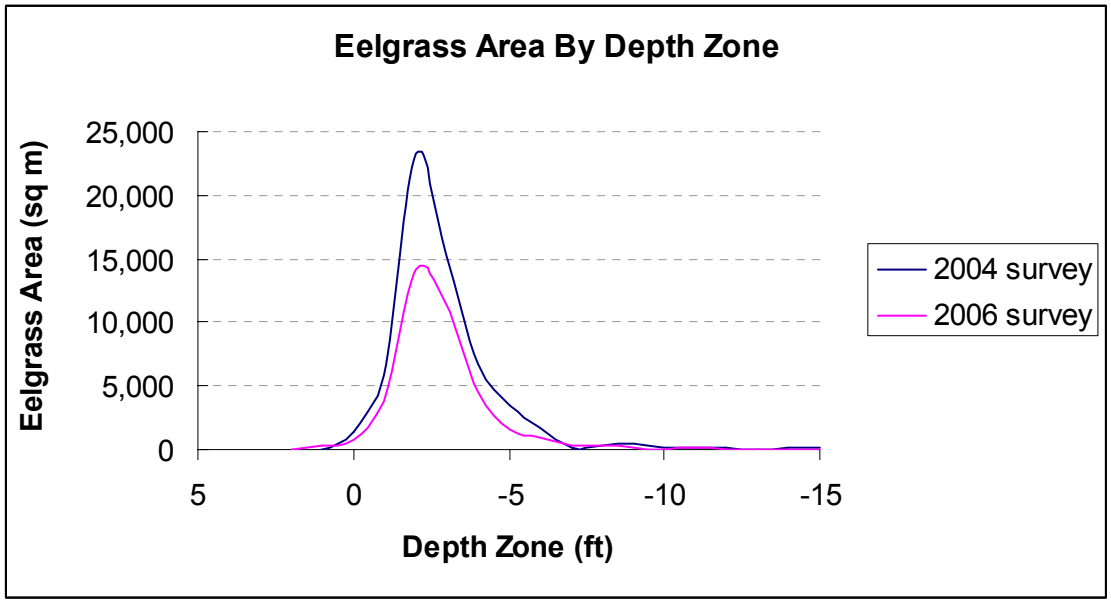
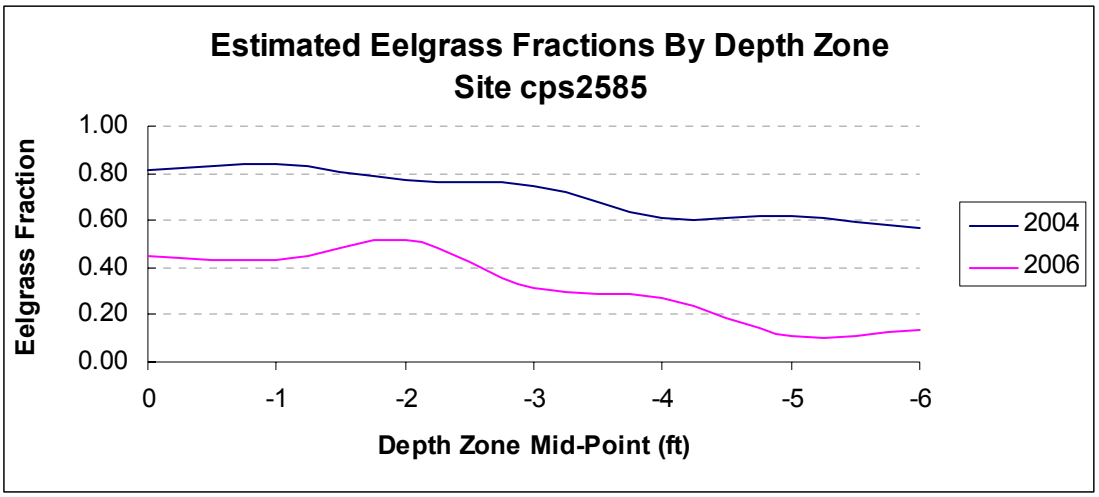


Figure 12. Estimated eelgrass areas by depth zone from the 2004 and 2006 surveys.

Table 5. Estimated eelgrass fractions by site, year, and depth zone.

Depth Zone Mid-Point (ft)	cps2585			cps2586		
	2004	2006	change	2004	2006	change
0	0.82	0.45	-45%	0.12	0.25	103%
-1	0.84	0.43	-49%	0.31	0.19	-39%
-2	0.77	0.51	-33%	0.62	0.40	-35%
-3	0.75	0.31	-58%	0.67	0.55	-17%
-4	0.61	0.27	-56%	0.68	0.51	-26%
-5	0.62	0.11	-82%	0.63	0.36	-44%
-6	0.57	0.13	-77%	0.54	0.31	-43%



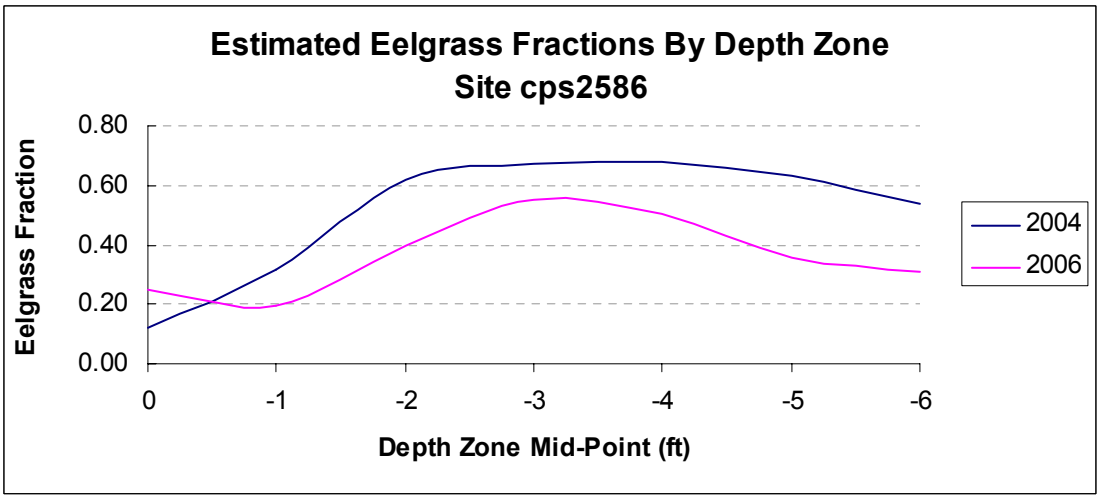


Figure 13. Estimated eelgrass fractions by site, date, and depth zone.

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APPENDIX A

Field Notes

Time	Site	Track	Comment
0940	cps2585	1	South end of site. Similar to previous survey. Shallow grass.
0946	cps2585	2	North of #1. Shallow fringing bed. Similar to 2004 survey.
0950	cps2585	3	North of #2. A bit less grass. Lots of *Ulvoids* on all of these tracks … thick.
0957	cps2585	4	Track moved south to avoid a mooring line.
1002	cps2585	5	Similar to previous track.
1007	cps2585	6	Lots of thick *Ulva*. No grass. A few small fish.
1012	cps2585	7	Same.
1018	cps2585	8	Same.
1023	cps2585	9	Stinky boat moored here. Lots of *Ulva*. No grass.
1028	cps2585	10	Moved a bit south to avoid a mooring buoy. Plenty of *Ulva*, but doesn't extend as deep as previous track.
1033	cps2585	11	Similar to previous track. No grass. Near grass sighted in 2004.
1039	cps2585	12	No grass. Lots of Ulva and some stringy brown (red?) algae (grassillaria?). Also, what was that invertebrate? Grass near here in 1999.
1044	cps2585	13	No grass. Similar to previous track. Grass here in 1999 and 2004.
1050	cps2585	14	Shallow bed of grass. Looks like less than 2004 and 1999. Lots of *Ulva*.
1055	cps2585	15	No grass. Grass here in 2004 and 1999. Lots of *Ulva* and some assorted algae.
1100	cps2585	16	One *Z. marina* plant. More mixed algae.
1106	cps2585	17	No grass. Lots of *Ulva*. No grass in 2004 or 1999 either.
1112	cps2585	18	A few *Z. marina* plants out deeper, before drop-off. No shallow *Z. marina* plants.
1117	cps2585	19	*Z. marina* similar to 2004. Just get shallow edge of *Z. marina* at +6.5 tide.
1125	cps2585	20	Sparse shallow *Z. marina*. May have missed shallowest couple of plants
1150	cps2586	1	South end of site. Just a little grass at shallow end. May be less than in 2004.
1158	cps2586	2	No grass. Grass at shallow end in 2004. Lots of *Ulva*.
1208	cps2586	3	No grass. Lots of *Ulva*. Some *Laminaria*. No grass in 2004.
1217	cps2586	4	As above.
1227	cps2586	5	As above.
1236	cps2586	6	Grass distribution similar to 2004. Maybe a bit less.
1249	cps2586	7	Scraggly *Z. marina* consistent with 2004. Lots of *Ulva* mixed in.
1302	cps2586	8	Similar distribution to 2004. A couple of dead colorless looking patches of *Z. marina*. Wasting disease??
1314	cps2586	9	New Dig8 tape. Scraggly Z. marina across delta in similar area to that in 2004. Lots of *Ulva* and some *Laminaria*.
1325	cps2586	10	As above, but patchier on shallow edge. Clicker on too long.
1335	cps2586	11	Sparse patchy grass across same area as in 2004.
1344	cps2586	12	Very sparse and patchy at shallow edge. At mouth of Chim Creek.
1356	cps2586	13	New DVD. A lot less grass than in 2004. Lots of *Ulva*. Creek channel?
1405	cps2586	14	More like 2004.

1413	cps2586	15	As above.
1420	cps2586	16	As above.
1426	cps2586	17	As above.
1430	cps2586	18	No grass. No grass in 2004 either.
1435	cps2586	19	No grass. Consistent with 2004.
1441	cps2586	20	Did not get shallow edge of grass. Close.

APPENDIX B

Tables of Estimates

Table 6. Videographic data and estimates from the 2004 survey at site cps2585 using the sample polygon from the 2006 survey.

Transect	Date	Total Length (m)	Sample Length (m)	Eelgrass Length (m)	Eelgrass Fraction	Speed (m/s)	Patches
1	9/5/2004	92.3	49.3	38.4	0.7792	0.64	4
2	9/5/2004	103.4	97.1	39.7	0.4091	0.84	3
3	9/5/2004	90.2	42.8	0.0	0.0000	0.97	0
4	9/5/2004	108.2	17.7	5.3	0.2969	0.84	1
5	9/5/2004	89.3	24.4	21.6	0.8862	0.74	1
6	9/5/2004	75.0	22.1	18.0	0.8138	0.82	1
7	9/5/2004	82.8	5.5	0.0	0.0000	0.68	0
8	9/5/2004	107.1	12.5	8.8	0.7018	0.83	1
17	9/5/2004	97.3	29.8	28.8	0.9641	0.85	1
18	9/5/2004	80.2	38.6	33.3	0.8610	0.97	1
19	9/5/2004	83.0	51.7	48.6	0.9399	1.10	1
Totals		1,009.0	392.0	242.0			14

Estimated mean eelgrass fraction:	0.6191
Estimated variance of eelgrass fraction:	0.0126
Estimated st error of eelgrass fraction:	0.1122
Approximate lower 80% limit:	0.4755
Approximate upper 80% limit:	0.7627
Total sample area within perimeter (sq m):	19,112
Estimated basal area coverage (sq m):	11,832
Estimated variance of basal area coverage (sq m):	4,595,281
Estimated st error of basal area coverage (sq m):	2,144
Approx. lower 80% limit:	9,088
Approx. upper 80% limit:	14,576
Minimum patch/gap length (m):	1.00
Patchiness Index:	2.91
Average vessel speed (m/s):	0.85

Table 7. Videographic data and estimates from the 2004 survey at site cps2586 using the sample polygon from the 2006 survey.

Transect	Date	Total Length (m)	Sample Length (m)	Eelgrass Length (m)	Eelgrass Fraction	Speed (m/s)	Patches
1	9/5/2004	71.5	52.0	47.2	0.9063	0.88	1
2	9/5/2004	60.0	33.8	28.8	0.8525	1.09	1
3	9/5/2004	56.4	29.9	0.0	0.0000	1.11	0
4	9/5/2004	92.0	52.4	14.1	0.2689	1.03	2
5	9/5/2004	114.0	85.6	56.3	0.6585	1.06	6
6	9/5/2004	144.5	102.2	84.1	0.8231	1.11	3
7	9/5/2004	204.3	141.1	101.9	0.7225	1.09	2
8	9/5/2004	216.6	157.2	119.0	0.7573	1.26	9
9	9/5/2004	212.8	145.6	73.3	0.5032	1.15	11
10	9/5/2004	229.0	150.5	91.0	0.6049	1.15	13
11	9/5/2004	256.2	166.8	80.5	0.4830	1.14	4
12	9/5/2004	305.3	154.7	57.9	0.3743	1.19	13
13	9/5/2004	245.6	192.3	96.8	0.5033	1.28	14
14	9/5/2004	274.7	141.5	93.7	0.6623	1.08	9
15	9/5/2004	177.2	94.5	43.2	0.4569	1.13	5
19	9/5/2004	236.2	13.7	10.1	0.7357	0.98	1
20	9/5/2004	202.5	20.9	16.7	0.8009	1.05	2
Totals		3,099.0	1,735.0	1,015.0			96

Estimated mean eelgrass fraction:	0.5850
Estimated variance of eelgrass fraction:	0.0017
Estimated st error of eelgrass fraction:	0.0408
Approximate lower 80% limit:	0.5327
Approximate upper 80% limit:	0.6372
Total sample area within perimeter (sq m):	81,214
Estimated basal area coverage (sq m):	47,507
Estimated variance of basal area coverage (sq m):	10,999,668
Estimated st error of basal area coverage (sq m):	3,317
Approx. lower 80% limit:	43,261
Approx. upper 80% limit:	51,752
Minimum patch/gap length (m):	1.00
Patchiness Index:	9.39
Average vessel speed (m/s):	1.13

Table 8. Videographic data and estimates from the 2006 survey at site cps2585.

Transect	Date	Total Length (m)	Sample Length (m)	Eelgrass Length (m)	Eelgrass Fraction	Vessel Speed (m/s)	Patches
1	9/12/2006	92.7	40.0	29.2	0.7301	0.73	1
2	9/12/2006	107.3	44.2	40.4	0.9133	0.80	1
3	9/12/2006	112.1	33.1	14.1	0.4272	0.60	1
12	9/12/2006	116.3	5.9	0.0	0.0000	0.98	0
13	9/12/2006	106.5	17.5	0.0	0.0000	1.17	0
14	9/12/2006	117.9	37.5	16.5	0.4406	0.96	1
15	9/12/2006	127.7	22.2	0.0	0.0000	0.85	0
16	9/12/2006	132.7	25.4	0.9	0.0335	0.88	0
17	9/12/2006	94.0	53.3	0.0	0.0000	1.01	0
18	9/12/2006	88.3	74.1	4.1	0.0558	0.99	1
19	9/12/2006	178.3	77.4	21.2	0.2737	0.82	4
20	9/12/2006	199.1	35.1	9.2	0.2628	0.65	2
Totals		1,473.0	466.0	136.0			11

Estimated mean eelgrass fraction:	0.2913
Estimated variance of eelgrass fraction:	0.0089
Estimated standard error of eelgrass fraction:	0.0946
Approximate lower 80% limit:	0.1702
Approximate upper 80% limit:	0.4123
Total sample area within perimeter (sq m):	19,112
Estimated basal area coverage (sq m):	5,567
Estimated variance of basal area coverage (sq m):	3,265,469
Estimated standard error of basal area coverage (sq m):	1,807
Approx. lower 80% limit:	3,254
Approx. upper 80% limit:	7,880
Minimum patch/gap length (m):	1.00
Patchiness Index:	2.18
Average vessel speed (m/s):	0.84

Table 9. Videographic data and estimates from the 2006 survey at site cps2586.

Transect	Date	Total Length (m)	Sample Length (m)	Eelgrass Length (m)	Eelgrass Fraction	Speed (m/s)	Patches
1	9/12/2006	215.2	25.5	5.3	0.2070	0.95	2
2	9/12/2006	255.9	16.1	0.0	0.0000	0.80	0
6	9/12/2006	397.6	110.8	39.5	0.3568	0.82	3
7	9/12/2006	410.1	141.5	79.2	0.5599	0.90	5
8	9/12/2006	370.3	200.0	57.8	0.2892	0.91	7
9	9/12/2006	342.4	153.8	53.6	0.3487	0.92	10
10	9/12/2006	274.7	169.2	65.6	0.3879	0.87	3
11	9/12/2006	249.6	150.4	59.3	0.3939	0.86	4
12	9/12/2006	242.3	144.0	58.9	0.4090	0.89	5
13	9/12/2006	198.1	146.3	2.5	0.0173	0.83	1
14	9/12/2006	208.6	145.9	82.7	0.5667	0.84	3
15	9/12/2006	164.8	118.8	99.9	0.8407	0.89	4
16	9/12/2006	124.5	87.5	49.3	0.5634	0.86	4
17	9/12/2006	94.5	70.3	26.1	0.3721	0.94	5
18	9/12/2006	108.3	42.2	0.0	0.0000	1.01	0
19	9/12/2006	121.8	29.3	0.0	0.0000	0.98	0
20	9/12/2006	133.2	53.2	44.3	0.8318	0.72	3
Totals		3,912.0	1,805.0	724.0			59

Estimated mean eelgrass fraction:	0.4012
Estimated variance of eelgrass fraction:	0.0029
Estimated st error of eelgrass fraction:	0.0535
Approximate lower 80% limit:	0.3327
Approximate upper 80% limit:	0.4697
Total sample area within perimeter (sq m):	81,214
Estimated basal area coverage (sq m):	32,582
Estimated variance of basal area coverage (sq m):	18,907,171
Estimated standard error of basal area coverage (sq m):	4,348
Approx. lower 80% limit:	27,016
Approx. upper 80% limit:	38,148
Minimum patch/gap length (m):	1.00
Patchiness Index:	5.24
Average vessel speed (m/s):	0.88

Table 10. Depth data and estimates from the 2004 survey at site cps2585 using the sample polygon from the 2006 survey.

Transect	Date	Max Track Depth (ft)	Max Eelgrass Depth (ft)	Min Eelgrass Depth (ft)	Min Track Depth (ft)
1	9/5/2004	-8.5	-3.8	0.6	0.6
2	9/5/2004	-22.9	-14.8	0.4	0.4
4	9/5/2004	-17.7	-3.3	-2.5	-1.2
5	9/5/2004	-18.2	-5.3	-0.7	-0.7
6	9/5/2004	-16.2	-6.3	-1.4	-0.8
8	9/5/2004	-16.4	-2.5	-0.7	-0.2
17	9/5/2004	-17.7	-6.1	-0.8	-0.8
18	9/5/2004	-15.3	-3.9	0.5	0.5
19	9/5/2004	-17.7	-6.1	0.3	0.3
	n		9	9	
	min		-14.8	-2.5	
	max		-2.5	0.6	
	mean		-5.8	-0.5	
	standard deviation		3.6429	1.0446	
	standard error		1.2143	0.3482	
	t stat		2.3060	2.3060	
	lower 95% limit		-8.6	-1.3	
	upper 95% limit		-3.0	0.3	

Table 11. Depth data and estimates from the 2004 survey at site cps2586 using the sample polygon from the 2006 survey.

Transect	Date	Max Track Depth (ft)	Max Eelgrass Depth (ft)	Min Eelgrass Depth (ft)	Min Track Depth (ft)
1	9/5/2004	-10.7	-5.4	-0.3	-0.3
2	9/5/2004	-9.3	-6.1	-2.0	-1.0
4	9/5/2004	-12.7	-5.8	-3.5	-0.8
5	9/5/2004	-29.5	-6.3	-1.6	-0.7
6	9/5/2004	-17.7	-5.2	-1.4	-0.4
7	9/5/2004	-18.6	-8.5	-1.2	-0.3
8	9/5/2004	-23.8	-14.8	-1.0	-0.5
9	9/5/2004	-11.7	-3.5	-1.4	-0.4
10	9/5/2004	-14.0	-8.3	-1.0	-0.2
11	9/5/2004	-13.8	-7.6	-2.3	-0.6
12	9/5/2004	-14.3	-5.9	-2.1	-0.4
13	9/5/2004	-6.9	-4.9	-1.4	-0.6
14	9/5/2004	-7.4	-3.6	-1.2	-0.4
15	9/5/2004	-6.0	-2.8	-1.3	-0.7
19	9/5/2004	-17.2	-4.3	-2.4	-2.1
20	9/5/2004	-18.1	-5.7	-1.1	-1.0

n		16	16
min		-14.8	-3.5
max		-2.8	-0.3
mean		-6.2	-1.6
standard deviation		2.8184	0.7402
standard error		0.7046	0.1851
t stat		2.1314	2.1314
lower 95% limit		-7.7	-2.0
upper 95% limit		-4.7	-1.2

Table 12. Depth data and estimates from the 2006 survey at site cps2585.

Transect	Date	Max Track Depth (ft)	Max Eelgrass Depth (ft)	Min Eelgrass Depth (ft)	Min Track Depth (ft)
1	9/12/2006	-17.5	-2.8	0.9	0.9
2	9/12/2006	-19.1	-7.6	0.1	0.9
3	9/12/2006	-19.3	-4.6	-1.6	1.1
14	9/12/2006	-23.9	-2.6	0.4	0.9
16	9/12/2006	-24.3	-7.3	NA	0.2
18	9/12/2006	-27.3	-13.4	NA	0.4
19	9/12/2006	-26.0	-3.5	1.5	1.5
20	9/12/2006	-25.0	-2.5	0.8	1.5
	n		8	6	
	min		-13.4	-1.6	
	max		-2.5	1.5	
	mean		-5.5	0.3	
	standard deviation		3.7871	1.0671	
	standard error		1.3389	0.4356	
	t stat		2.3646	2.5706	
	lower 95% limit		-8.7	-0.8	
	upper 95% limit		-2.4	1.5	

Table 13. Depth data and estimates from the 2006 survey at site cps2586.

Transect	Date	Max Track Depth (ft)	Max Eelgrass Depth (ft)	Min Eelgrass Depth (ft)	Min Track Depth (ft)
1	9/12/2006	-24.6	-4.1	-1.9	0.3
6	9/12/2006	-24.0	-2.5	-0.3	0.3
7	9/12/2006	-24.1	-3.0	-1.0	-0.1
8	9/12/2006	-26.2	-3.9	-0.8	-0.5
9	9/12/2006	-28.6	-6.2	-1.9	-0.3
10	9/12/2006	-22.0	-7.7	-2.1	-0.3
11	9/12/2006	-25.1	-8.2	-1.1	-0.5
12	9/12/2006	-20.2	-3.7	-0.9	-0.4
13	9/12/2006	-23.0	-3.7	-2.4	-0.5
14	9/12/2006	-22.3	-6.6	-1.7	-0.3
15	9/12/2006	-16.5	-9.4	-1.4	-0.3
16	9/12/2006	-17.9	-4.8	-1.6	-0.4
17	9/12/2006	-15.8	-6.2	-2.8	-0.6
20	9/12/2006	-21.3	-5.9	0.6	0.6
	n		14	14	
	min		-9.4	-2.8	
	max		-2.5	0.6	
	mean		-5.4	-1.4	
	standard deviation		2.0830	0.8856	
	standard error		0.5567	0.2367	
	t stat		2.1604	2.1604	
	lower 95% limit		-6.6	-1.9	
	upper 95% limit		-4.2	-0.9	