San Juan County Underwater Videographic and Hydroacoustic Eelgrass Survey Methodology

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06/23/2004

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

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APPENDIX A

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Introduction

The Friends of the San Juans, with the assistance of project partners (San Juan County Marine Resources Committee, Washington State Department of Natural Resources, University of Washington, and Washington State Department of Fish and Wildife), developed a comprehensive multi-phased project to assess and evaluate nearshore marine habitat, including eelgrass (*Zostera marina*) and forage fish (surf smelt *Hypomesus pretiosus pretiosus*, Pacific sandlance *Ammodytes hexapterus*, and Pacific herring *Clupea harengus pallasi*), throughout the entire county. This Appendix discusses the underwater videographic and hydroacoustic eelgrass assessment methods.

No comprehensive eelgrass survey for San Juan County has ever been conducted. Thom and Hallum (1991) reviewed Puget Sound eelgrass surveys prior to 1990. These included hydrographic charts dating to 1855, the Coastal Zone Atlas prepared from aerial photographs taken in 1973-74, and Washington State Department of Fish and Wildlife (WDFW) herring spawn surveys since 1975. They noted that these early surveys underrepresented eelgrass distribution in the San Juan Islands because eelgrass is found predominantly in the subtidal zone.

In selecting a method for surveying San Juan County eelgrass, we considered all currently available methods. Sabol et al. (2002) provide an excellent review of techniques used to characterize and monitor submerged aquatic vegetation (SAV), including eelgrass. They divide the methods into three groups: (1) physical (manual); (2) off-water-remote; and (3) on-water remote. Physical methods include direct observation and measurement by divers. There have been numerous site specific eelgrass surveys of this type in San Juan County related to shoreline modification projects, such as dock and bulkhead construction. WDFW has responsibility for issuing Hydraulic Project Approvals for such projects, and provides recommended guidelines for eelgrass/macro algae habitat surveys at four levels: (1) preliminary surveys to determine eelgrass presence/absence; (2) higher resolution intermediate surveys are required if eelgrass is present; (3) intensive surveys must be conducted if the eelgrass bed is a known herring spawning site; and (4) monitoring surveys must be conducted if mitigation was required. Preliminary surveys may be conducted at any time of the year; all other surveys must be conducted between June 1 and September 30. These surveys are usually conducted by divers with transects berthed 20 to 40 ft apart. These methods provide the greatest level of detail, but they are too labor intensive to be considered for surveying the entire shoreline of San Juan County.

Off-water remote sensing methods interpret aerial photography (still or video) or satellite imagery by either a human interpreter or by a computer algorithm. In 1995 the Washington State Department of Natural Resources (DNR) used aerial video photography from a helicopter to survey the entire shoreline of Washington State, including San Juan County. The results, known as the ShoreZone survey, were presented as linear shoreline segments having no, patchy, or continuous eelgrass. A limitation of the DNR ShoreZone survey was its inability to adequately identify subtidal resources. In general, off-water remote sensing methods work well when the water is clear and calm and the vegetation is easily identifiable and does not extend too deep. For example, vertical true-color aerial photography has been used successfully to monitor eelgrass in Padilla Bay where conditions are near ideal (Bulthuis et al. 2003). Off-water remote sensing methods are inappropriate for San Juan County because eelgrass can be difficult to differentiate from some macro algae and can grow to depths of –30 ft Mean Lower Low Water (MLLW), which is too deep to be seen from an aerial platform.

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

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

The DNR SVMP stratifies the Puget Sound shoreline and associated eelgrass resources into two types: “Flats” and “Fringe.” The same field sampling methods are used at each type of site, but the statistics for parameter estimation are slightly different. Flats are broad areas in which the lengths of the shoreline and the -20 ft isobath are of much different length. There are 67 sites of this type in Puget Sound, including 18 in San Juan County. Fringe sites are defined to be 1,000 meters of shoreline in which the shoreline and the -20 ft isobath lengths are approximately equal. These sites are characterized by a relatively narrow band of eelgrass along a well defined shoreline. There are 2,188 of these sites throughout Puget Sound, of which 516 are located in San Juan County.

For the San Juan County eelgrass survey we decided that a combination of underwater videography and single beam hydroacoustics (BioSonics system) would be the most cost-effective method. Underwater videography would be our primary sampling tool because it provides the most accurate species identification. Hydroacoustics would be used in areas where the camera could not be towed (e.g., rocky, jagged shoreline), and a portable drop camera would be used to validate our interpretation of any questionable acoustic images.

We also concluded that estimating all of the DNR SVMP parameters for the entire shoreline of San Juan County (18 flats sites and 516 fringe sites) would require too much time and money. Therefore, we decided to estimate the DNR SVMP parameters only for the flats sites. For the fringe sites, our goal was to delineate only the deepwater edge of any eelgrass beds and to estimate the mean maximum eelgrass depth for each site. These fringe site parameters could be estimated using zig-zag transects along the deepwater edge of any eelgrass beds. A single zig-zag transect along the entire site is more time efficient than a series of transects perpendicular to the shoreline because the camera is continuously deployed along the entire length of a site (i.e., there is no setup time between transects). And, a critical advantage of surveying only along the deepwater edge is that surveying can be conducted during any tide stage, thus increasing the number of working hours each day.

The specific goals of the survey were:

- For each flats site, draw polygons to delineate all eelgrass beds, estimate basal area coverage, patchiness index, and mean minimum and maximum eelgrass depths.
- For each fringe site, draw a line delineating the deepwater edge of eelgrass beds and estimate the mean maximum eelgrass depth.
- Measure once each day between 10 am and 2 pm water quality parameters (temperature, salinity, pH, dissolved oxygen, and photosynthetically available radiation).

Although there was a strong desire to conduct the entire survey during the period June 1 to Septmember 30, scheduling conflicts prevented us from doing so. After consultation with Brian Williams (WDFW habitat biologist) and Dr. Sandy Wyllie-Echeverria (University of Washington) we decided that any sampling conducted outside the June 1 to September 30 window should be at regions known to have eelgrass. If we were to survey an area outside the June 1 to September 30 window and find no eelgrass, one could argue that the area might have had eelgrass later during the prime growing season.

Methods

Personnel

We surveyed on 61 days between April 30 and September 25, 2003. Table 1 lists the field personnel during each day of the survey.

Field personnel list for the months of April and May.

Date	Vessel Master	Deckhand/Scientist
4/30/03	Jim Norris	Ian Fraser
5/1/03	Brad Jensen	Ian Fraser
5/2/03	Brad Jensen	Ian Fraser
5/5/03	Brad Jensen	Ian Fraser
5/6/03	Brad Jensen	Ian Fraser
5/7/03	Brad Jensen	Ian Fraser
5/8/03	Brad Jensen	Ian Fraser
5/19/03	Brad Jensen	Ian Fraser
5/20/03	Brad Jensen	Ian Fraser
5/21/03	Brad Jensen	Ian Fraser
5/22/03	Lou Schwartz	Ian Fraser
5/23/03	Lou Schwartz	Ian Fraser
5/26/03	Jim Norris	Ian Fraser
5/27/03	Brad Jensen	Ian Fraser
5/28/03	Brad Jensen	Ian Fraser
5/29/03	Brad Jensen	Ian Fraser
5/30/03	Brad Jensen	Ian Fraser
6/2/03	Lou Schwartz	Ian Fraser
6/3/03	Lou Schwartz	Ian Fraser
6/4/03	Brad Jensen	Ian Fraser
6/5/03	Brad Jensen	Ian Fraser
6/6/03	Brad Jensen	Ian Fraser
6/9/03	Lou Schwartz	Jim Norris
6/10/03	Lou Schwartz	Jim Norris
6/11/03	Brad Jensen	Jim Norris
6/12/03	Brad Jensen	Jim Norris
6/13/03	Brad Jensen	Jim Norris
6/16/03	Lou Schwartz	Ian Fraser
6/17/03	Lou Schwartz	Ian Fraser
6/18/03	Jim Norris	Ian Fraser
6/19/03	Jim Norris	Ian Fraser
6/23/03	Lou Schwartz	Ian Fraser
6/24/03	Lou Schwartz	Ian Fraser
6/25/03	Lou Schwartz (am) Brad Jensen (pm)	Ian Fraser
6/26/03	Brad Jensen	Ian Fraser
6/27/03	Brad Jensen	Ian Fraser
6/28/03	Brad Jensen	Ian Fraser
7/25/03	Jim Norris	Anita Fraser
7/26/03	Jim Norris	Anita Fraser
7/27/03	Jim Norris	Anita Fraser
7/28/03	Jim Norris	Anita Fraser
7/31/03	Jim Norris	Anita Fraser
8/1/03	Jim Norris	Anita Fraser
8/3/03	Jim Norris	Anita Fraser
8/6/03	Jim Norris	Anita Fraser
8/7/03	Jim Norris	Anita Fraser
8/8/03	Jim Norris	Anita Fraser
8/11/03	Jim Norris	(none)
8/14/03	Jim Norris	Anita Fraser
8/15/03	Jim Norris	Anita Fraser
8/17/03	Jim Norris	Anita Fraser
8/19/03	Jim Norris	(none)
8/20/03	Jim Norris	(none)
8/21/03	Jim Norris	Ian Fraser
8/22/03	Jim Norris	Ian Fraser
8/23/03	Jim Norris	Anita Fraser
8/24/03	Jim Norris	Anita Fraser
9/22/03	Brad Jensen	Jim Norris
9/23/03	Brad Jensen	Jim Norris
9/24/03	Brad Jensen	Jim Norris
9/25/03	Brad Jensen	Jim Norris

Study Area

We defined the study area to be all of the potential eelgrass habitat in San Juan County. Results from the DNR SVMP indicated that potential eelgrass habitat includes the depth range of +3 ft to –30 ft MLLW. Thus, we included in our study area not only the immediate shoreline, but also shallow offshore shoals. To ensure that no surveying occurred outside the period June 1 through September 30 in areas without eelgrass, we subdivided the study area into two general regions based on the DNR ShoreZone survey: (1) areas with previously observed eelgrass; and (2) areas where eelgrass has not been previously observed (Fig. 1).

Figure 1. Areas in San Juan County where continuous or patchy eelgrass (both shown in green) was reported by the Washington State Department of Natural Resources ShoreZone Survey (Nearshore Habitat Program 2001).

Survey Design

We used the DNR SVMP flats and fringe sites to partition the study area into discrete units and to assign unique identification numbers. Three vessels were used during the survey. The 36-ft *R/V Brendan D II* was used prior to July 1 and during late September in areas without significant navigation hazards (Fig. 2). An aluminum work skiff was used during July and August in the hazardous areas (Fig. 3). The 32-ft *R/V Shani II* served as a living platform and office during the skiff survey. We did not survey the sites in consecutive order around the county. Instead, the vessel(s) used and the units sampled on a given day were determined by considering a number of factors: eelgrass presence (from the ShoreZone survey), wind, currents, tide height, and navigation hazards. The table at the end of this appendix lists the sites visited each sampling day.

Prior to June 1, we selected only those units for which the DNR ShoreZone survey indicated eelgrass presence. On windy days, we selected units on lee shores. Currents at some sites and times were too strong to safely and effectively deploy the underwater camera. Sampling at those sites was postponed until slack water. For fringe sites, tide height was generally not a factor because we were only surveying the deepwater edge of the eelgrass beds, and most eelgrass extended well below mean lower low water (MLLW; the vertical datum used throughout this report). But for flats sites, surveying was only conducted during times when tide height was above +5 ft so we could survey the shallow water edge of the eelgrass beds. Sites with dangerous navigation hazards (e.g., rocks, shoals) were surveyed in July and August with the aluminum work skiff.

The San Juan County eelgrass inventory was conducted using underwater videographic and acoustic methods consistent with those used by the DNR SVMP (Berry et al. 2003). Instead of collecting water quality data at every site, we only collected these data once each day between 1000 and 1400. These data included temperature, salinity, dissolved oxygen, pH, and photosynthetically available radiation (PAR). The following subsections describe the eelgrass sampling design within the two types of sites.

Flats Sites

There are 18 flats sites in San Juan County (Fig. 4), of which we surveyed 15. We did not survey Picnic Cove, Hunter Bay, and Swifts Bay because they were sampled by the DNR SVMP in 2002 or 2003. We surveyed Prevost Harbor, Nelson Bay, Westcott Bay, Garrison Bay, Mitchell Bay, False Bay, Fisherman's Bay, Barlow Bay, Mud Bay, Shoal Bay, Blind Bay, Squaw Bay, Thatcher Bay, Shallow Bay, and Fossil Bay. At the request of Friends of the San Juans, we also surveyed the following sites as though they were flats sites: Open Bay, Reid Harbor, Salmon Bank, and East Sound.

At each of these sites we used straight-line underwater videographic transects in a grid pattern systematically placed throughout the site. We also used zig-zag and meandering transects to help delineate the edges of any eelgrass beds. During data analysis, only the straight-line transects were used to estimate parameters.

In cases where we were confident that the hydroacoustic system could accurately identify eelgrass, we did not use the underwater camera. Prevost Harbor, False Bay, and Shallow Bay were surveyed with the skiff, and thus we only used the hydroacoustic system to identify eelgrass at those sites. Table 2 summarizes the flats sites surveyed.

Figure 2. *R/V Brendan D II* used during April, May, June, and September.

Figure 3. Aluminum work skiff used during July and August.

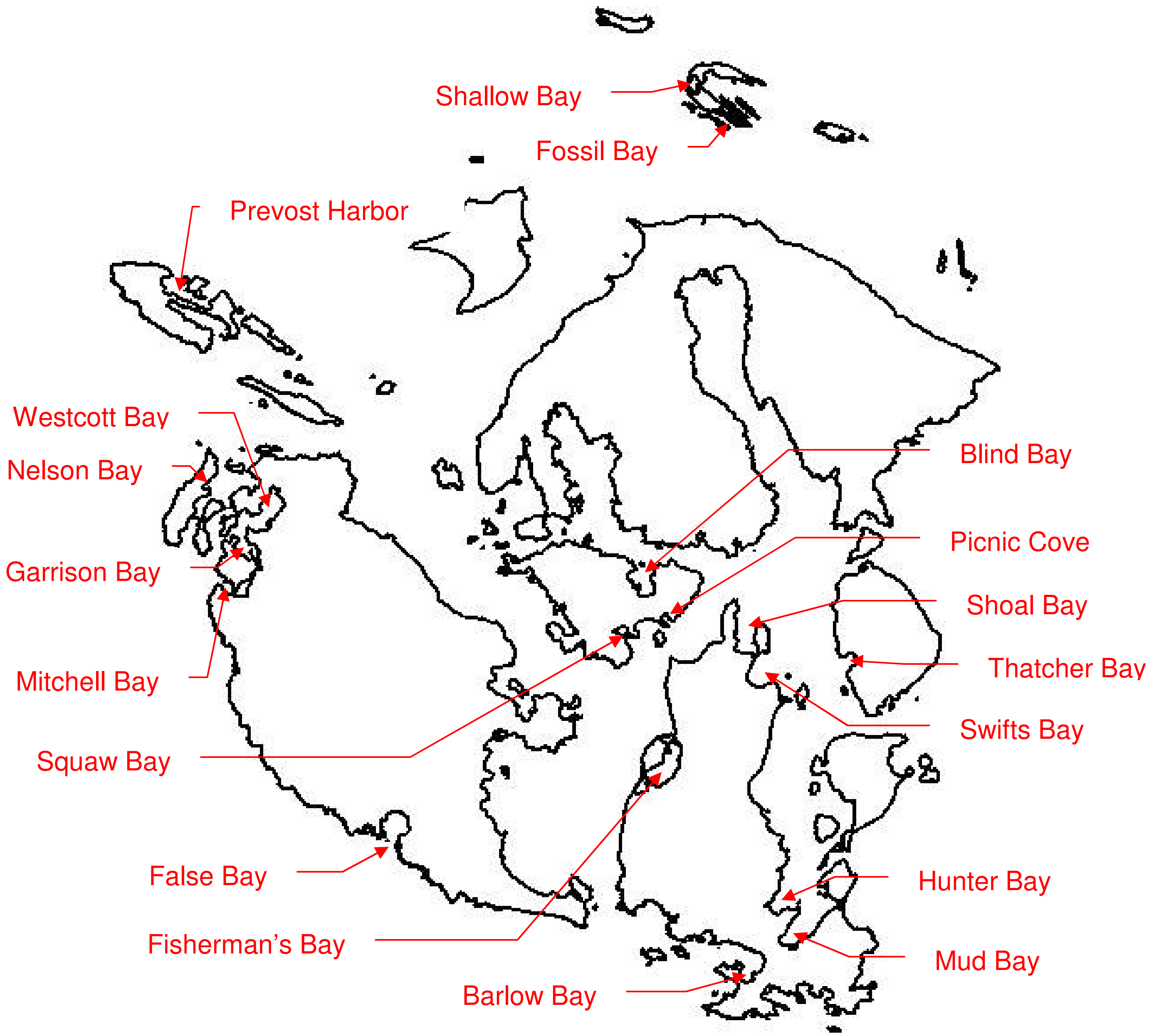

Figure 4. Washington State Department of Natural Resources Submerged Vegetation Monitoring Project flats sites.

Table 1. Summary of San Juan County flats sites sampled during May through September 2003.

Date	Flats ID	Name	Primary Survey Type
5/7/03	67	Fossil Bay	Underwater videographic
5/21/03	53	Westcott Bay	Underwater videographic
5/22/03	54	Garrison Bay	Underwater videographic
5/27/03	59	Mud Bay	Underwater videographic
5/28/03	55	Mitchell Bay	Underwater videographic
5/28/03	52	Nelson Bay	Underwater videographic
5/29/03	63	Blind Bay	Underwater videographic
5/30/03	61	Shoal Bay	Underwater videographic
6/6/03	65	Thatcher Bay	Underwater videographic
6/12/03	57	Fisherman's Bay	Underwater videographic
6/13/03	58	Barlow Bay	Underwater videographic
8/15/03	51	Prevost Harbor	Hydroacoustic
8/17/03	56	False Bay	Hydroacoustic
8/23/03	66	Shallow Bay	Hydroacoustic

Fringe Sites

There are 516 fringe sites in San Juan County, of which 12 were surveyed by the DNR SVMP during 2000-2003 (Fig. 2). We did not survey those sites. There were eight sites that were extremely short (<50 m long), and we did not survey these sites independently. Instead, we included them with adjacent sites (Table 9). We also did not survey five sites that we felt were unlikely to have any eelgrass and which are located within the National Wildlife Refuge system: three sites around Peapod Rocks (sjs0515, sjs0516, sjs0517) and two sites around Colville Island (sjs0742, sjs0743).

Table 2. San Juan County fringe sites that were too short to sample independently.

ID	Name
sjs0298	Sucia Island
sjs0505	Ripple Island
sjs0512	Flattop Island
sjs0563	Cliff Island
sjs0681	Willow Island
sjs0688	Turn Island
sjs0694	James Island
sjs0741	Long Island

In most cases we used a single zig-zag transect along the entire site. To effectively sample small pocket beaches, we also used straightline transects perpendicular to the shoreline. Occasionally, we used meandering transects to survey areas around obstructions, such as docks or rocks.

At sites with extremely low eelgrass probability (due to steep cliffs, rocks, or kelp) we did not use the underwater camera. Instead, we used only the BioSonics echosounder to look for eelgrass. If the echosounder signal was difficult to interpret, we passed over the area a second time with the underwater camera deployed to validate our interpretation of the signal.

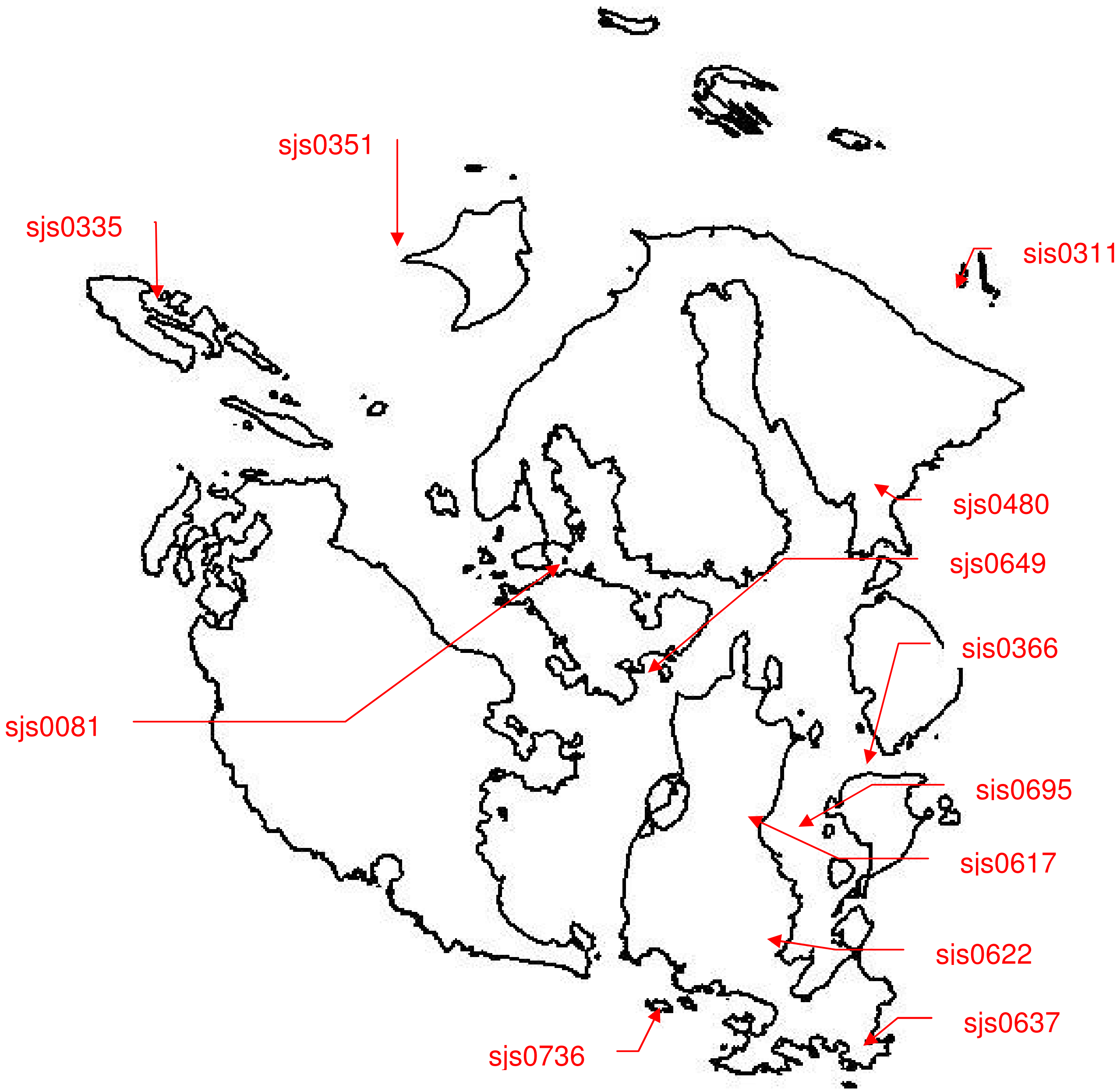

Figure 5. Fringe sites not surveyed because they were surveyed by the DNR SVMP during 2000 – 2003.

Brendan D II *Survey Methods*

Equipment

Table 4 lists the survey equipment used onboard the *R/V Brendan D II*. Position data were acquired using a Trimble Ag132 DGPS processor with the antenna located at the tip of the cargo boom used to deploy the camera. Differential corrections were received from the United States Coast Guard public DGPS network using the NAD 83 datum. Portable transducers mounted on both the starboard and port sides near the transom collected depth below transducer and bottom discrimination data. The American Pioneer and Garmin transducers were located on the starboard side and the BioSonics transducer was located on the port side. Underwater video images were obtained 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. A 500 watt underwater light provided illumination when needed. The towfish was deployed directly off the stern of the vessel using the cargo boom and boom winch. 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 laptop computer equipped with a video overlay controller and data logger software integrated DGPS data (date, time, latitude, longitude), user supplied transect information (transect number and site code), and the video signal. Video images were stored directly onto two VHS videotapes using two four head video cassette recorders and onto a Sony Digital8 videotape using a Sony DVR-TRV310 camcorder. Date, time, position, and transect information also were stored on a floppy disk at 1 s intervals. Television 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.

A real-time plotting system used a multiplexer to integrate National Marine Electronic Association 0132 standard sentences produced by the DPGS, the Garmin and American Pioneer depth sounders, and a user-controlled toggle switch to indicate eelgrass presence/absence. These data streams were forwarded to a laptop personal computer running a spreadsheet program with macro and plotting capabilities (Microsoft Excel 7.0). A red cursor plotted the current position of the vessel. When the UV camera was down and observing the seabed, a thin black line on the plotter traced the camera's position. As the vessel moved along the track line, the chief scientist watched the TV monitor and clicked the eelgrass toggle switch on or off each time eelgrass appeared or disappeared from view. When the eelgrass toggle was on, the track line pattern changed to a thick green line and the eelgrass positions were stored on a separate worksheet. The result was a real-time plot of the area sampled and where eelgrass was observed.

Table 3. Survey equipment used onboard the *R/V Brendan D II* during this survey.

Item	Manufacturer/Model
Differential GPS	Trimble AgGPS 132 (sub-meter accuracy)
Depth Sounders	Garmin Fishfinder 240 (200 KHz transducer) American Pioneer Fishscope V (160 KHz transducers) BioSonics 2400 T system with Submerged Aquatic Vegetation software
Sea Surface Temperature	Garmin Fishfinder 240 (w/temperature sensor)
Underwater Camera	Deep Sea Power & Light SeaCam 2000
Lasers	Deep Sea Power & Light
Underwater Light	Deep Sea Power & Light RiteLite (500 watt)
Real-time Plotting Computer	Sony VAIO
Data Backup System	Sony CD-ROM
Color Printer	Hewlett-Packard HP DeskJet 842C
Video Overlay Computer	Toshiba 1200 Laptop
Video Overlay Controller	Discovery Bay Software
VCR#1 (master tapes)	General Electric VG4043 VHS 4-Head
VCR#2 (backup tapes)	Zenith TV/VCR Combo 4-Head
Digital VideoTape Recorder	Sony DVC310 Digital8 Camcorder

Vessel Operations

For flats sites, at the start of each straight-line transect, the vessel was backed close to the shoreline or dock and the camera was lowered to just above the bottom. Visual references were noted and the VCRs 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 (less than 1 m/sec). At the end of the transect, the VCRs were stopped, the camera was retrieved, and the vessel was moved to the next transect position. For meandering transects, the vessel was controlled from the aft control station. Once the camera was deployed, the vessel was maneuvered as close as possible to physical barriers, such as moored vessels, mooring lines, pilings, and piers.

For fringe sites we generally used a single zig-zag transects running the full length of the site (Fig. 6). Sites with extremely low eelgrass probability usually had navigation hazards, especially rocks. For these sites we used only the BioSonics hydroacoustic system and placed the deckhand on the bow as a lookout as we traveled as close as possible to the rocky shoreline. If the helmsman observed possible eelgrass on the BioSonics display, we cruised over the suspect area a second time with the underwater video camera deployed.

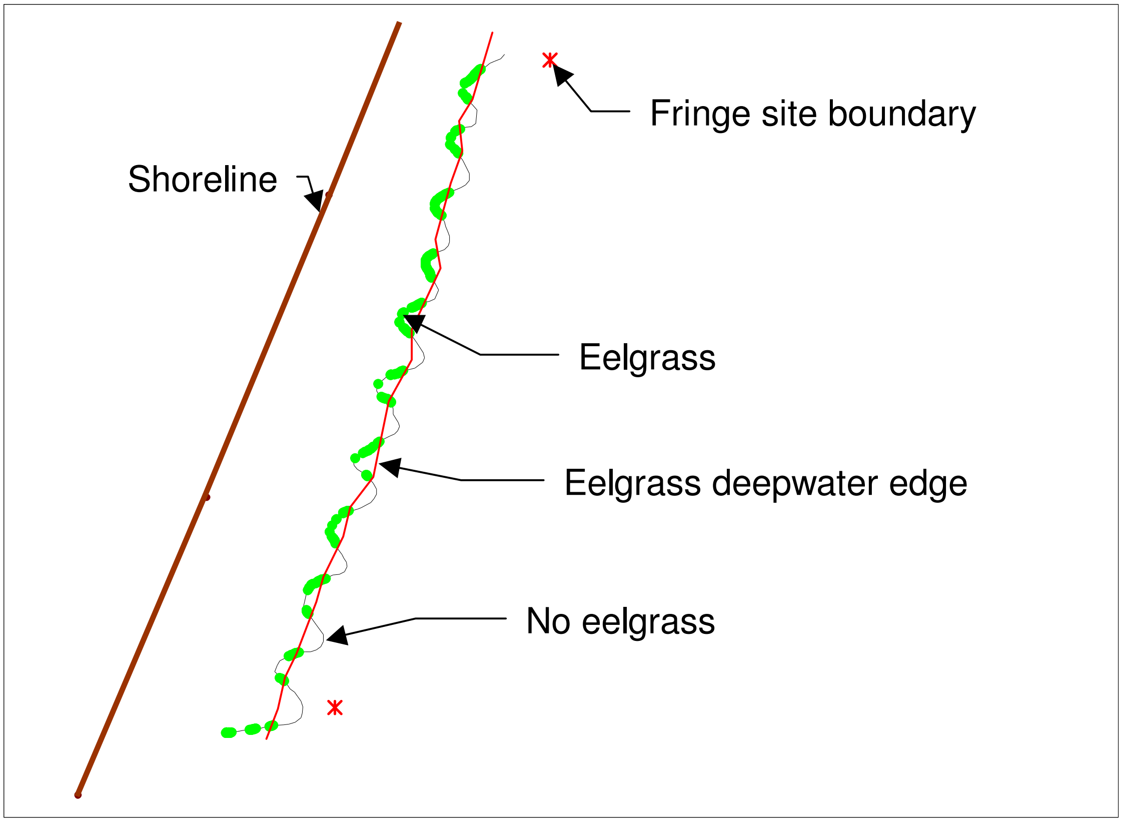

Figure 6. Sample zig-zag transect (site sjs0616).

Skiff Survey Methods

Equipment

Table 5 lists the equipment used on the aluminum work skiff. The skiff was a double ended flat bottom "bartender" design with a 40 horsepower outboard engine mounted in a well near the stern. The DGPS antenna was attached to the top of the davit used to deploy the underwater camera. An electric pot hauler with a 1.5 in spacer between the hauling sheaves served as a winch for lowering and retrieving the underwater camera. The SplashCam was attached to a small weighted towfish. The BioSonics transducer was mounted on a pole directly beneath the DGPS antenna. The video monitor and VCR were housed in a plywood box just aft of the steering station and forward of the engine. A towel with viewing cutout was placed over the front of the box. The real-time computer was placed on top of the plywood box and covered with a smaller removable plywood box. The BioSonics surface unit and computer were placed under the dash.

Vessel Operations

Vessel operations in the skiff were similar to those in the *Brendan D II*. The main difference is that the BioSonics system was used as the primary eelgrass identification tool. Whenever there was uncertainty, we lowered the SplashCam to validate eelgrass presence/absence.

Table 4. Survey equipment used onboard the aluminum work skiff during this survey.

Item	Manufacturer/Model
Differential GPS	Trimble AgGPS 132 (sub-meter accuracy)
Depth Sounders	BioSonics 2400 T system with Submerged Aquatic Vegetation software
Underwater Camera	SplashCam (Ocean Engineering)
Real-time Plotting Computer	MarsPal
Video Overlay Controller	Ocean Engineering
VCR	General Electric VG4043 VHS 4-Head

Data Post-Processing

Underwater Video

Data stored on floppy disks 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. Qualitative notes were made regarding the presence of other biota for each track. The resulting data were plotted in AutoCAD along with the shoreline and approximate structure locations. For flats sites, polygons were drawn around eelgrass observations to define the eelgrass bed outlines. For fringe sites, a single line was drawn connecting the deepwater edge observations.

Hydroacoustic Data

The Biosonics 2400 T 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 each track. During post-processing, individual track files are combined into larger files and processed through EcoSAV software. The output is a text file with time, depth, and position data. These data are then merged with the tide correction data (see sub-section below) to give corrected depths.

On tracks used for estimating mean maximum eelgrass depth, the echosounder display for the track is replayed using the BioSonics Visual Analyzer program. At this point the operator has two displays of the seabed—the underwater video data and the echosounder data. Both pieces of information are used to determine which ping (and associated time stamp) in the echosounder recording represents the eelgrass maximum depth for a given track (or for a given zig or zag section of a track). The corrected depth for this time stamp is then read from the corrected depth file.

Tide Heights

Raw depths collected from the BioSonics echosounder measure the distance between the seabed and the transducer. To correct these depths to the 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 daily and immediately after taking on fuel. 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. When the survey site was located between tide prediction stations, the used the average of nearby prediction stations. Port Townsend (station ID 0995; 48 06.90 N 122 45.00 W) is the reference station for all San Juan county tide prediction stations. 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://www.co-ops.nos.noaa.gov/data_res.html**).

Data Analysis

We estimated the total basal area coverage of eelgrass at each flats site using methods described in Norris et al. (1997). 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 (ft) of transect *i* passing through the polygon and a_i = length (ft) 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 feet covered by eelgrass ($\hat{E}$) is given by:

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

where *A* is the area of the eelgrass polygons.

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

Maximum and minimum eelgrass depths refer to the shallow- and deep-water 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 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 average of these collections of maximum and minimum depth measurements.

Water Quality Parameters

Water quality profiles were taken between 10:00 am and 2:00 pm on most days, usually while anchored for lunch. The exact time was determined by the chief scientist. If eelgrass was observed at the site, the profile was taken near the central deep-water edge of the eelgrass. If the depth was 3 m or less, measurements were taken every 0.5 m; if the depth was greater than 3 m, measurements were taken every 1.0 m. If no eelgrass was observed at the site, the water quality data were taken near the center of the site at a depth of approximately -20 ft MLLW. All measurements were taken with a HydroLab Data Sonde IV.

References

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Acknowledgements

We wish to thank the following people who assisted in making this project a success: Stephanie Buffum-Field (Friends of the San Juans); Jim Slocomb (San Juan County Marine Resource Committee); Sandy Wyllie-Echeveria (University of Washington); Brian Williams (Washington State Department of Fish and Wildlife); Brad Jensen and Lou Schwartz (Sound Vessels, Inc.); Amy Sewell, Helen Berry, Blain Reeves (Washington State Department of Natural Resources); Pema Kitaeff,, Cinamon Moffett, and Meredith Barrett (Marine Resources Consultants).

TABLE 5.

List of sites visited each sampling day.

Dates	ID	Name
4/30	**598**	Lopez Island
4/30	**599**	Lopez Island
4/30	**600**	Lopez Island
4/30	**610**	Lopez Island, Spencer Spit north side
4/30	**614**	Lopez Island, Spencer Spit south side
4/30	**615**	Lopez Island
4/30	**616**	Lopez Island
5/1	**127**	San Juan Island, 4th of July Beach
5/1	**589**	Lopez Island
5/1	**590**	Lopez Island
5/1	**591**	Lopez Island
5/1	**592**	Lopez Island, Fishermans Bay
5/1	**593**	Lopez Island, Fishermans Bay
5/1	**594**	Lopez Island, Fishermans Bay
5/1	**595**	Lopez Island
5/1	**596**	Lopez Island
5/1	**597**	Lopez Island
5/2	**84**	Shaw Island, north side
5/2	**85**	Shaw Island, north side
5/2	**86**	Shaw Island, Neck Point
5/2	**87**	Shaw Island, Neck Point
5/2	**88**	Shaw Island, Tift Rocks
5/2	**89**	Shaw Island, west side
5/2	**90**	Shaw Island, Post Office Bay
5/2	**91**	Shaw Island, Parks Bay
5/2	**92**	Shaw Island, Parks Bay
5/2	**93**	Shaw Island, Point George
5/5	**69**	Shaw Island, Indian Cove
5/5	**71**	Shaw Island, west side
5/5	**72**	Shaw Island, west side
5/5	**73**	Shaw Island, Hankin Point
5/5	**75**	Shaw Island, Hudson Bay
5/5	**79**	Shaw Island, north side
5/6	**357**	Waldron Island, east side
5/6	**358**	Waldron Island, Mail Bay
5/6	**448**	Orcas Island
5/6	**449**	Orcas Island, West Beach
5/6	**450**	Orcas Island

Dates	ID	Name
5/6	**451**	Orcas Island, Freeman Island
5/6	**452**	Orcas Island
5/6	**453**	Orcas Island
5/6	**454**	Orcas Island, Point Doughty
5/6	**455**	Orcas Island
5/6	**456**	Orcas Island
5/6	**457**	Orcas Island, airport
5/7	**348**	Waldron Island, Cowlitz Bay
5/7	**349**	Waldron Island, Cowlitz Bay
5/7	**350**	Waldron Island, Sandy Point
5/7	**352**	Waldron Island, North Bay
5/7	**353**	Waldron Island, Fishery Point
5/7	**354**	Waldron Island, north side
5/7	**355**	Waldron Island, north side
5/7	**356**	Waldron Island, Hammond Point
5/8	**103**	Decatur Island, Reeds Bay
5/8	**104**	Decatur Island, west side
5/8	**114**	Decatur Island, Decatur Head
5/8	**115**	Decatur Island, White Cliff
5/8	**116**	Decatur Island, se side
5/8	**117**	Decatur Island, se side
5/8	**370**	Blakely Island
5/8	**371**	Blakely Island
5/8	**372**	Blakely Island
5/19	**128**	San Juan Island, Griffin Bay
5/19	**129**	San Juan Island, Griffin Bay
5/19	**130**	San Juan Island, Griffin Bay
5/19	**131**	San Juan Island, Low Point
5/19	**132**	San Juan Island, Mulno Cove
5/19	**133**	San Juan Island, Merrifield Cove
5/19	**136**	San Juan Island, North Bay
5/19	**137**	San Juan Island, Argyle Lagoon
5/20	**169**	San Juan Island, Pearl Island
5/20	**170**	San Juan Island, Pearl Island
5/20	**171**	San Juan Island, Pearl Island
5/20	**172**	San Juan Island, Roche Harbor
5/20	**173**	San Juan Island, Roche Harbor
5/20	**174**	San Juan Island, Bazalgette Point

Dates	ID	Name
5/20	**175**	San Juan Island, White Point
5/20	**176**	San Juan Island, White Point
5/20	**179**	San Juan Island, Delacombe Point
5/20	**1308**	Henry Island, north side
5/20	**1309**	Henry Island, north side
5/20	**1311**	Henry Island, Mosquito Pass
5/20	**1312**	Henry Island, Mosquito Pass
5/20	**1313**	Henry Island, Mosquito Pass
5/21	**318**	Stuart Island, Reid Harbor
5/21	**341**	Stuart Island, Reid Harbor
5/21	**497**	Johns Island
5/21	**498**	Johns Island
5/21	**499**	Johns Island
5/22	**414**	Orcas Island
5/22	**428**	Orcas Island
5/22	**433**	Orcas Island
5/22	**434**	Orcas Island
5/22	**435**	Orcas Island
5/23	**122**	San Juan Island, Cattle Point
5/23	**123**	San Juan Island, Goose Island
5/23	**143**	San Juan Island, Pear Pt. Peninsula
5/23	**147**	San Juan Island, Friday Harbor
5/23	**583**	Lopez Island
5/23	**587**	Lopez Island
5/23	**588**	Lopez Island
5/26	**402**	Orcas Island
5/26	**403**	Orcas Island
5/26	**418**	Orcas Island
5/26	**419**	Orcas Island
5/29	**376**	Orcas Island
5/29	**379**	Orcas Island, Buck Bay
5/30	**389**	Orcas Island
5/30	**390**	Orcas Island
5/30	**391**	Orcas Island, Ship Bay
5/30	**392**	Orcas Island, Madrona Point
6/2	**486**	Blakely Island
6/2	**487**	Blakely Island
6/2	**488**	Blakely Island
6/2	**489**	Blakely Island
6/2	**490**	Blakely Island
6/2	**491**	Blakely Island
6/2	**492**	Blakely Island
6/2	**493**	Blakely Island
6/2	**601**	Lopez Island
6/2	**602**	Lopez Island, Upright Head

Dates	ID	Name
6/2	**685**	Blakely Island, Pointer Island
6/3	**344**	Waldron Island, south side
6/3	**345**	Waldron Island, Point Disney
6/3	**346**	Waldron Island, Cowlitz Bay
6/3	**347**	Waldron Island, Cowlitz Bay
6/3	**359**	Waldron Island, south side
6/3	**360**	Waldron Island, south side
6/3	**361**	Waldron Island, south side
6/3	**362**	Waldron Island, south side
6/3	**442**	Orcas Island
6/3	**443**	Orcas Island
6/3	**444**	Orcas Island
6/3	**445**	Orcas Island
6/3	**446**	Orcas Island
6/3	**447**	Orcas Island
6/4	**80**	Shaw Island, north side
6/4	**82**	Shaw Island, north side
6/4	**83**	Shaw Island, north side
6/4	**431**	Orcas Island
6/4	**432**	Orcas Island
6/4	**436**	Orcas Island
6/4	**437**	Orcas Island, Steep Point
6/4	**555**	Wasp Islands, Crane Island
6/4	**556**	Wasp Islands, Crane Island
6/4	**557**	Wasp Islands, Crane Island
6/4	**558**	Wasp Islands, Crane Island
6/5	**66**	Shaw Island, se side
6/5	**67**	Shaw Island, se side
6/5	**94**	Shaw Island, Point George
6/5	**95**	Shaw Island, Hicks Bay
6/5	**96**	Shaw Island, Hicks Bay
6/5	**97**	Shaw Island, Hoffman Bay
6/5	**151**	San Juan Island, Point Caution
6/5	**152**	San Juan Island, Point Caution
6/5	**153**	San Juan Island, SJ Channel
6/5	**154**	San Juan Island, SJ Channel
6/5	**155**	San Juan Island, SJ Channel
6/5	**367**	Blakely Island
6/5	**369**	Blakely Island
6/6	**112**	Decatur Island, ne side
6/6	**113**	Decatur Island, Decatur Head
6/6	**363**	Blakely Island
5/8 & 6/6	**364**	Blakely Island, Armigage Island
6/6	**366**	Blakely Island

Dates	ID	Name
6/8	**634**	Lopez Island, Telegraph Bay
6/9	**106**	Decatur Island, Sylvan Cove
6/9	**107**	Decatur Island, north side
6/9	**108**	Decatur Island, north side
6/9	**109**	Decatur Island, north side
6/9	**110**	Decatur Island, north side
6/9	**111**	Decatur Island, Fauntleroy Point
6/9	**695**	Decatur Island, Trump Island
6/9	**696**	Decatur Island, Trump Island
6/10	**121**	San Juan Island, Cattle Point
6/10	**203**	San Juan Island, Eagle Cove
6/10	**204**	San Juan Island, west side
6/10	**205**	San Juan Island, west side
6/10	**206**	San Juan Island, South Beach
6/10	**207**	San Juan Island, South Beach
6/10	**643**	Lopez Island, Aleck Bay
6/10	**644**	Lopez Island, Aleck Bay
6/11	**459**	Orcas Island, Thompson Point
6/11	**460**	Orcas Island, Thompson Point
6/11	**461**	Orcas Island
6/11	**462**	Orcas Island
6/11	**463**	Orcas Island, Racoon Point
6/11	**464**	Orcas Island
6/11	**465**	Orcas Island
6/11	**466**	Orcas Island
6/11	**467**	Orcas Island
6/11	**468**	Orcas Island
6/11	**469**	Orcas Island
6/11	**470**	Orcas Island
6/11	**471**	Orcas Island
6/11	**472**	Orcas Island, Lawrence Point
6/11	**473**	Orcas Island
6/12	**156**	San Juan Island, SJ Channel
6/12	**440**	Orcas Island
6/17	**157**	San Juan Island, SJ Channel
6/17	**158**	San Juan Island, SJ Channel
6/17	**159**	San Juan Island, SJ Channel
6/17	**160**	San Juan Island, Rocky Bay
6/17	**161**	San Juan Island, Rocky Bay
6/17	**162**	San Juan Island, Rocky Bay
6/17	**163**	San Juan Island, SJ Channel
6/17	**164**	San Juan Island, Limestone Point
6/17	**165**	San Juan Island, north side
6/17	**166**	San Juan Island, north side
6/17	**167**	San Juan Island, Davison Head

Dates	ID	Name
6/17	**168**	San Juan Island, Davison Head
6/18	**393**	Orcas Island
6/18	**394**	Orcas Island
6/18	**395**	Orcas Island
6/18	**396**	Orcas Island
6/18	**397**	Orcas Island
6/18	**398**	Orcas Island
6/18	**399**	Orcas Island
6/18	**400**	Orcas Island
6/18	**401**	Orcas Island
6/18	**404**	Orcas Island, Twin Rocks SP
6/18	**405**	Orcas Island
6/18	**406**	Orcas Island
6/18	**407**	Orcas Island
6/19	**74**	Shaw Island, NW side
6/19	**378**	Orcas Island
6/19	**380**	Orcas Island, Olga
6/19	**381**	Orcas Island
6/19	**382**	Orcas Island
6/19	**383**	Orcas Island
6/19	**384**	Orcas Island
6/19	**385**	Orcas Island, Rosario Point
6/19	**386**	Orcas Island
6/19	**387**	Orcas Island
6/19	**388**	Orcas Island
6/23	**319**	Stuart Island, Reid Harbor
6/23	**320**	Stuart Island, Reid Harbor
6/23	**321**	Stuart Island
6/23	**322**	Stuart Island
6/23	**323**	Stuart Island
6/23	**324**	Stuart Island
6/23	**325**	Stuart Island
6/23	**326**	Stuart Island
6/23	**327**	Stuart Island, Turn Point
6/23	**328**	Stuart Island
6/23	**329**	Stuart Island
6/23	**330**	Stuart Island, Charles Point
6/23	**342**	Stuart Island, Reid Harbor
6/23	**343**	Stuart Island, Reid Harbor
6/24	**180**	San Juan Island, Hanbury Point
6/24	**182**	San Juan Island, Smugglers Cove
6/24	**183**	San Juan Island, west side
6/24	**184**	San Juan Island, Andrews Bay
6/24	**185**	San Juan Island, Smallpox Bay
6/24	**186**	San Juan Island, west side

Dates	ID	Name
6/24	**1300**	Henry Island, Open Bay
6/24	**1301**	Henry Island, Open Bay
6/24	**1302**	Henry Island, Kellett Bluff
6/24	**1303**	Henry Island, Kellett Bluff
6/24	**1304**	Henry Island, west side
6/24	**1305**	Henry Island, west side
6/24	**1306**	Henry Island, west side
6/24	**1307**	Henry Island, McCracken Point
6/25	**438**	Orcas Island
6/12 & 6/25	**439**	Orcas Island
6/4 & 6/25	**441**	Orcas Island
6/25	**501**	Johns Island
6/25	**502**	Johns Island
6/25	**510**	Flattop Island
6/25	**513**	Speiden Island, Sentinal Island
6/25	**514**	Speiden Island, Sentinal Island
6/25	**524**	Speiden Island
6/25	**525**	Speiden Island
6/25	**526**	Speiden Island
6/25	**527**	Speiden Island
6/25	**528**	Speiden Island
6/25	**529**	Speiden Island
6/25	**530**	Speiden Island
6/25	**531**	Speiden Island
6/25	**532**	Speiden Island
6/25	**533**	Speiden Island
6/25	**534**	Speiden Island
6/26	**474**	Orcas Island
6/26	**475**	Orcas Island, Doe Bay
6/26	**476**	Orcas Island
6/26	**477**	Orcas Island, Doe Bay
6/26	**478**	Orcas Island, Doe Island
6/26	**479**	Orcas Island
6/26	**481**	Orcas Island
6/26	**482**	Orcas Island
6/26	**483**	Orcas Island
6/27	**269**	Patos Island
6/27	**270**	Patos Island
6/27	**271**	Patos Island
6/27	**272**	Patos Island
6/27	**273**	Patos Island
6/27	**274**	Patos Island
6/27	**275**	Patos Island
6/27	**299**	Matia Island

Dates	ID	Name
6/27	**300**	Matia Island
6/27	**301**	Matia Island
6/27	**302**	Matia Island
6/27	**303**	Matia Island
6/27	**304**	Matia Island
6/27	**305**	Shipjack Island
6/27	**306**	Shipjack Island
6/28	**118**	Decatur Island, se side
6/28	**120**	San Juan Island, South Beach
6/28	**629**	Lopez Island, Lopez Pass
6/28	**630**	Lopez Island, Lopez Pass
6/28	**631**	Lopez Island, Shoal Bight N
6/28	**632**	Lopez Island, Shoal Bight S
6/28	**633**	Lopez Island, Cape St.Mary
7/25	**101**	Decatur Island, Center Island
7/25	**102**	Decatur Island, Center Island
7/26	**105**	Decatur Island, Brigantine Bay
7/27	**571**	Lopez Island
7/27	**638**	Lopez Island, Point Colville
7/27	**639**	Lopez Island, Blind Island
7/27	**640**	Lopez Island, McArdle Bay
7/27	**641**	Lopez Island, Hughes Bay
7/27	**642**	Lopez Island, Hughes Bay
7/27	**645**	Lopez Island, Aleck Bay
7/27	**646**	Lopez Island
7/27	**647**	Lopez Island, Flint Beach
7/27	**648**	Lopez Island
7/28	**572**	Lopez Island, Iceberg Point
7/28	**573**	Lopez Island
7/28	**574**	Lopez Island
7/28	**575**	Lopez Island, Johns Point
7/28	**576**	Lopez Island
7/28	**578**	Lopez Island
7/28	**579**	Lopez Island
7/28	**580**	Lopez Island
7/31	**618**	Lopez Island
7/31	**619**	Lopez Island, Small Island
7/31	**620**	Lopez Island
7/31	**621**	Lopez Island
8/1	**100**	Decatur Island, Center Island
8/1	**119**	Decatur Island, south tip
7/31 & 8/1	**627**	Lopez Island, Skull Island
8/1	**628**	Lopez Island
8/3	**149**	San Juan Island, Port of FH

Dates	ID	Name
8/3	**150**	San Juan Island, FH labs
8/6	**422**	Orcas Island
8/6	**423**	Orcas Island
8/6	**424**	Orcas Island
8/6	**425**	Orcas Island
8/6	**426**	Orcas Island
8/6	**427**	Orcas Island
8/6	**544**	Wasp Islands, Reef Island
8/6	**545**	Wasp Islands, Reef Island
8/6	**552**	Wasp Islands, McConnell Island
8/6	**553**	Wasp Islands, McConnell Island
8/6	**554**	Wasp Islands, McConnell Island
8/7	**144**	San Juan Island, Turn Point
8/7	**145**	San Juan Island, Turn Point
8/7	**146**	San Juan Island, Friday Harbor
8/7	**148**	San Juan Island, Friday Harbor
8/7	**543**	Jones Island
8/7	**560**	Wasp Islands, Yellow Island
8/7	**561**	Wasp Islands, Yellow Island
8/7	**562**	Wasp Islands, Cliff Island
8/7	**682**	Brown Island
8/7	**684**	Brown Island
8/8	**195**	San Juan Island, west side
8/8	**196**	San Juan Island, Pile Point
8/8	**197**	San Juan Island, Kanaka Bay
8/8	**199**	San Juan Island, west side
8/8	**200**	San Juan Island, west side
8/8	**201**	San Juan Island, west side
8/8	**202**	San Juan Island, Eagle Point
8/11	**134**	San Juan Island, Griffin Bay
8/11	**135**	San Juan Island, Dinner Island
8/11	**140**	San Juan Island, Pear Point
8/11	**141**	San Juan Island, Danger Rock
8/11	**142**	San Juan Island, Reef Point
8/11	**686**	San Juan Island, Turn Island
8/11	**687**	San Juan Island, Turn Island
8/14	**331**	Stuart Island
8/14	**333**	Stuart Island, Satellite Island
8/14	**334**	Stuart Island, Satellite Island
8/15	**337**	Stuart Island
8/15	**338**	Stuart Island
8/15	**339**	Stuart Island
8/15	**340**	Stuart Island, Gossip Island
8/15	**500**	Johns Island
8/15	**503**	Johns Island

Dates	ID	Name
8/15	**504**	Johns Island, Ripple Island
8/15	**506**	Cactus Islands
8/15	**507**	Cactus Islands
8/15	**508**	Cactus Islands
8/15	**509**	Cactus Islands
8/15	**511**	Flattop Island
8/17	**191**	San Juan Island, west side
8/17	**192**	San Juan Island, west side
8/17	**193**	San Juan Island, west side
8/17	**194**	San Juan Island, west side
8/19	**124**	San Juan Island, Cape San Juan
8/19	**125**	San Juan Island, Cape San Juan
8/19	**126**	San Juan Island, Fish Creek
8/19	**187**	San Juan Island, Bellevue Point
8/19	**188**	San Juan Island, west side
8/19	**189**	San Juan Island, Deadman Bay
8/19	**190**	San Juan Island, west side
8/19	**1314**	Henry Island, Mosquito Pass
8/20	**98**	Decatur Island, Rim islands
8/20	**99**	Decatur Island, Reeds Bay
8/20	**581**	Lopez Island
8/20	**582**	Lopez Island
8/20	**584**	Lopez Island
8/20	**585**	Lopez Island, Deadman Island
8/20	**586**	Lopez Island
8/20	**697**	Decatur Island, Ram Island
8/20	**698**	Decatur Island, Ram Island
8/20	**735**	Charles Island, north side
8/20	**737**	Charles Island, west side
8/20	**738**	Lopez Island, Long Island
8/20	**739**	Lopez Island, Long Island
8/20	**740**	Lopez Island, Long Island
8/21	**373**	Blakely Island, Peavine Pass
8/21	**374**	Blakely Island, Obstruction Island
8/21	**375**	Blakely Island, Obstruction Island
8/21	**377**	Orcas Island
8/21	**408**	Orcas Island
8/21	**410**	Orcas Island
8/21	**484**	Blakely Island, Obstruction Island
8/21	**485**	Blakely Island, Obstruction Island
8/22	**307**	Clark Island
8/22	**308**	Clark Island
8/22	**309**	Clark Island
8/22	**310**	Clark Island
8/22	**312**	Clark Island

Dates	ID	Name
8/22	**313**	Clark Island
8/22	**314**	Clark Island
8/22	**315**	Clark Island
8/22	**316**	Clark Island
8/22	**317**	Clark Island
8/22	**416**	Orcas Island, Oak Island
8/22	**559**	Wasp Islands, Crane Island
8/22	**678**	Lopez Island, Flower Island
8/22	**679**	Lopez Island, Flower Island
8/23	**276**	Sucia Island
8/23	**277**	Sucia Island
8/23	**278**	Sucia Island
8/23	**280**	Sucia Island
8/23	**281**	Sucia Island
8/23	**282**	Sucia Island
8/24	**283**	Sucia Island
8/24	**284**	Sucia Island
8/24	**285**	Sucia Island
8/24	**286**	Sucia Island
8/24	**287**	Sucia Island
8/24	**288**	Sucia Island
8/24	**289**	Sucia Island
8/24	**290**	Sucia Island
8/24	**292**	Sucia Island
8/24	**293**	Sucia Island
8/24	**294**	Sucia Island
8/24	**295**	Sucia Island
8/24	**296**	Sucia Island
8/24	**297**	Sucia Island
8/24	**458**	Orcas Island
9/22	**613**	Lopez Island, Frost Island
9/22	**680**	Blakely Island, Willow Island
9/22	**691**	James Island
9/22	**692**	James Island
9/22	**693**	James Island
9/23	**415**	Orcas Island
9/23	**417**	Orcas Island
9/23	**420**	Orcas Island, West Sound
9/23	**421**	Orcas Island
9/23	**611**	Lopez Island, Frost Island
9/23	**612**	Lopez Island, Frost Island
9/24	**409**	Orcas Island
9/24	**411**	Orcas Island
9/24	**412**	Orcas Island
9/24	**413**	Orcas Island

Dates	ID	Name
9/24	**429**	Orcas Island
9/24	**430**	Orcas Island
9/24	**539**	Jones Island
9/24	**540**	Jones Island
9/24	**541**	Jones Island
9/24	**542**	Jones Island
9/24	**606**	Lopez Island, Humphrey Head
9/24	**650**	Shaw Island, Canoe Island
9/25	**138**	San Juan Island, Pear Pt. Peninsula
9/25	**139**	San Juan Island, Pear Pt. Peninsula
9/25	**635**	Lopez Island, Watmough Bay
9/25	**636**	Lopez Island, Boulder Island