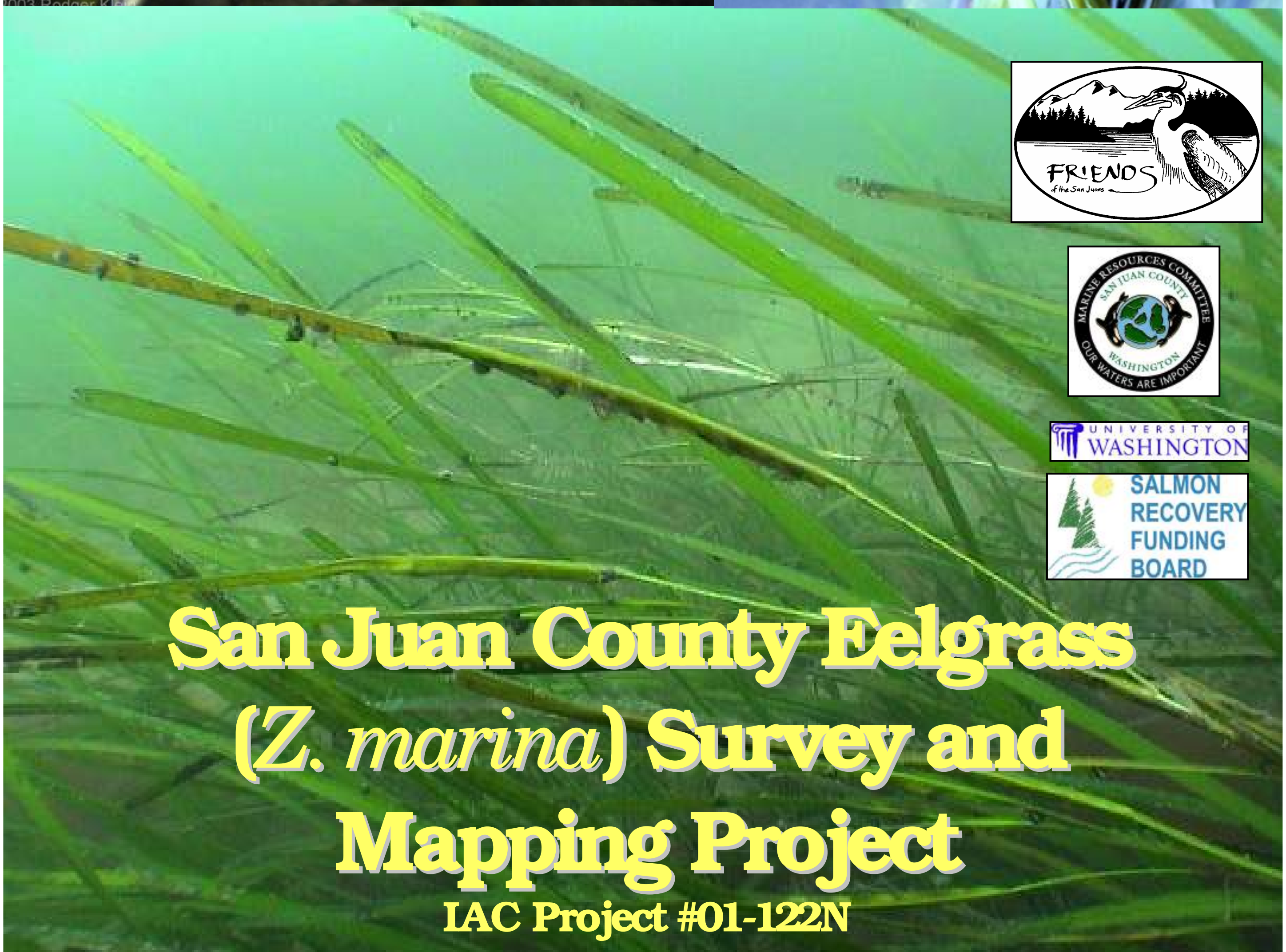
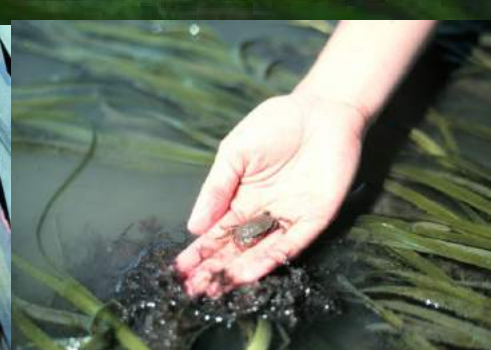


San Juan County Eelgrass (*Z. marina*) Survey and Mapping Project

IAC Project #01-122N



Final Report

San Juan County Eelgrass (*Z. marina*) Survey Mapping Project

Prepared for the Salmon Recovery Funding Board

IAC Project #01-122N

Prepared by:
FRIENDS of the San Juans

Contributing Authors:
J. Slocomb, S. Buffum-Field, S. Wyllie-Echeverria,
J. Norris, I. Fraser, and J. Cordell

PO Box 1344 Friday Harbor, WA 98250 Ph. 360-378-2319 Fax. 360-378-2324 Web site www.sanjuans.org

June 2004

This report should be cited:

FRIENDS of the San Juans, J. Slocomb, S. Buffum-Field, S. Wyllie-Echeverria, J. Norris, I. Fraser, and J. Cordell. 2004. San Juan County Eelgrass Survey Mapping Project Final Report, Friday Harbor, WA. 40 pages.

San Juan County Eelgrass (*Z. marina*) Survey and Mapping Project

EXECUTIVE SUMMARY

San Juan County, an aggregate island group in northern Washington State, has 408 miles of shoreline which provides valuable habitat for an array of marine plants and animals. The marine plant, *Zostera marina*, eelgrass, grows on submerged, soft-bottom land within the county and is protected by Washington State largely because of the many ecological services these plants provide such as spawning habitat for Pacific herring, out migrating corridors for juvenile salmon and foraging grounds for Great Blue Herons. While map products generated by the Washington State ShoreZone Inventory illustrate the presence of *Z. marina* along intertidal shorelines, the subtidal extent, in places 9 m (30 ft) deep, is not shown.

The Eelgrass Survey and Mapping Project completed comprehensive mapping of the deep water edge of eelgrass (*Z. marina*) growth in San Juan County. The entire shoreline of San Juan County was surveyed for *Z. marina* from April 30, 2003 to September 25, 2003.

This report graphically illustrates the deepwater edge of *Z. marina* growth along the entire shoreline of San Juan County because variation in this deep edge of growth can be a sensitive indicator of environmental change. These data provide a baseline against which future surveys can be compared. The format of the report is structured around a map book, sectioned to illustrate more fine scale detail. Data is overlain on two map products, USGS Quadrangles and NOAA Nautical Charts, to facilitate use by county planners, resource managers and research scientists. Following the map book are appendices that explain survey and GIS methodology and results from a pilot study designed to describe the relationship between the landscape patterns of *Z. marina* and the abundance of juvenile salmonid prey. Finally, while time series evaluation is beyond the scope of this report, using data from a parallel investigation delineating Pacific herring spawning habitat, two hotspots of *Z. marina* decline, Westcott/ Garrison Bay, San Juan Island and Blind Bay, Shaw Island, are identified and illustrated on the final two pages of the map book.

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APPENDICES

Acknowledgements

A special thank you to those who supported this project. Funders include: The Salmon Recovery Funding Board, the National Fish & Wildlife Foundation, Bullitt Foundation and the Russell Family Foundation; Volunteers of San Juan County who assisted in this project: the Laboratory of Jeffrey Cordell (UW School of Fisheries); and Lab Assistants: Terry Bidle, Letica Hopper, Tina Wyllie-Echeverria, Victoria Wyllie-Echeverria, Rebecca Wyllie-Echeverria, Tessa Wyllie-Echeverria; Daniel Penttila of Washington Department of Fish and Wildlife; Tom Mumford, Jr. of Washington State Department of Natural Resources; Joseph Gaydos of University of California, Davis SeaDoc Society.

Introduction

Project Purpose, Objective and Data Output

Habitat provided by underwater eelgrass prairies formed by clonal expansion of seagrass flora is critical for the survival of marine animals in all taxonomic groups (Duarte 2000; Kenworthy et al. in press). Seagrass loss can promote a cascading decline in nearshore biodiversity and sustainability. Damage to eelgrass prairies results from both natural and human-induced disturbance events, however direct impacts from human activities are on the rise (Short and Wyllie-Echeverria 1996; Hemminga and Duarte 2000). While seagrass restoration projects attempt to reverse ecosystem injury, the loss of ecological services during recovery can be significant. This knowledge and the fact that seagrass restoration is quite costly argues for a policy of conservation and protection (Coles and Fortes 2001; Kenworthy et al. in press). Unfortunately conservation and protection efforts are hampered by a lack of accurate baseline maps of seagrass distribution (Short and Wyllie-Echeverria 1996).

Tracking the maximum depth of seagrass growth is an essential feature in determining both the health of a coastal ecosystem and the vigor of a seagrass population (Dennison et. al. 1993; Short and Burdick 1996, Morris et. al. 2000). Changes in this metric – the lower limit of seagrass growth – can be caused by eutrophication, sedimentation or a combination of both. Eutrophication and sedimentation can be caused by watershed activities such as seepage from septic systems, excessive use of fertilizer, stormwater run-off and upstream erosion resulting from the removal of vegetation or a combination of these destructive agents (Kenworthy et al. in press). Therefore it is important not only to know where seagrasses are growing but also how the lower limit of growth varies over time.

The primary purpose of this project was to remotely sense the lower limit of the seagrass, *Zostera marina L.* (eelgrass) within the boundaries of San Juan County, Washington using the combined technologies of underwater video (Norris et al. 1997) and hydroacoustics (Sabol et al. 2002). Both of these remote sensing platforms have proven effective in regions where the lower limit of seagrass growth cannot be determined using conventional aerial photography. For a discussion of how the different systems were used within the sampling program refer to Appendix A. A secondary objective of the project was to provide basal area coverage (Norris et al 1997) for *Z. marina* in extensive shallow water environments and pocket beaches following protocol established by the Washington State Department of Natural Resources (Berry et al. 2003). In addition pilot studies on the relationship between

Z. marina cover and juvenile salmonid prey species richness and abundance were conducted at five sites in San Juan County.

In the map book that follows (See Appendix B for an explanation of methodological approach) we graphically illustrate the geographic extent and the lower limit of growth for *Z. marina* within the boundaries of San Juan County for 2003. The data is displayed in two complimentary formats for each separate map page; United States Geological Survey (USGS) Quadrangles Maps to permit analysis of the relationship between watershed topography and *Z. marina* lower limit and National Oceanic and Atmospheric Administration (NOAA) Nautical Charts to allow users to compare the location of the lower limit of growth to bathymetry and coastal geomorphology.

Project Importance

One of five species of seagrass flora within the waters of San Juan County (Dethier 1990; Wyllie-Echeverria and Ackerman 2003), *Z. marina* (eelgrass) offers a multitude of well-documented ecological services to the nearshore marine environment (Phillips 1984; Simenstad 1994). *Z. marina* provides nursery and foraging habitat for Dungeness crab (*Cancer magister*), substrate for Pacific herring (*Clupea harengus pallasi*) spawn, and foraging grounds for Great Blue Herons (*Ardea herodias*). The benefits and importance of *Z. marina*, including its critical role as a nursery habitat for juvenile outmigrating salmon (Phillips 1984; Simenstad 1994), suggested that an understanding of the current distribution of this species was the required first step in the protection of San Juan County's nearshore habitats.

The San Juan County Eelgrass Survey and Mapping Project completed comprehensive mapping of the deep water edge of *Z. marina* growth. The entire shoreline of San Juan County was surveyed for *Z. marina* from April 30, 2003 to September 25, 2003. The project also conducted pilot studies on the relationship between *Z. marina* cover and juvenile salmon prey species richness and abundance at five sites. This pilot study provides further explanation on how variations in *Z. marina* distribution and cover (continuous, discontinuous, and fragmented) affect the habitat requirements of juvenile salmonid prey. Preliminary results from this work can be found in Appendix C.

The maximum depth parameter for *Z. marina* is an important metric in quantifying broader ecosystem health as well as the vigor of local populations of *Z. marina* in habitable areas (e.g. appropriate substrate, temperature, salinity etc.). The maps contained herein provide a baseline for the landscape analysis necessary to conserve and protect the *Z. marina* populations in San Juan County; however, future efforts to update this information are recommended.

The importance of this evaluation takes on more significance as resource agencies begin to assess the impact of increased watershed development within San Juan County. Recent studies indicate that an increase of human activity has detrimentally impacted *Z. marina* placing extant populations at risk. Fresh et al. (in review) discuss the impact of float structures (i.e., structures linked to docks via ramps that allow vessels to be moored in deeper water to permit access during extreme low tide events) on *Z. marina* populations and conclude that attempts to alter the shading footprint, caused by float structures, have not been successful in preventing *Z. marina* loss. Austin et al. (2004) found damage to the *Z. marina* prairie can result from the deployment of submarine cables depending on the installation technique chosen. There is further discussion on *Z. marina* declines in San Juan County, WA in the Westcott Bay Taskforce Mini-Workshop (Appendix D of this report). These studies and the current declines in eelgrass habitat around Westcott and Blind Bays emphasize that more effort should be directed at determining local human impacts on this valuable resource.

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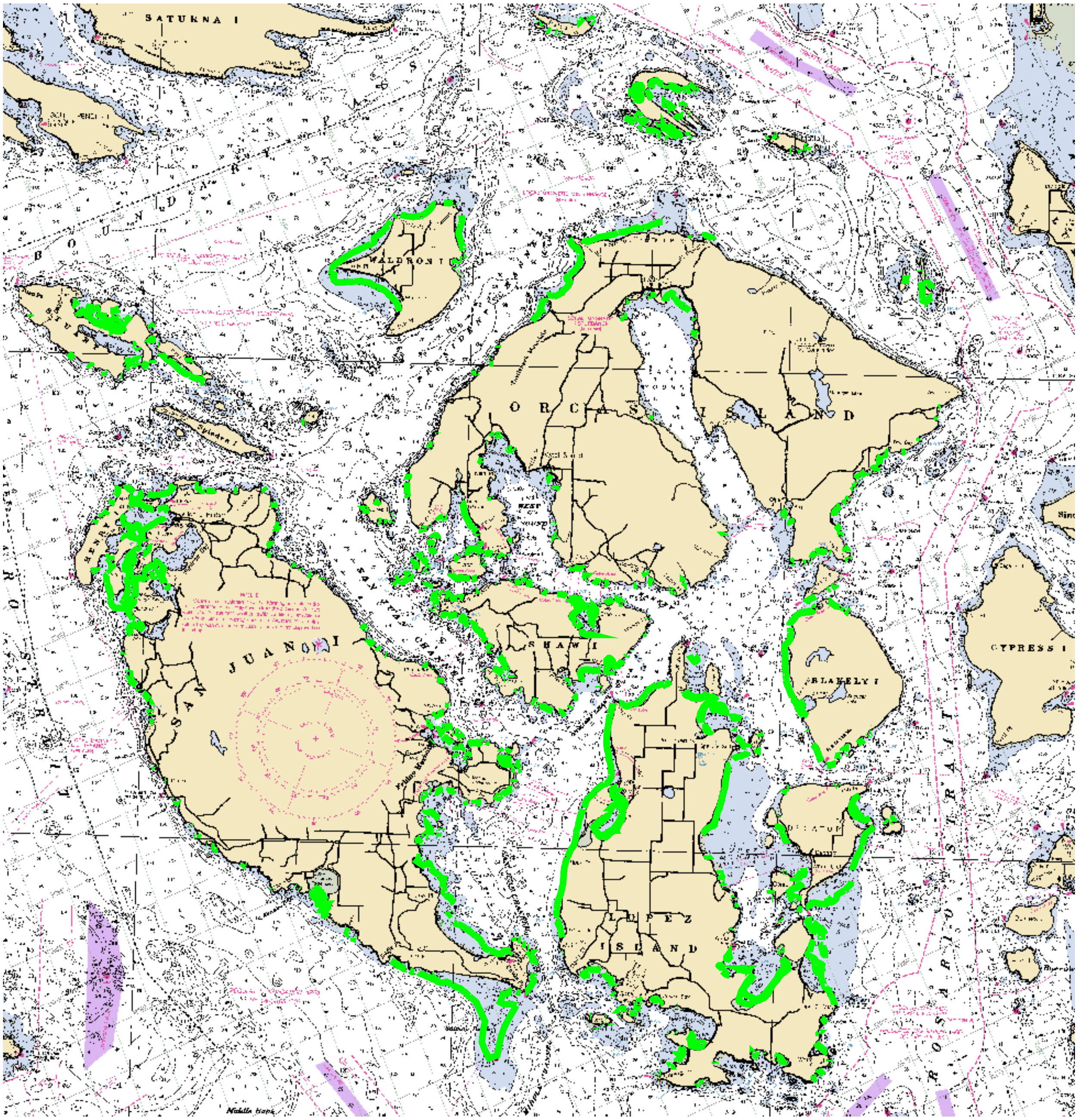
San Juan County Eelgrass Survey
(Z. marina)



Each section of this map book has two discrete maps: the first is a USGS Quadrangle overlain with the location of the deep edge of the eelgrass along the shoreline; the second is a NOAA Chart upon which the variation in maximum depth is represented by distinct colors. Maximum depth estimates were derived from mean maximum depth values along the trackline at each site. A full description of this process is described in Appendix A.

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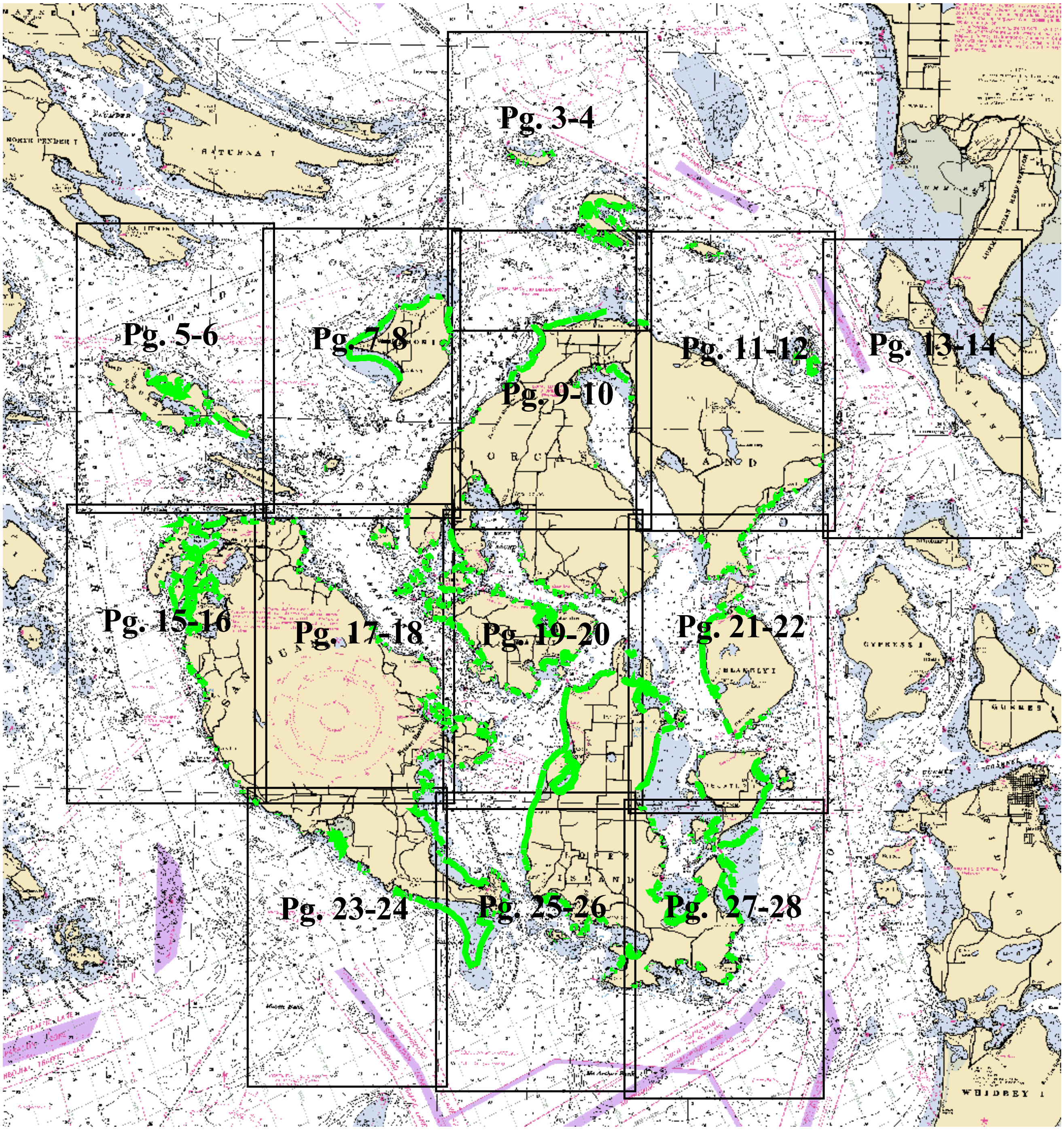

Limitations to using information in this map book.

This mapbook depicts the outer (deep) edge of all eelgrass (Z. marina) surveyed during Spring and Summer of 2003.

1. It cannot be assumed that the area between the deep edge and the beach contains eelgrass.
2. Depth data portrayed through line color may not "agree" with the depth contours on the underlying chart in some areas.
3. The depths portrayed in this study are based on mean lower low water (MLLW).
4. Depths shown on the nautical charts are in fathoms (6') except in the Blind Bay and Westcott Bay detail maps , mapbook pages 30 and 31 where depth is displayed on the nautical charts in fathoms with feet as a subscript.
5. Details of chart symbology can be found in NOAA Chart 1.

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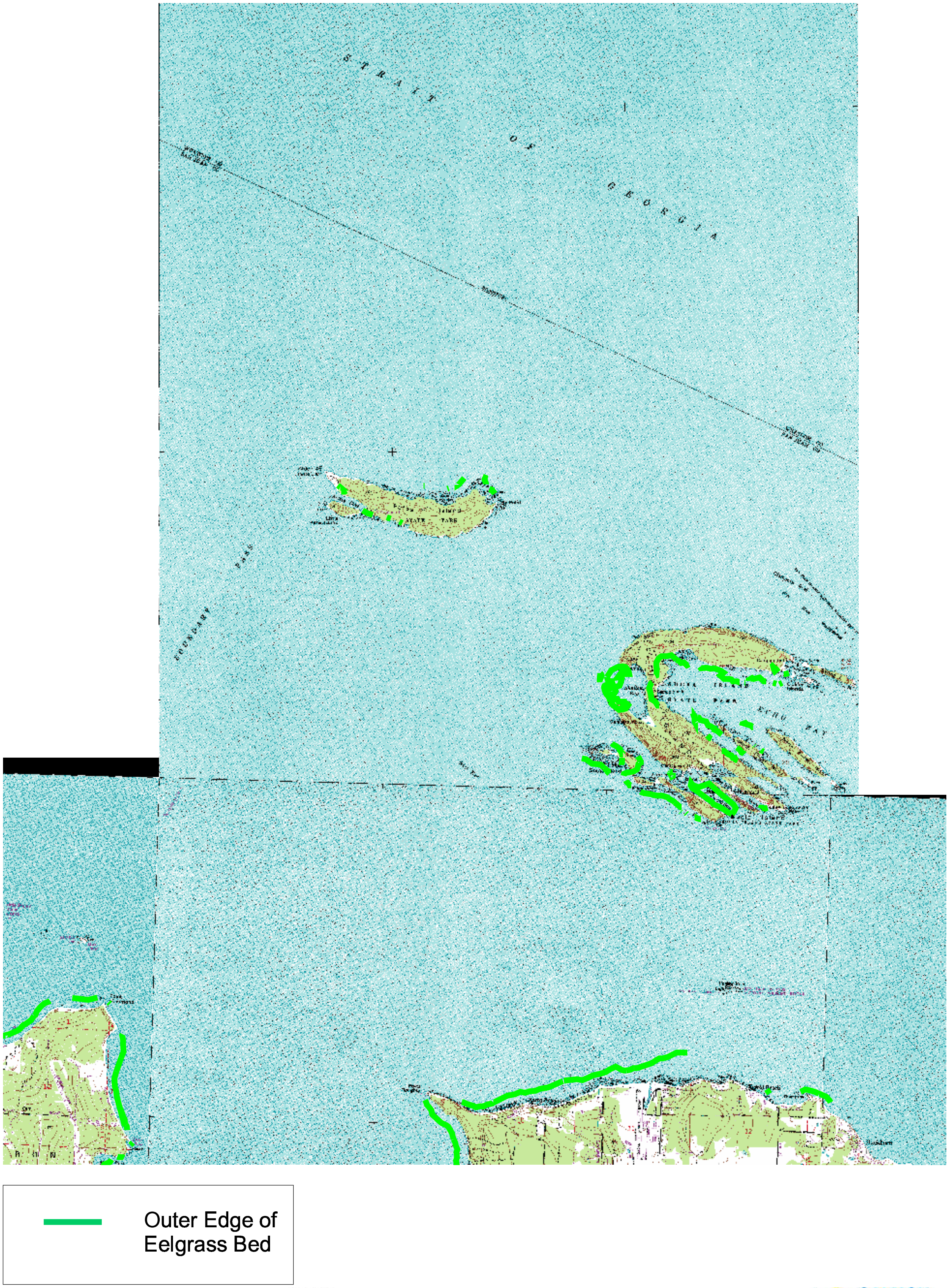
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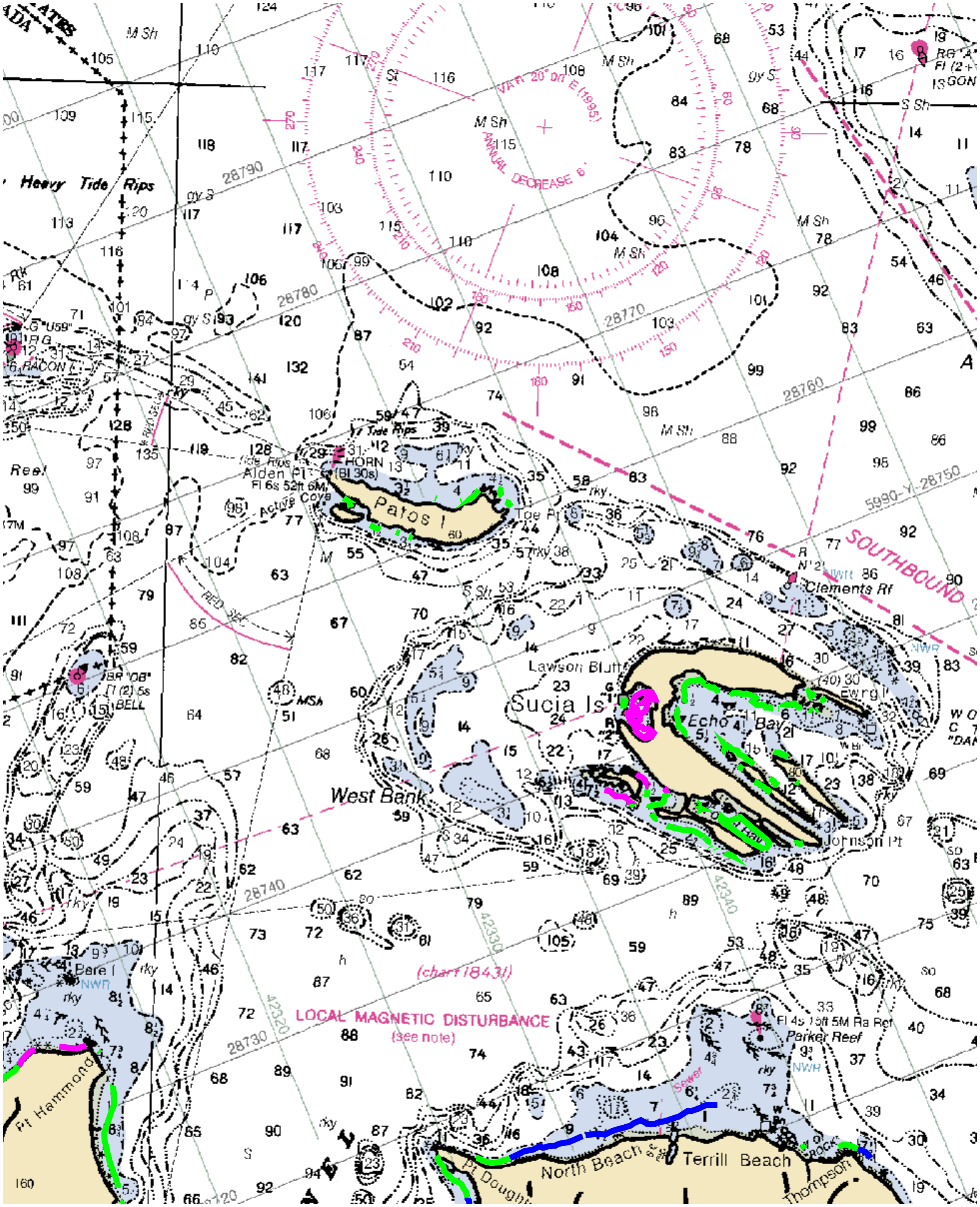
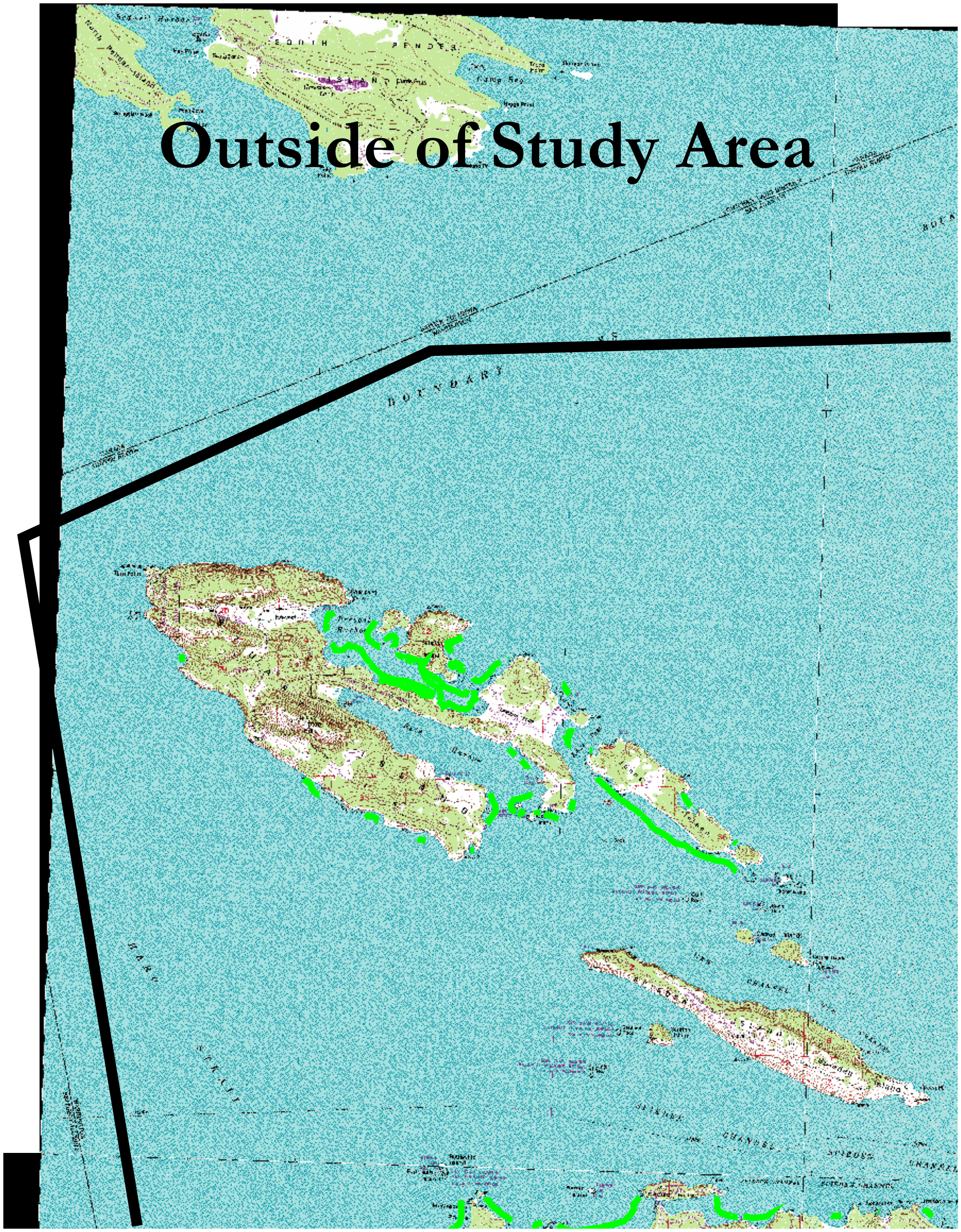
BOUNDARY PASS
STATE PARK
ECHO BAY
Outer Edge of Eelgrass Bed



Depth of Outer Edge of Eelgrass Bed (MLLW)

- 2 - 13 Ft.
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')



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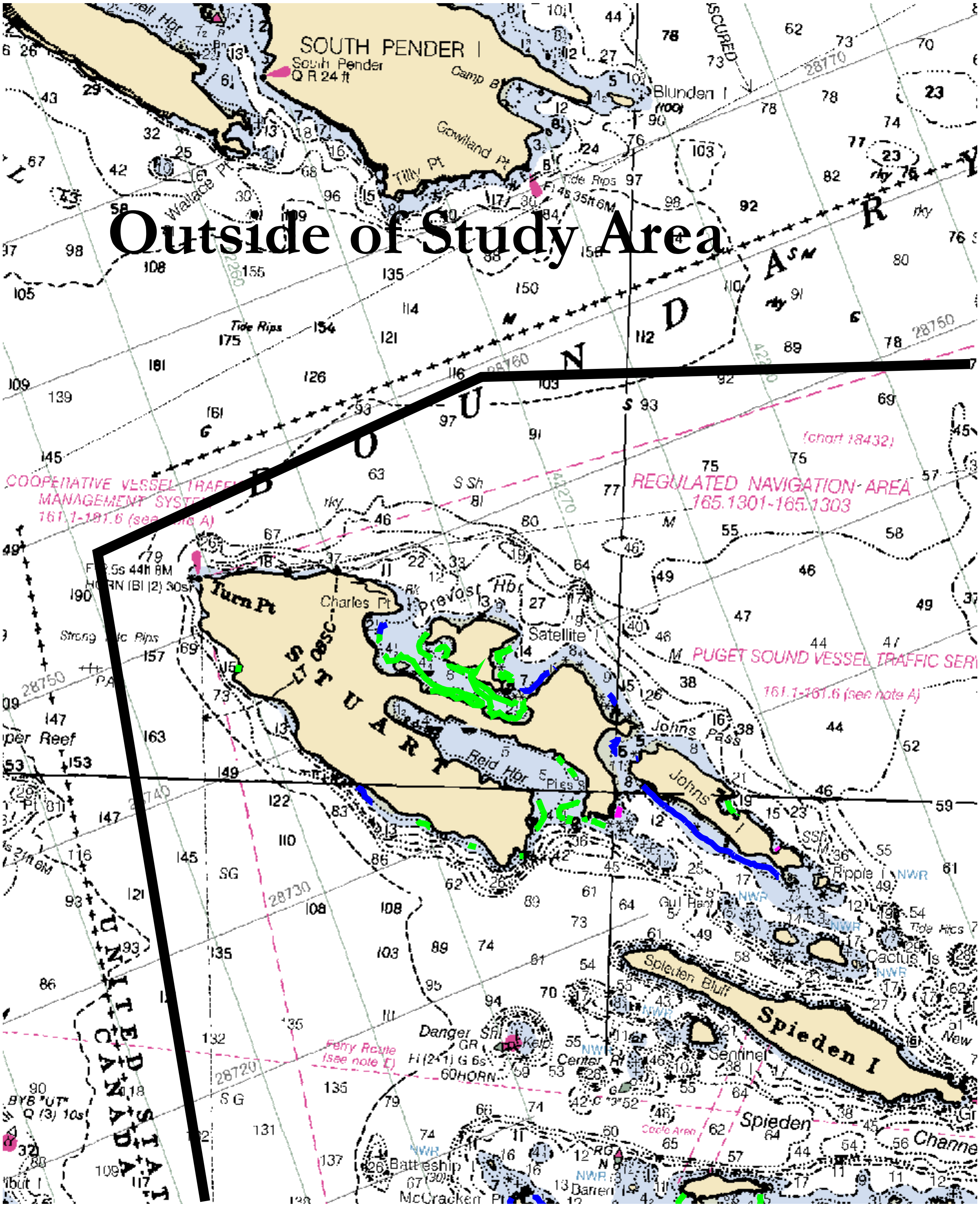

Depth of Outer Edge of Eelgrass Bed (MLLW)

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- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')

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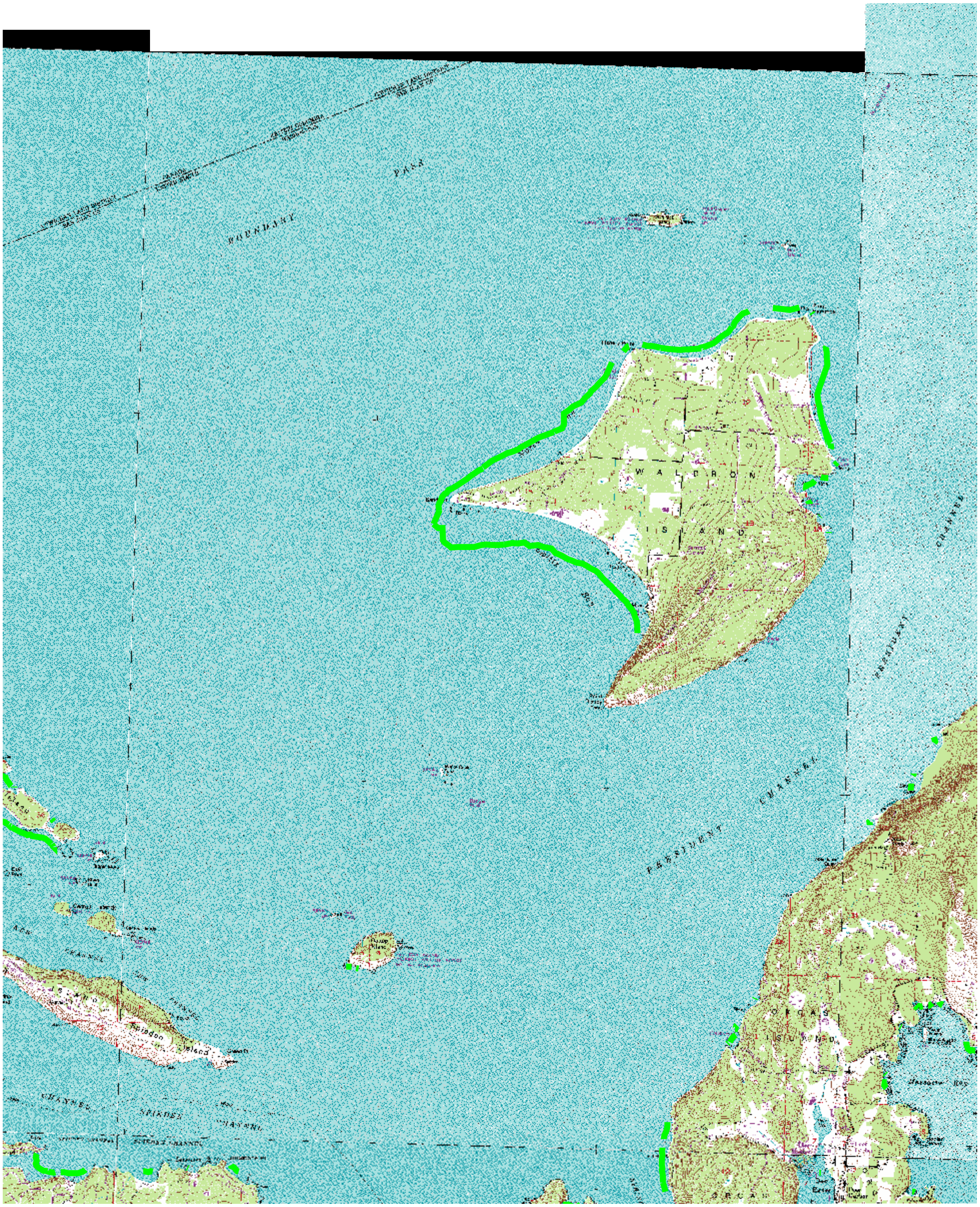

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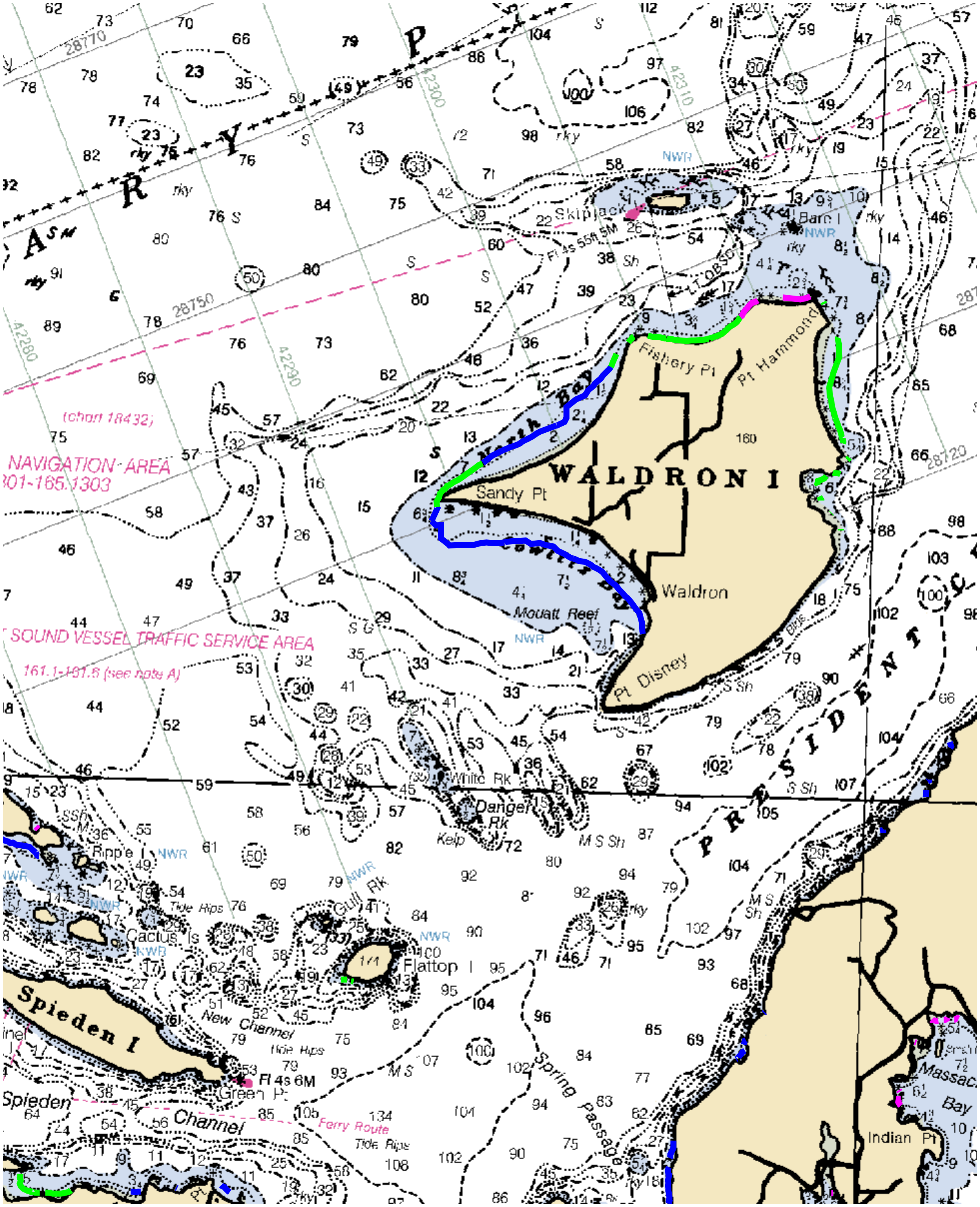


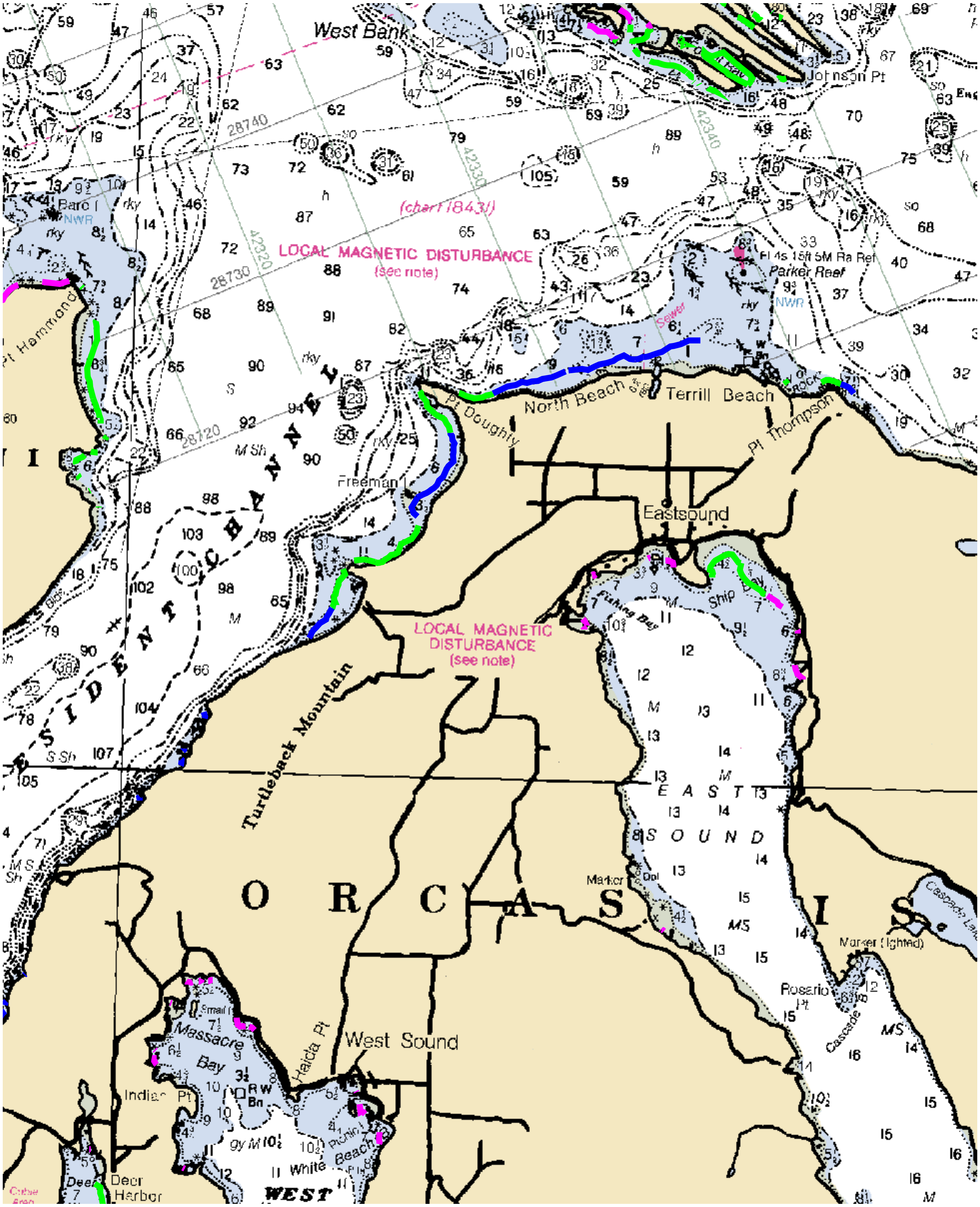
Depth of Outer Edge of Eelgrass Bed (MLLW)

- 2 - 13 Ft.
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')

5/30/2004 San Juan County Eelgrass (Z. marina) Survey

Outer Edge of Eelgrass Bed



Depth of Outer Edge of Eelgrass Bed (MLLW)

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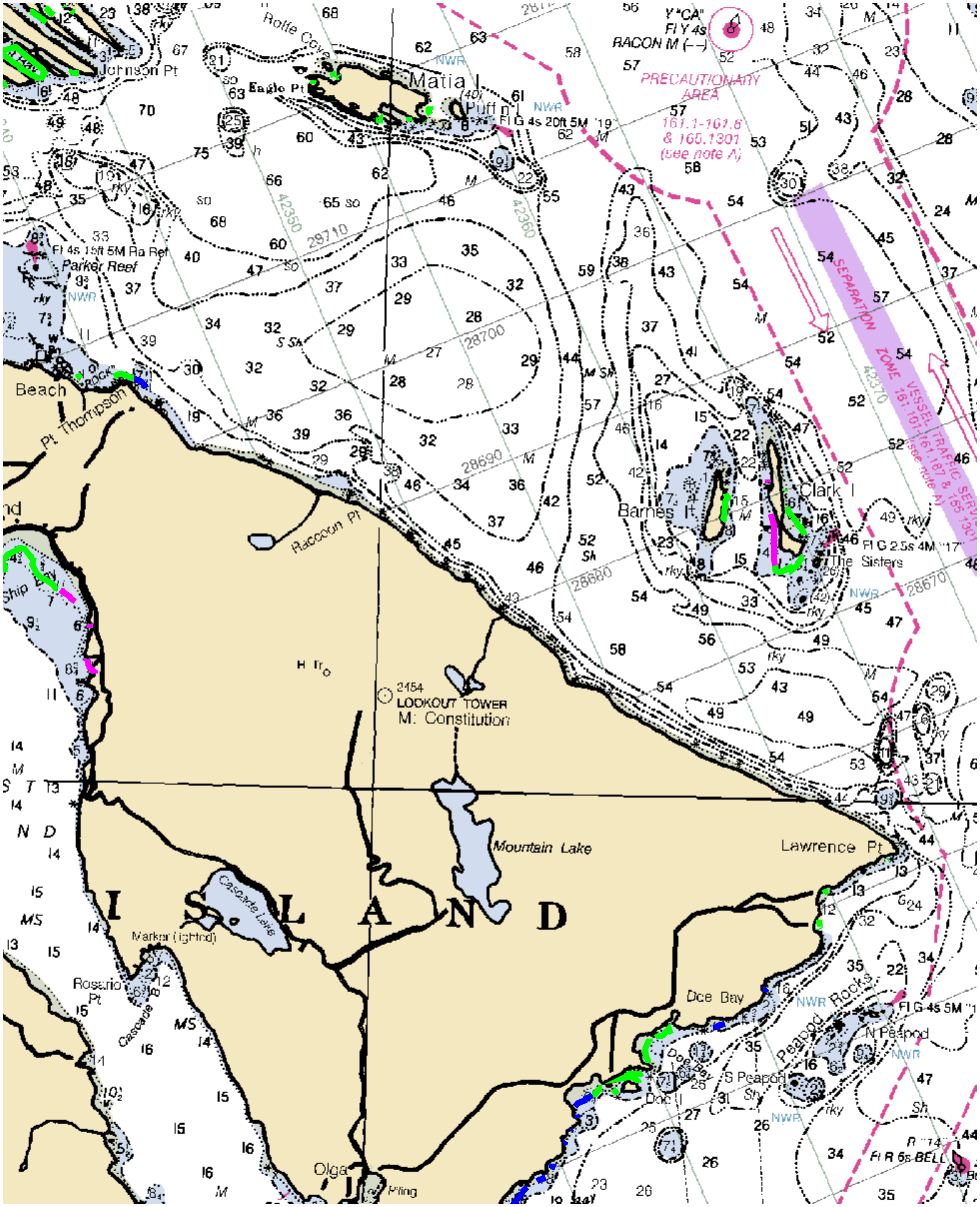
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')

5/30/2004 San Juan County Eelgrass (Z. marina) Survey

Outer Edge of Eelgrass Bed



Depth of Outer Edge of Eelgrass Bed (MLLW)

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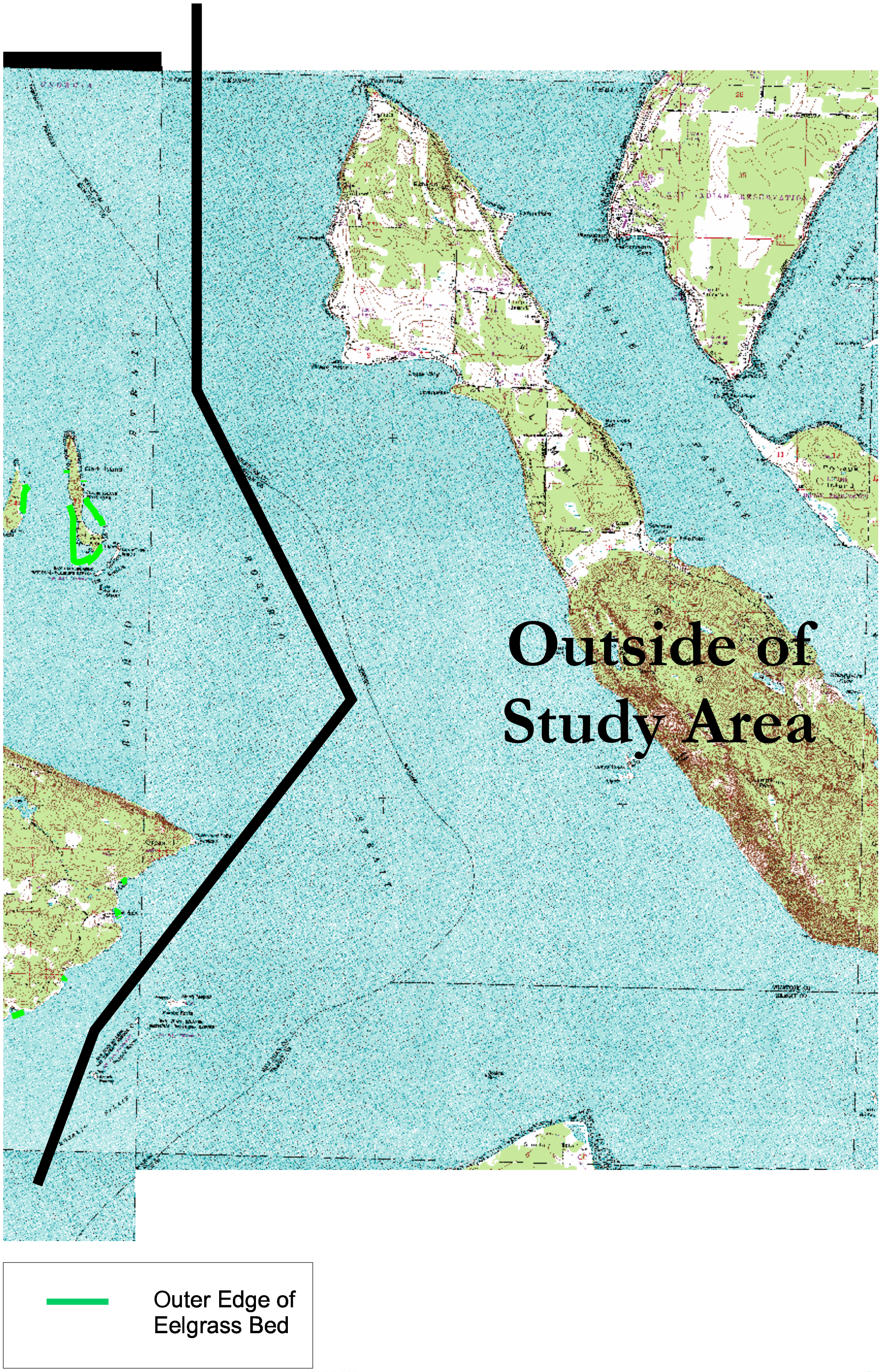
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')


Outside of
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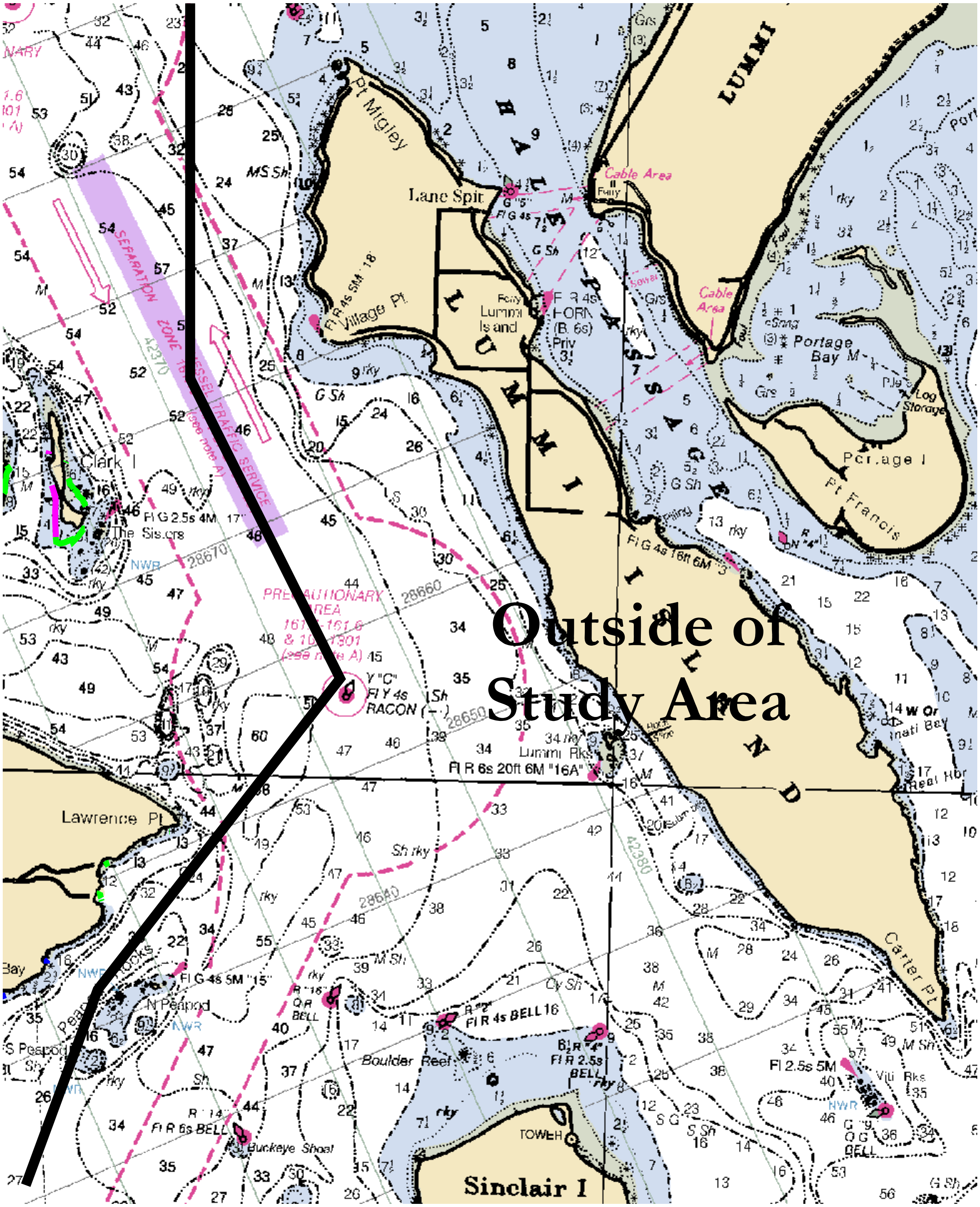
Outer Edge of
Eelgrass Bed



Depth of Outer Edge of Eelgrass Bed (MLLW)

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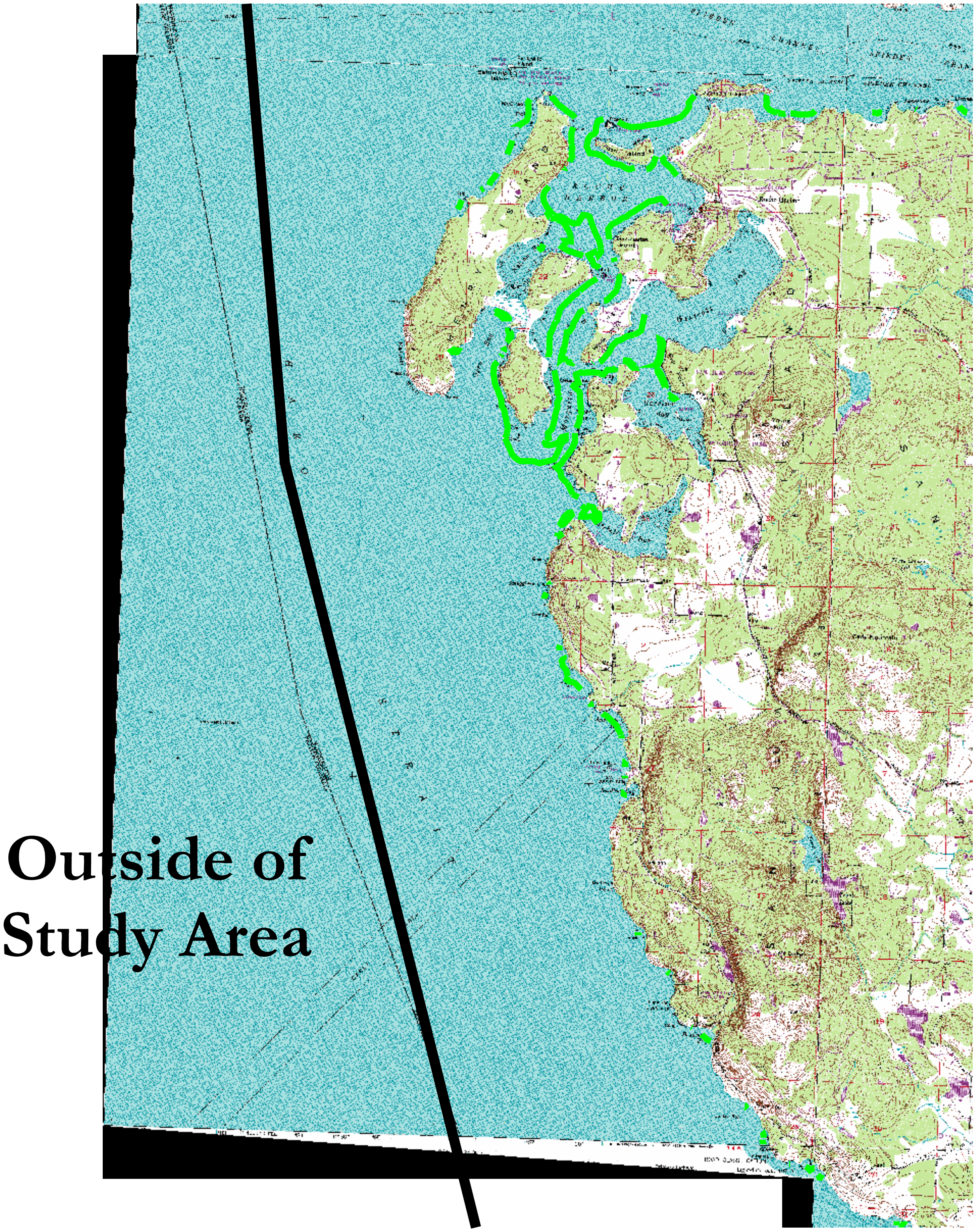
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')



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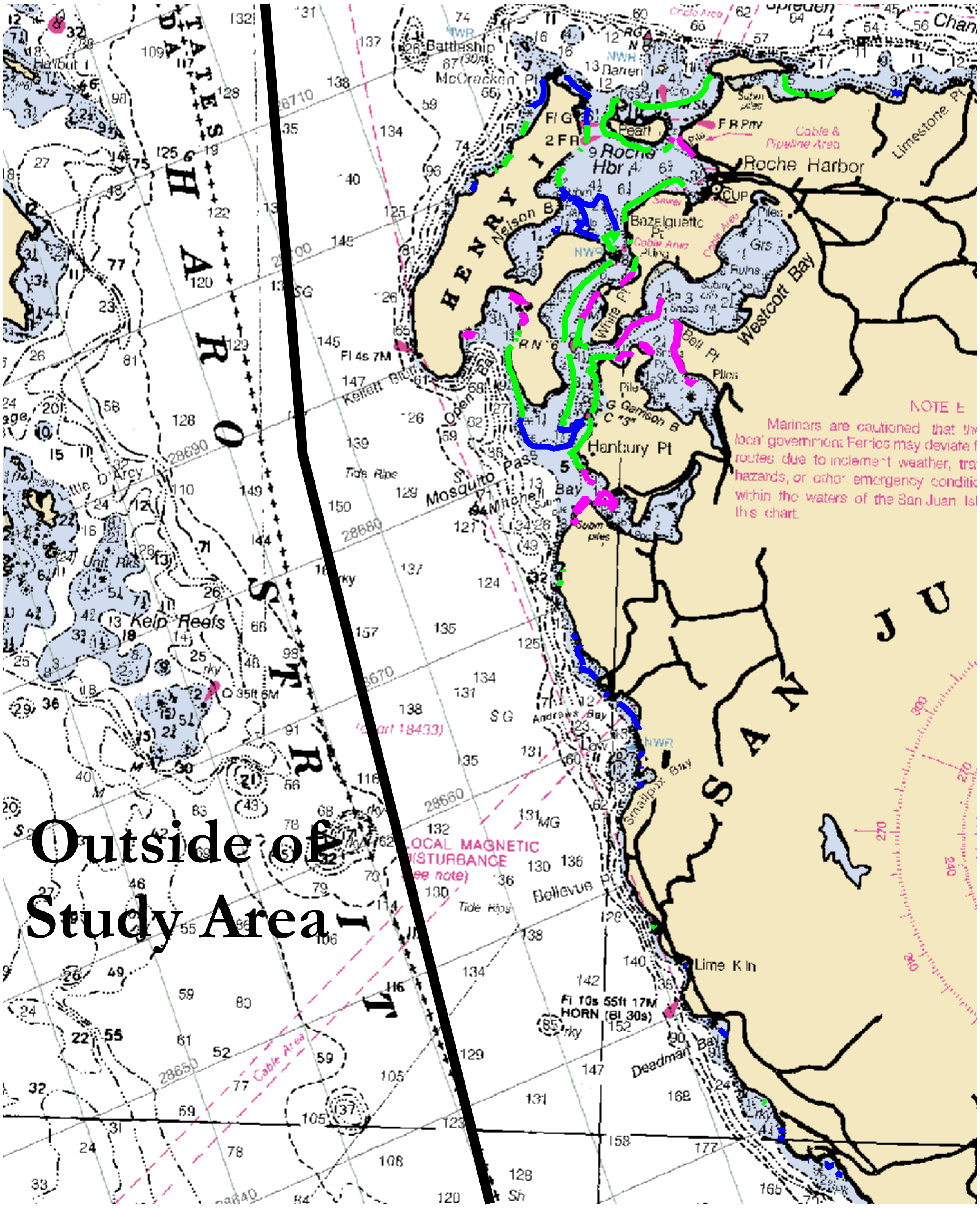

Depth of Outer Edge of Eelgrass Bed (MLLW)

- 2 - 13 Ft.
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')

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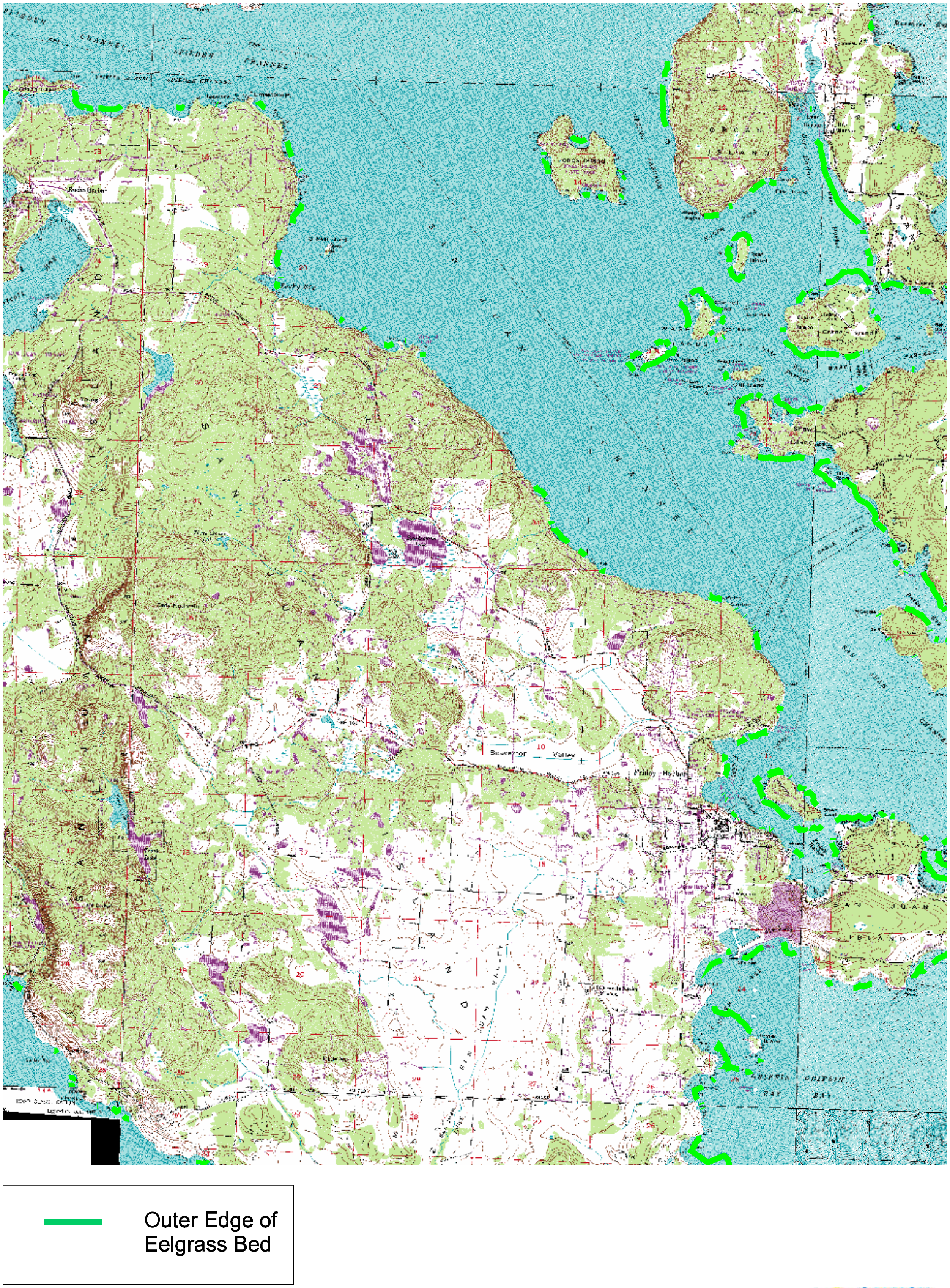
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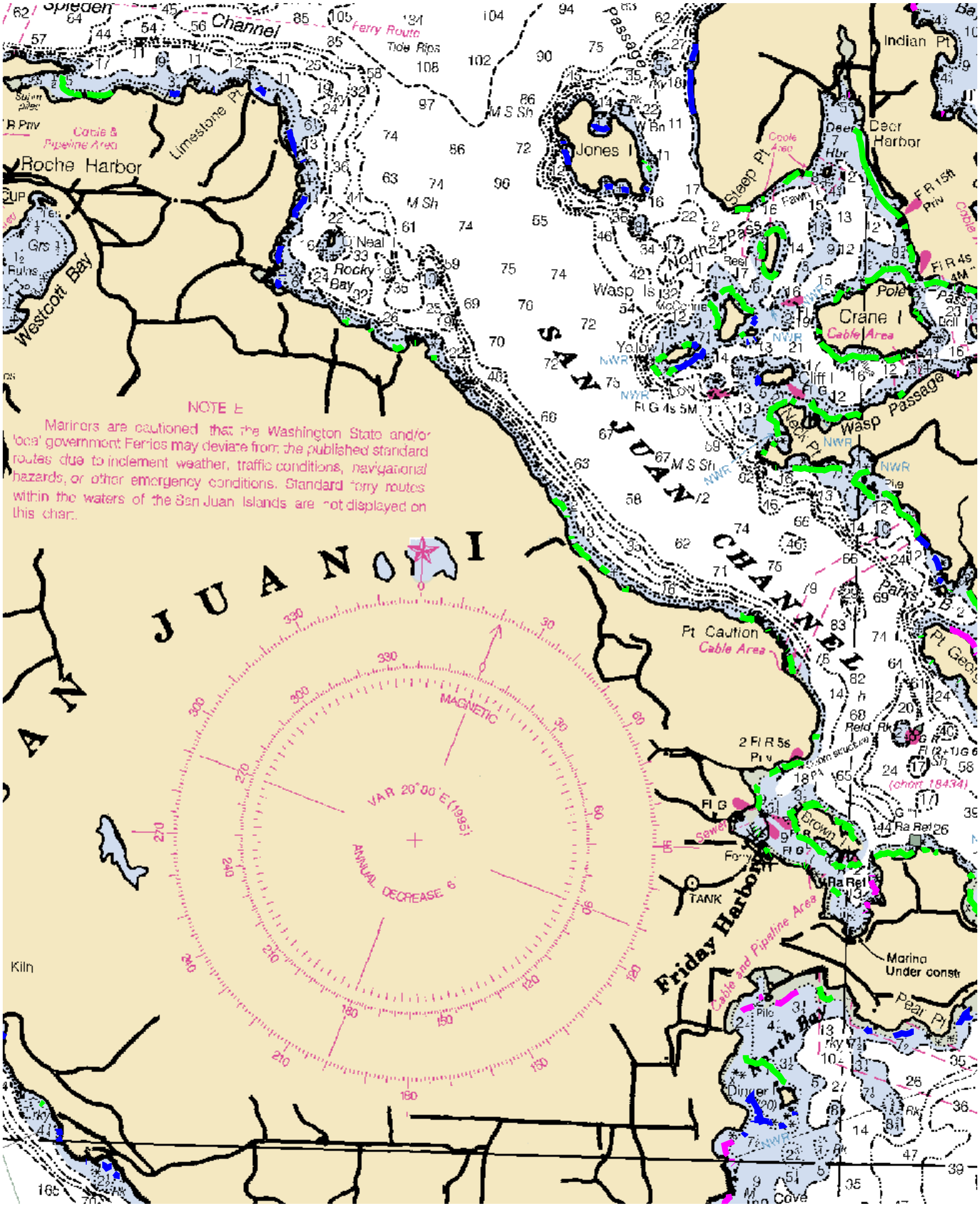

Depth of Outer Edge of Eelgrass Bed (MLLW)

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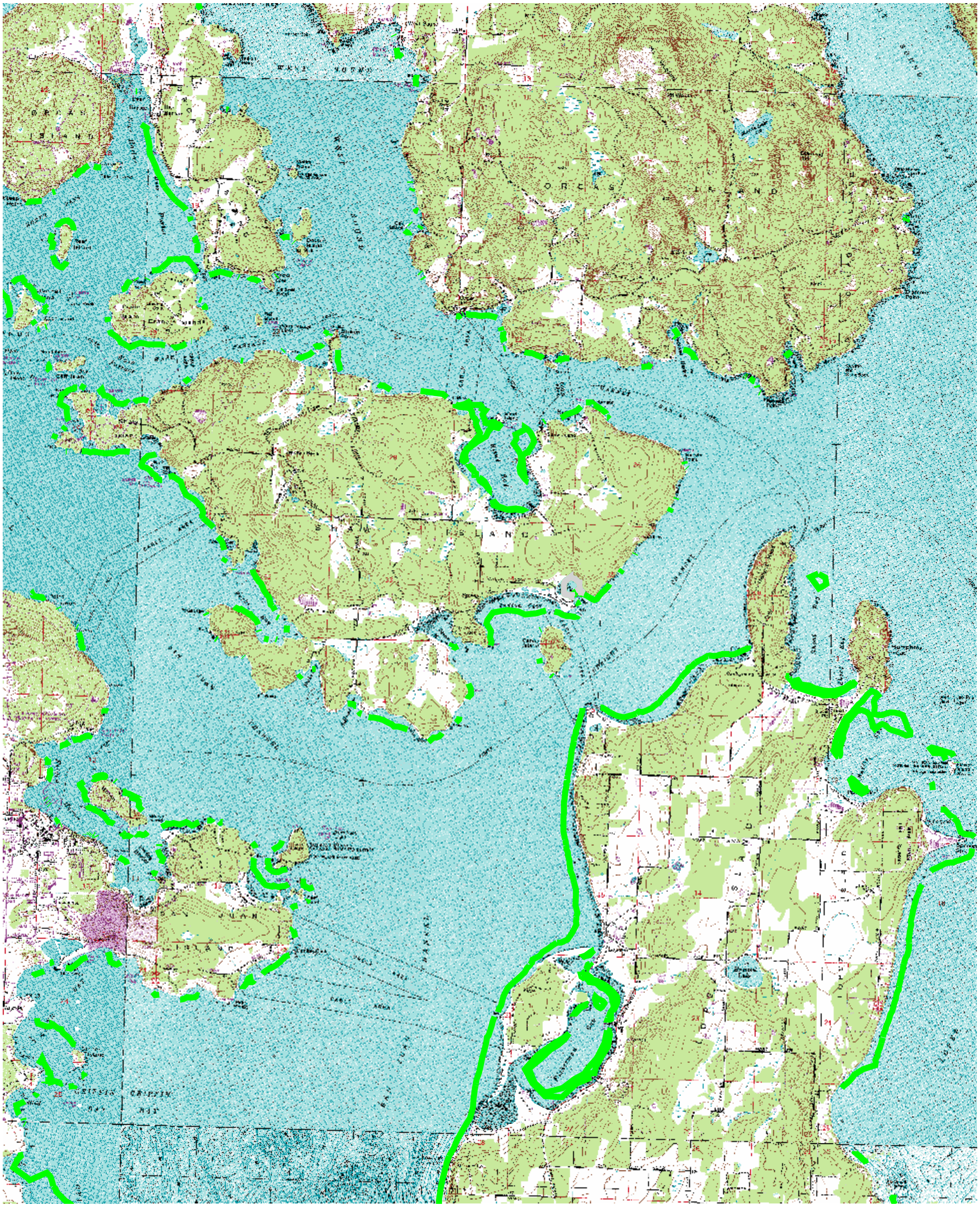
Depths are in fathoms (6')



Outer Edge of Eelgrass Bed

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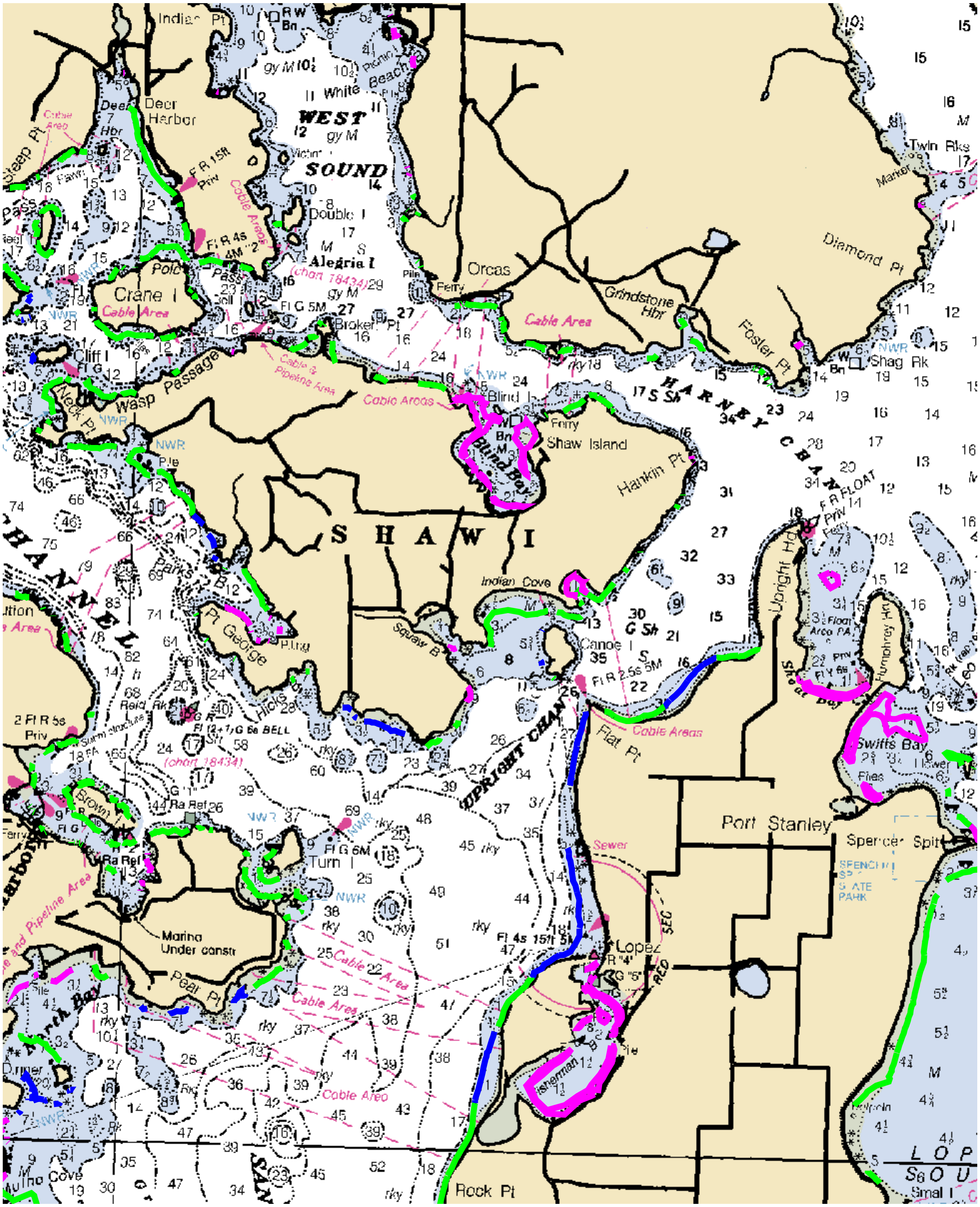

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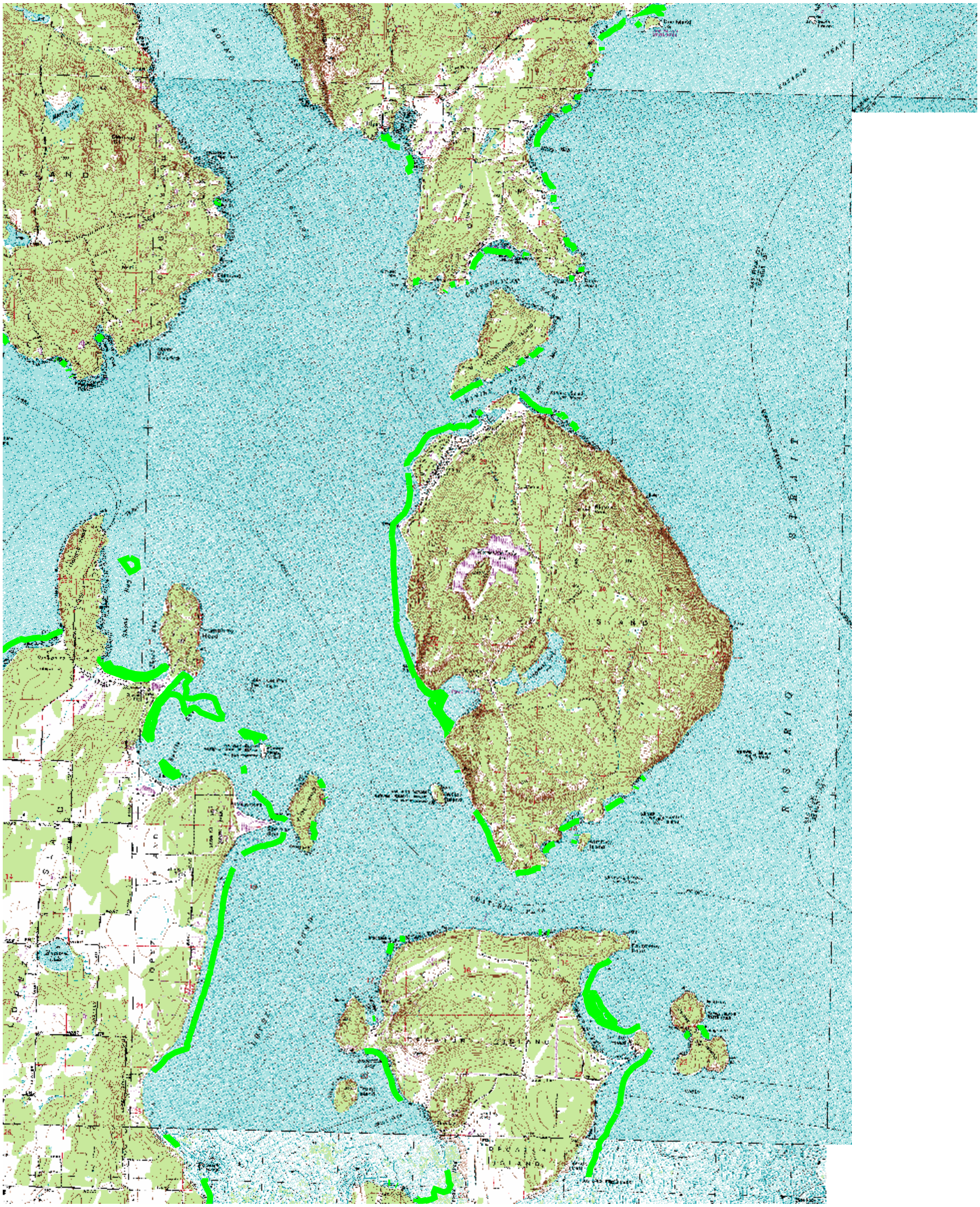
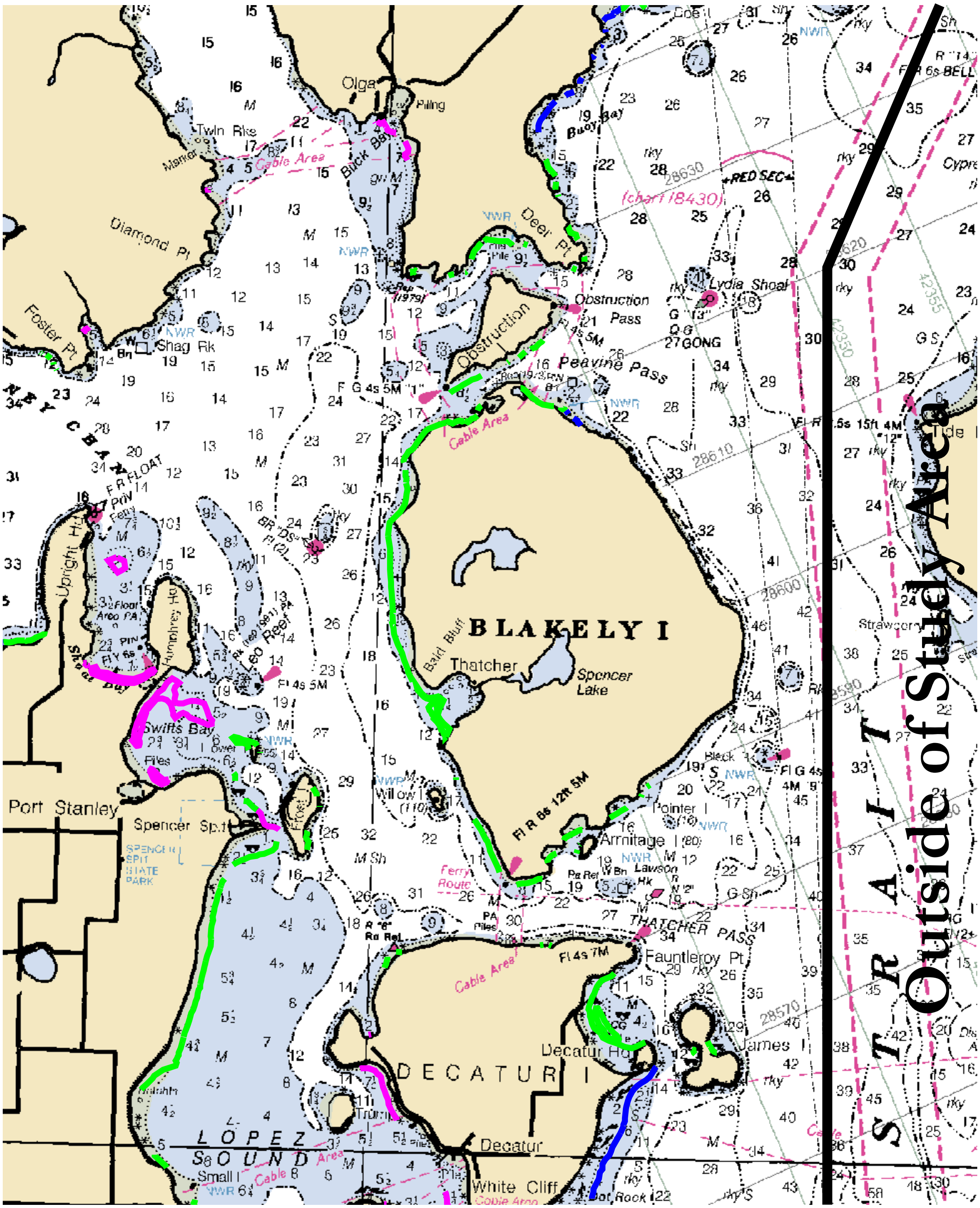


Outer Edge of Eelgrass Bed



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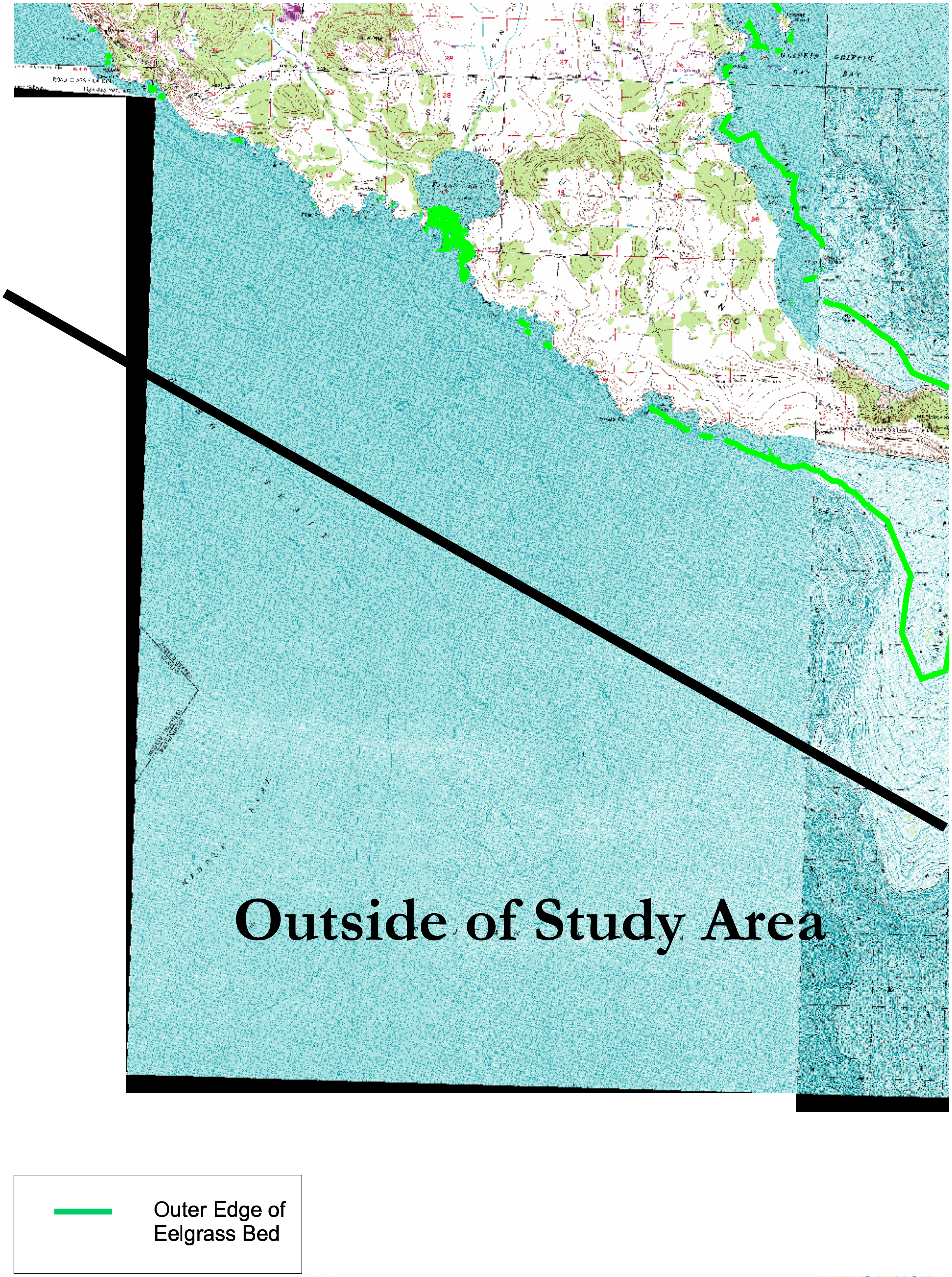
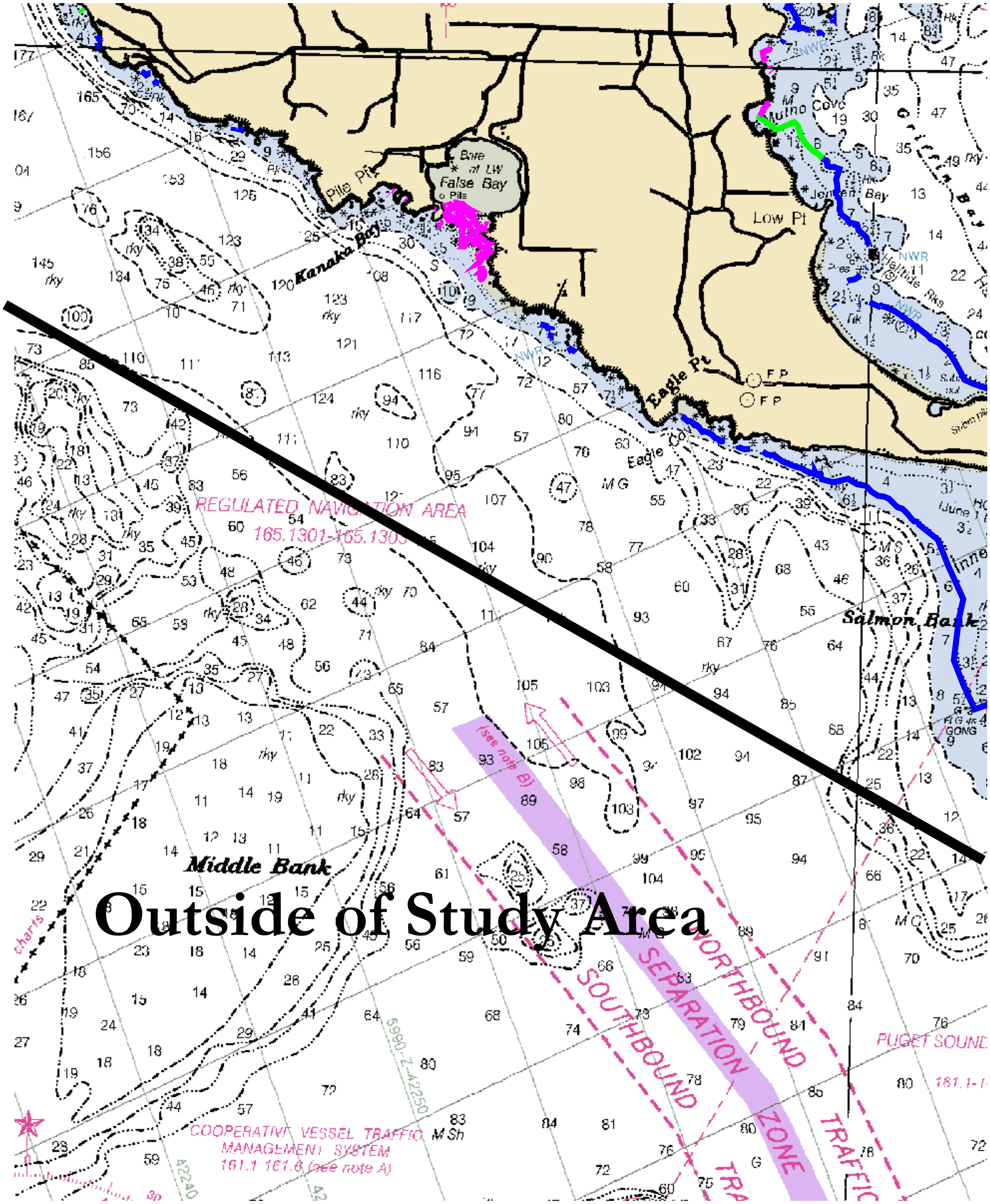
- 21 - 30 Ft.

Depths are in fathoms (6')


Outside of Study Area
Outer Edge of Eelgrass Bed



Depth of Outer Edge of Eelgrass Bed (MLLW)

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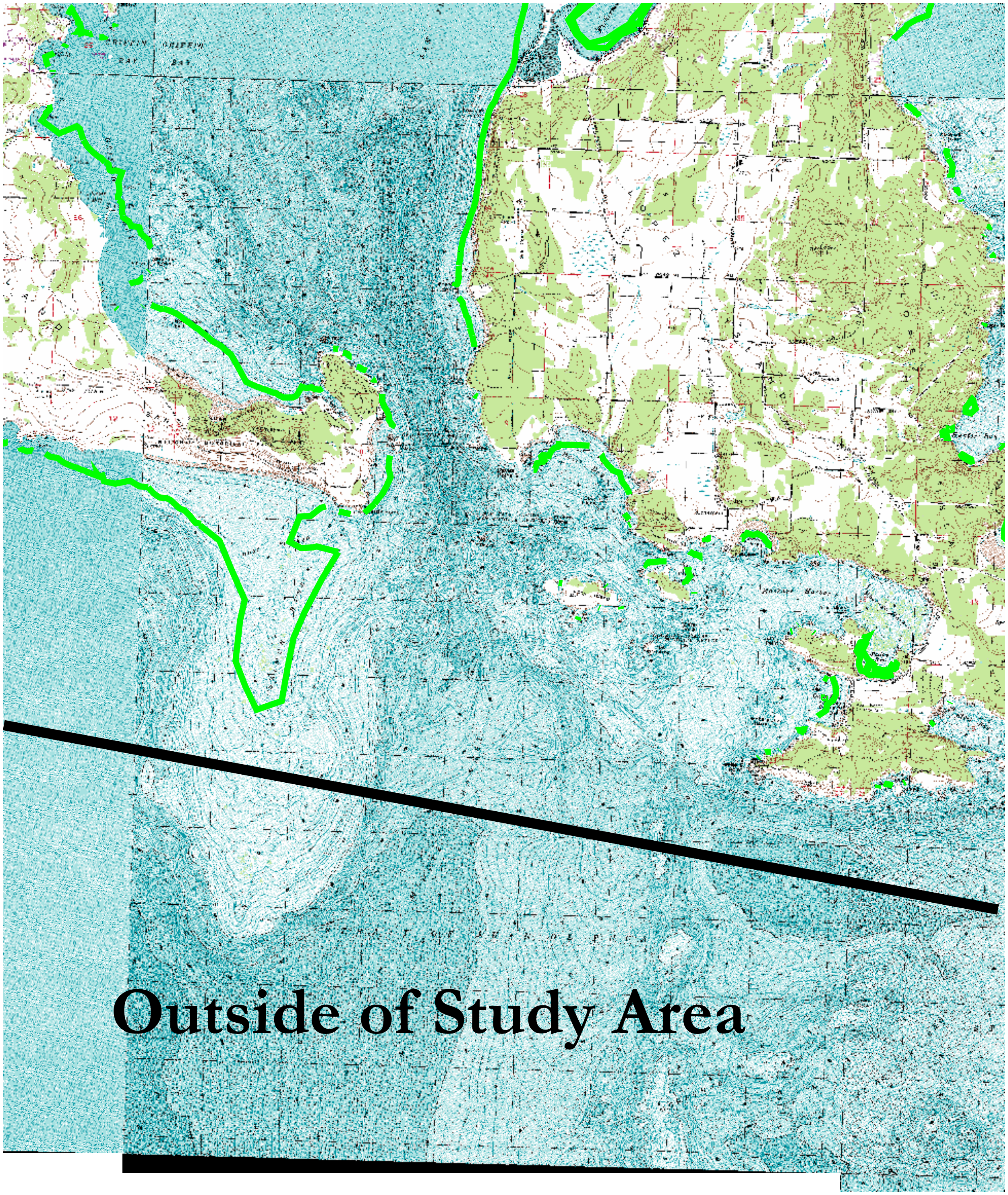
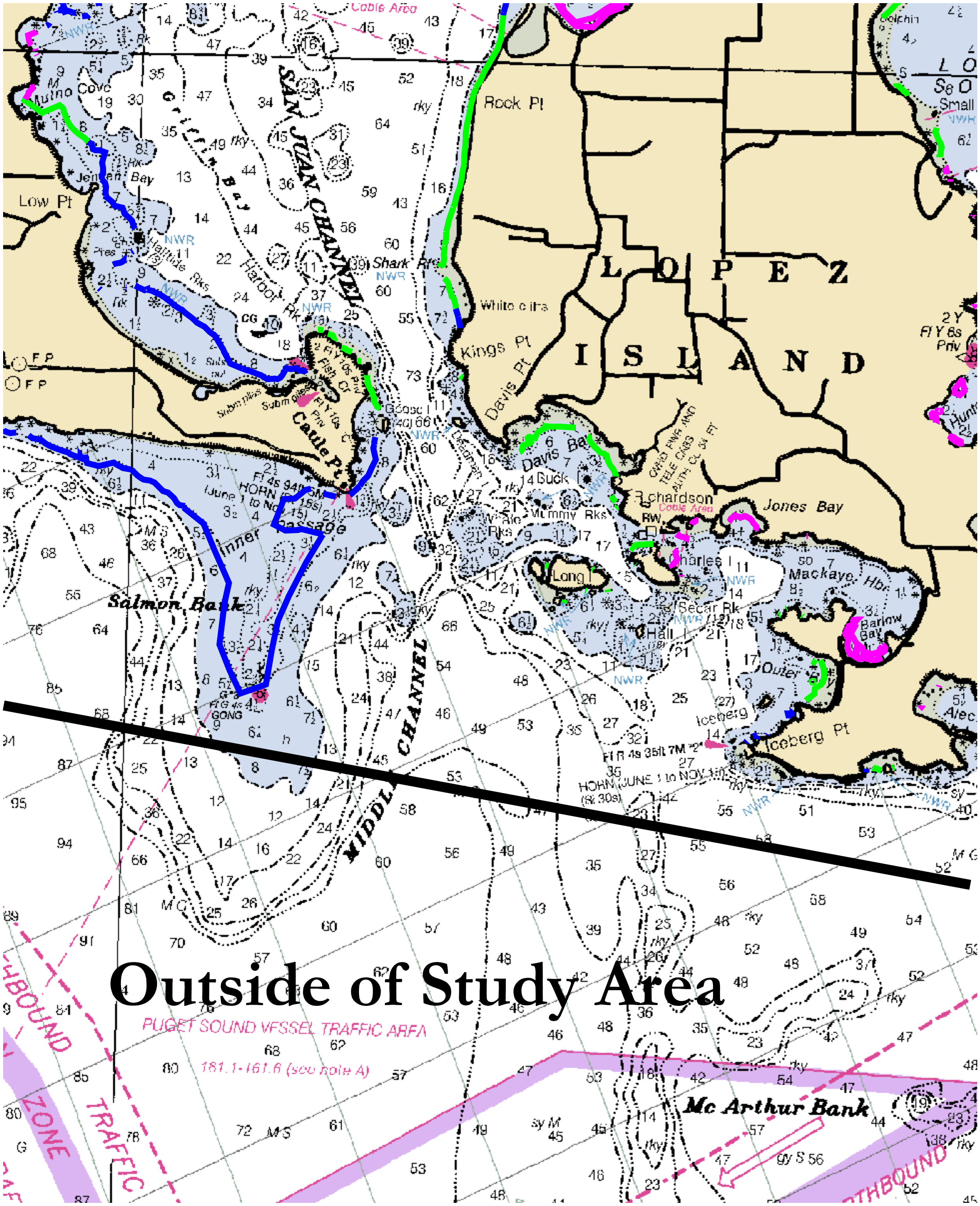
- 21 - 30 Ft.

Depths are in fathoms (6')



Outer Edge of Eelgrass Bed



Depth of Outer Edge of Eelgrass Bed (MLLW)

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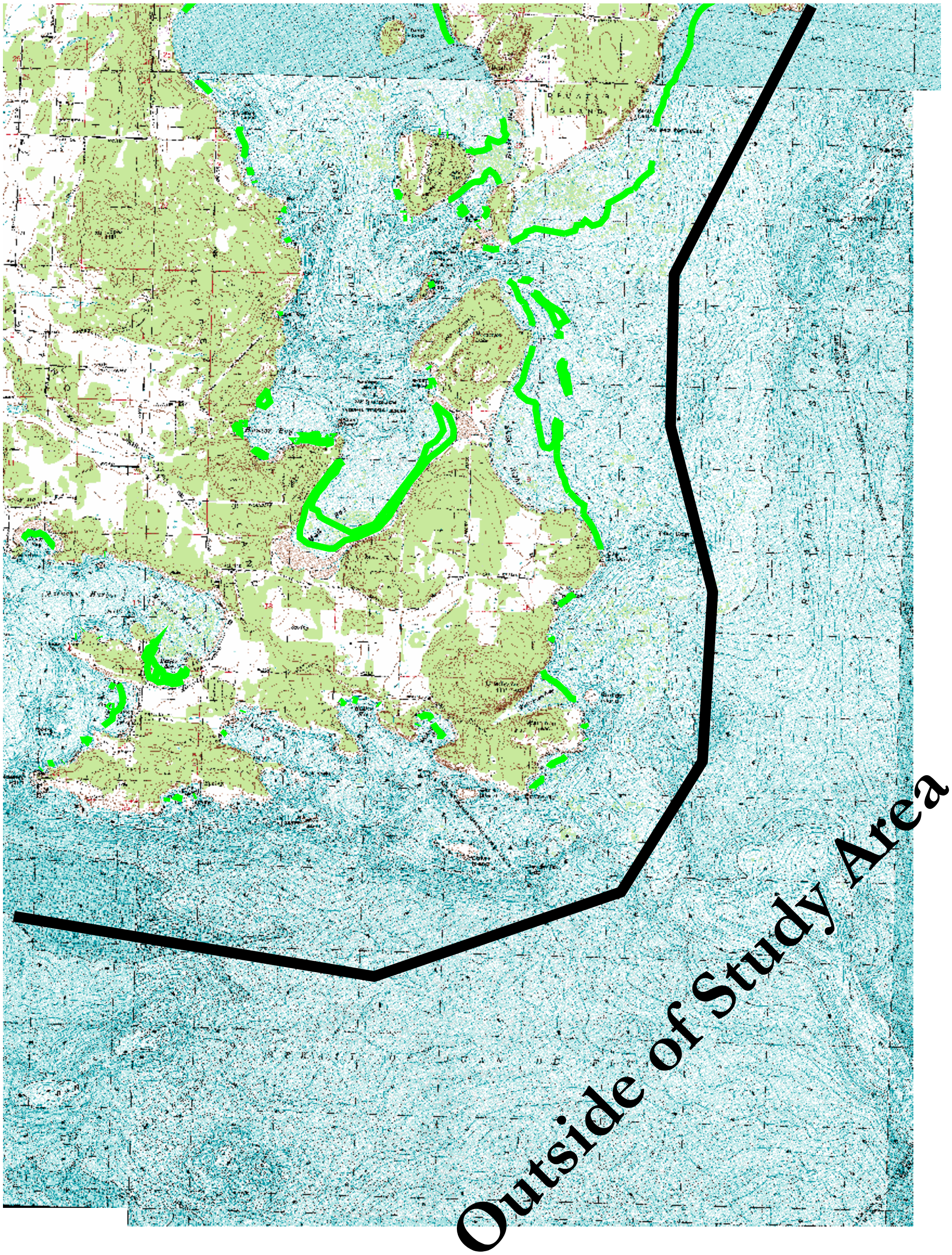
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')



Outer Edge of Eelgrass Bed

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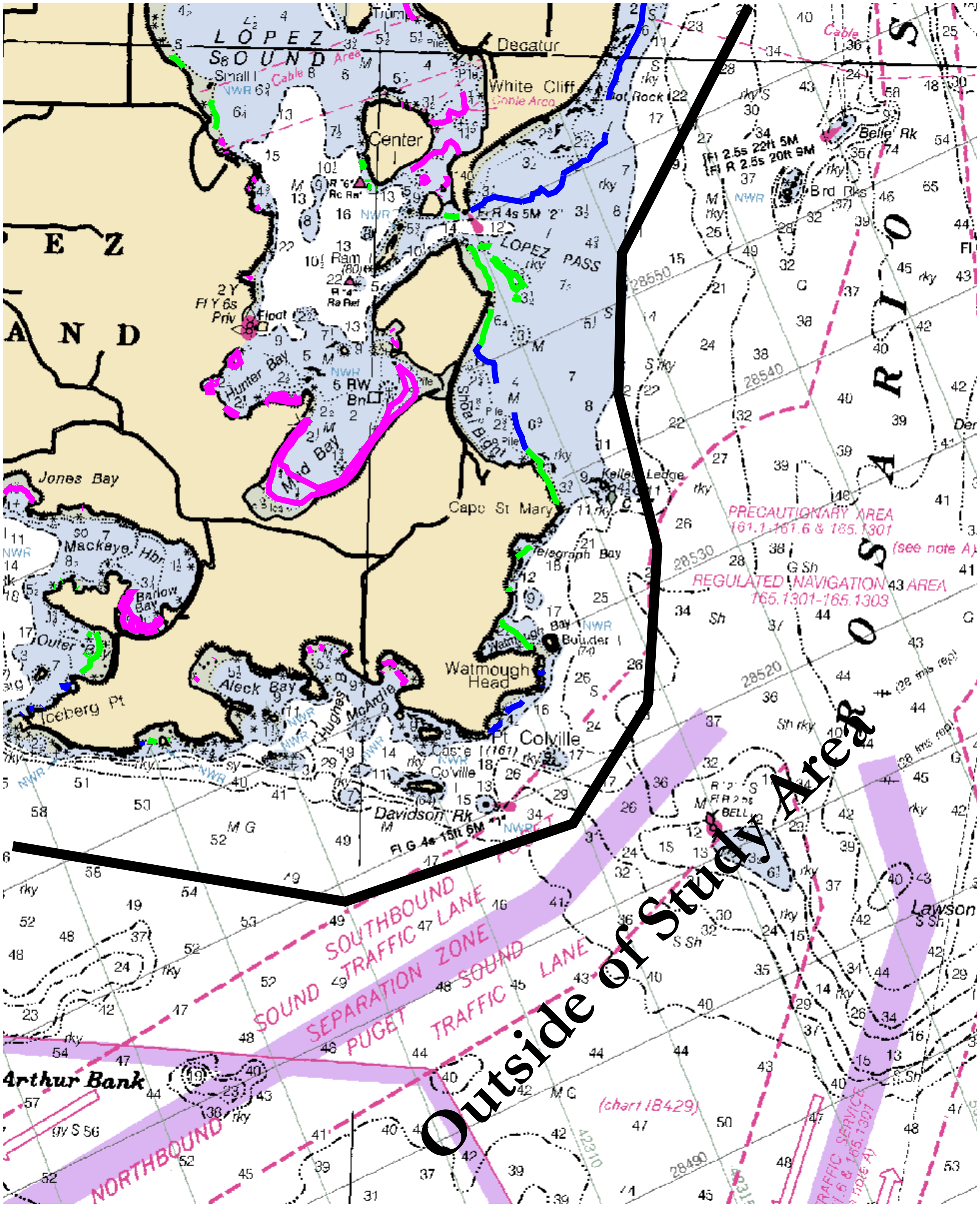

Depth of Outer Edge of Eelgrass Bed (MLLW)

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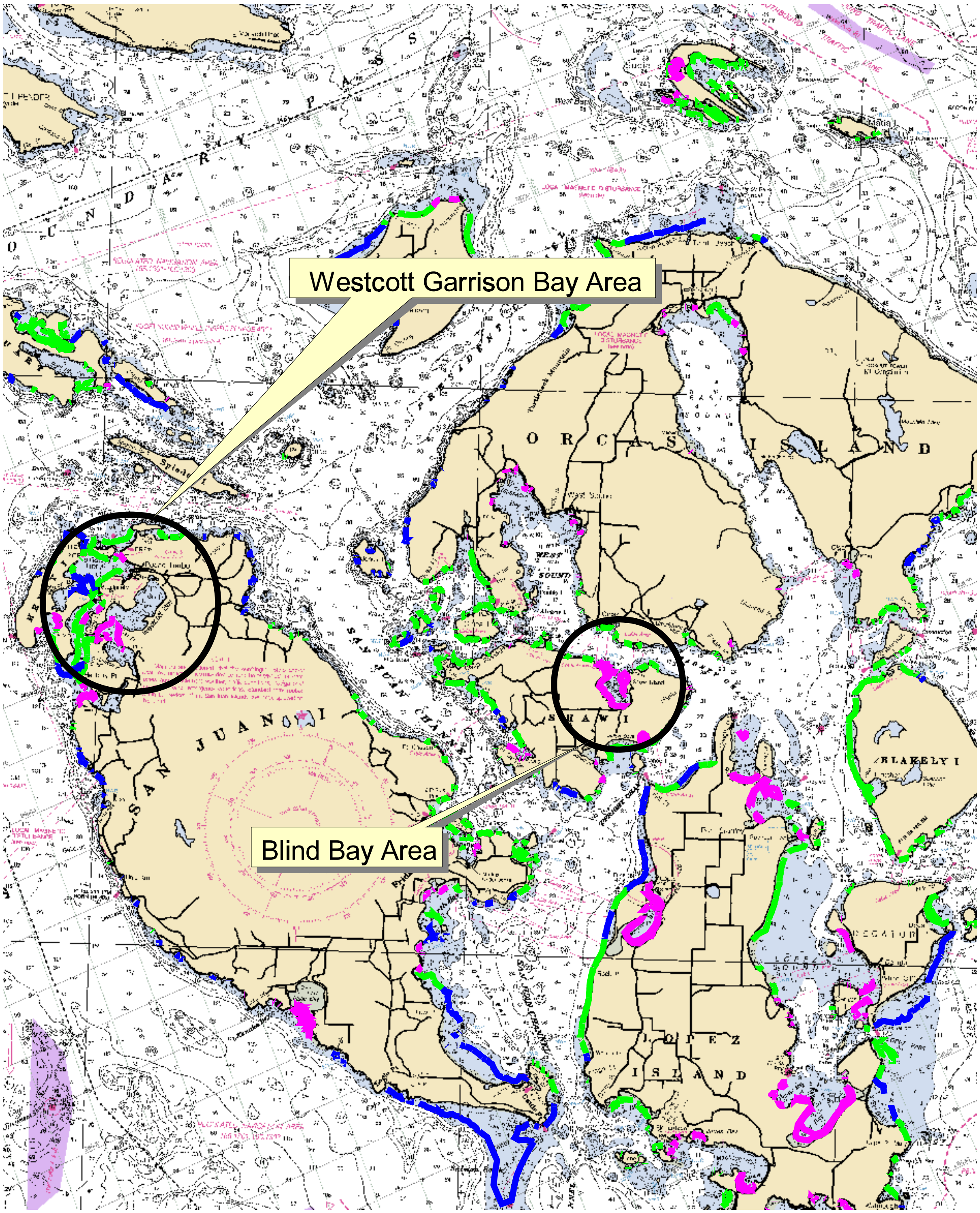
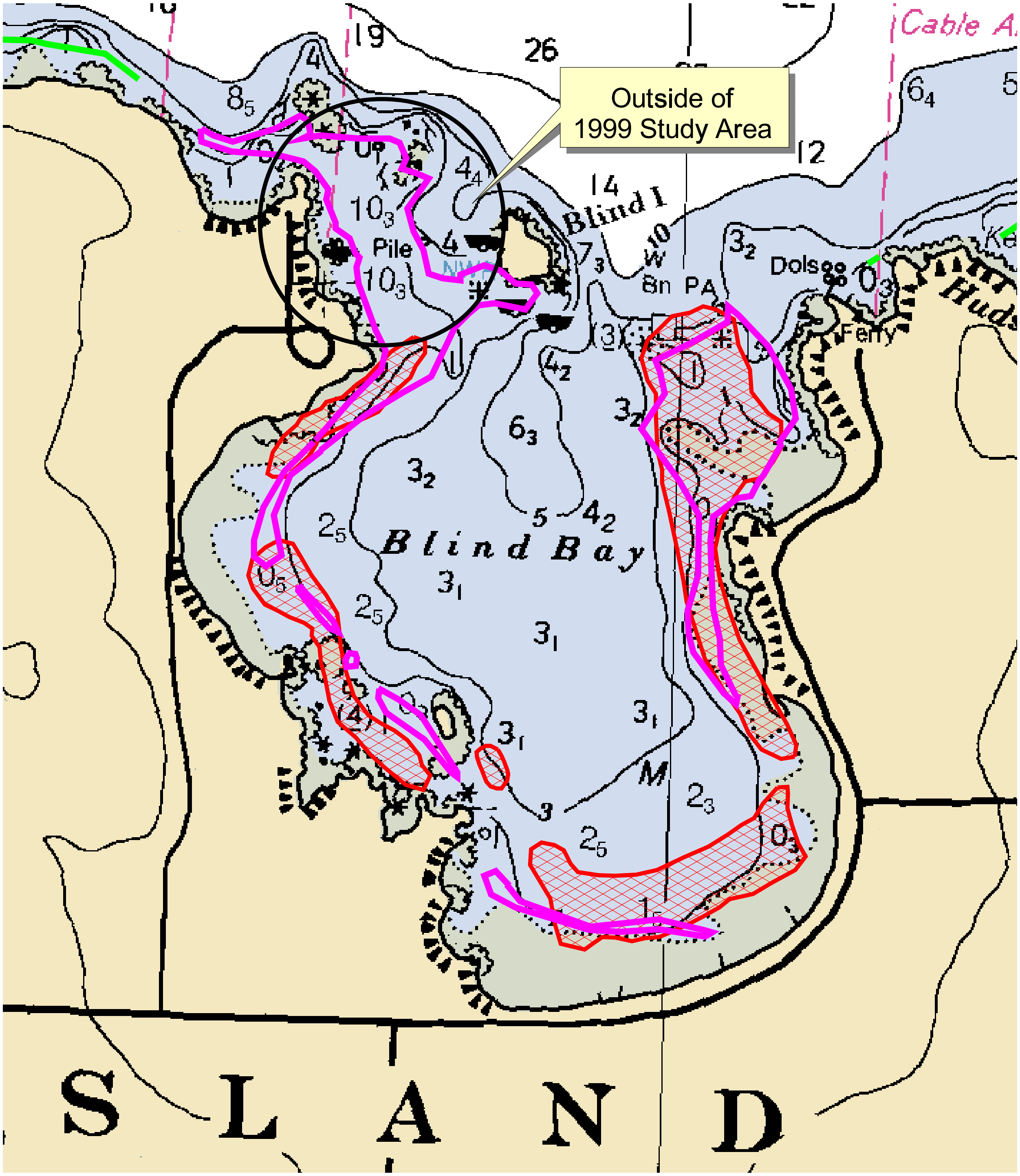
- 13 - 21 Ft.
- 21 - 30 Ft.

Depths are in fathoms (6')

Hotspots of Eelgrass Decline





Comparison of Z. marina distribution between
1999 and 2003 in Blind Bay.

Depth of Outer Edge of Eelgrass Bed

- 2 - 13 Ft.
- 13 - 21 Ft.
- 21 - 30 Ft.
- WDFW unpublished data 1999*

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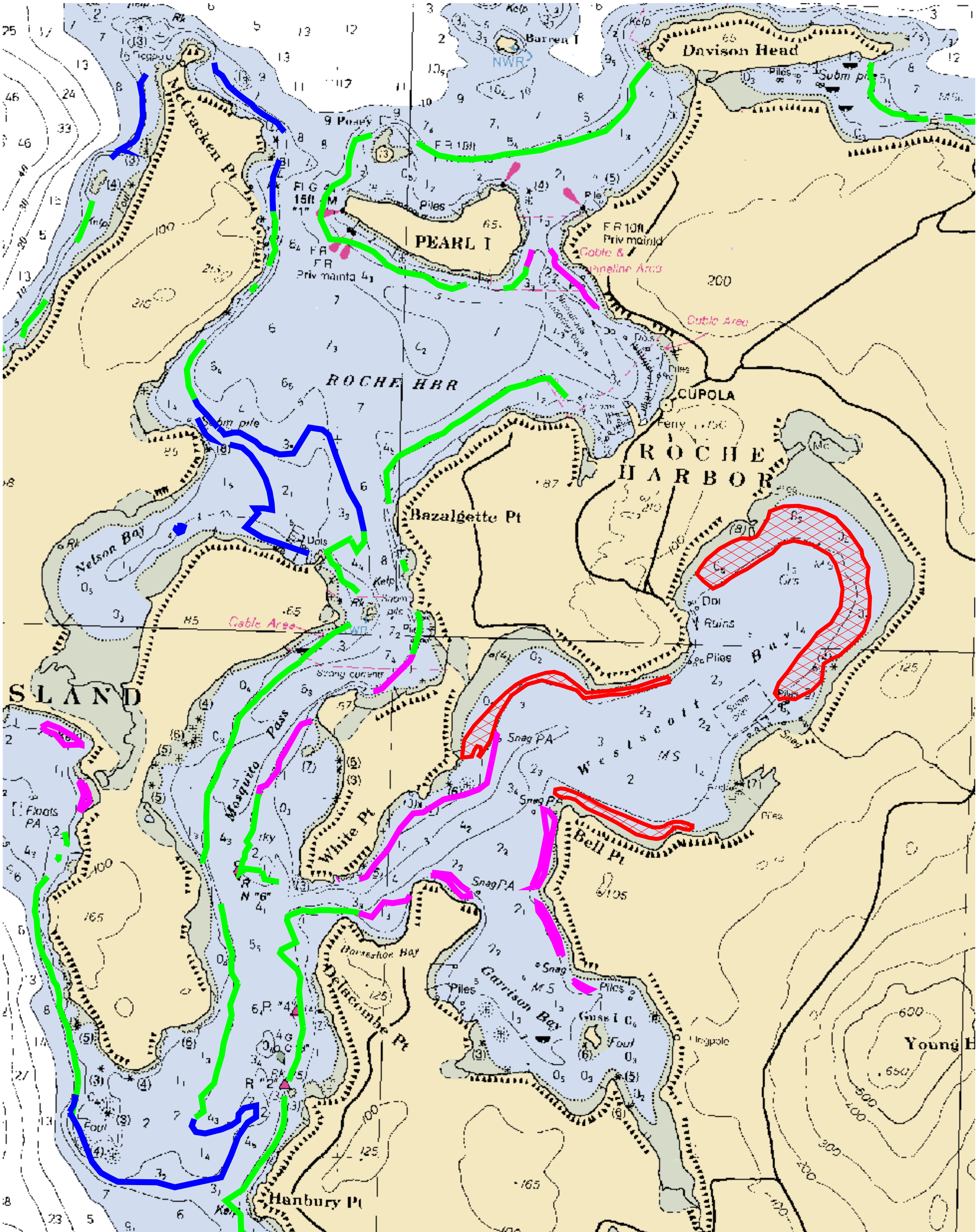
* Source: Washington State Department of Fish and Wildlife, Herring Spawn Deposition Survey.



Depth of Outer Edge of Eelgrass Bed

- 2 - 13 Ft.
- 13 - 21 Ft.
- 21 - 30 Ft.
- WADNR 2000

Comparison of Z. marina distribution between 2000 and 2003 in Westcott Bay.

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APPENDIX A

San Juan County Underwater Videographic and Hydroacoustic Eelgrass Survey Methodology

Prepared by
James G. Norris and Ian E. Fraser

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

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).

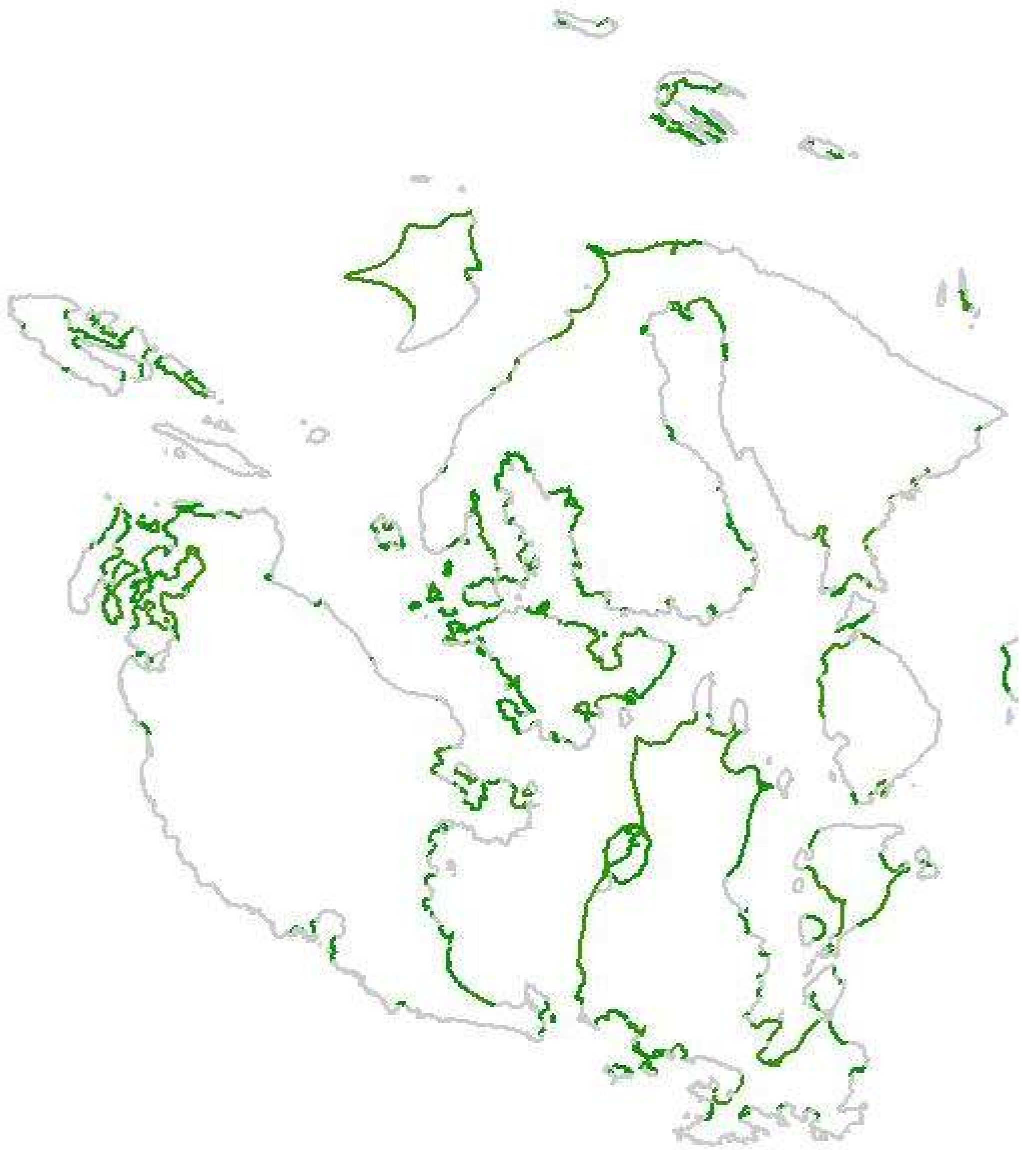

Figure 1. Areas in San Juan County where continuous or patchy eelgrass (both shown in green) was reported by the Washington State Department of Natural Resources ShoreZone Survey (Nearshore Habitat Program 2001).

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.

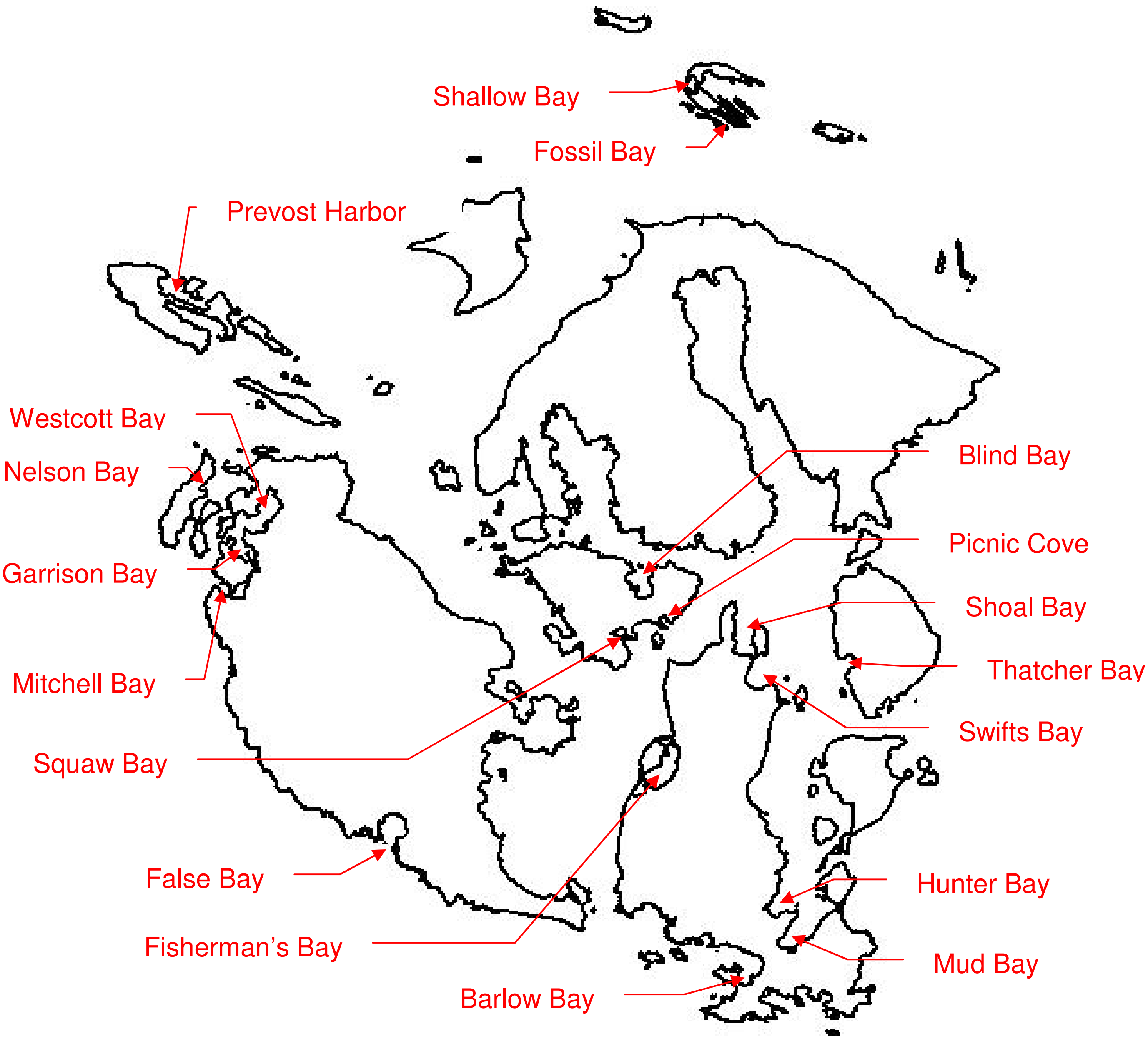

Figure 4. Washington State Department of Natural Resources Submerged Vegetation Monitoring Project flats sites.

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.

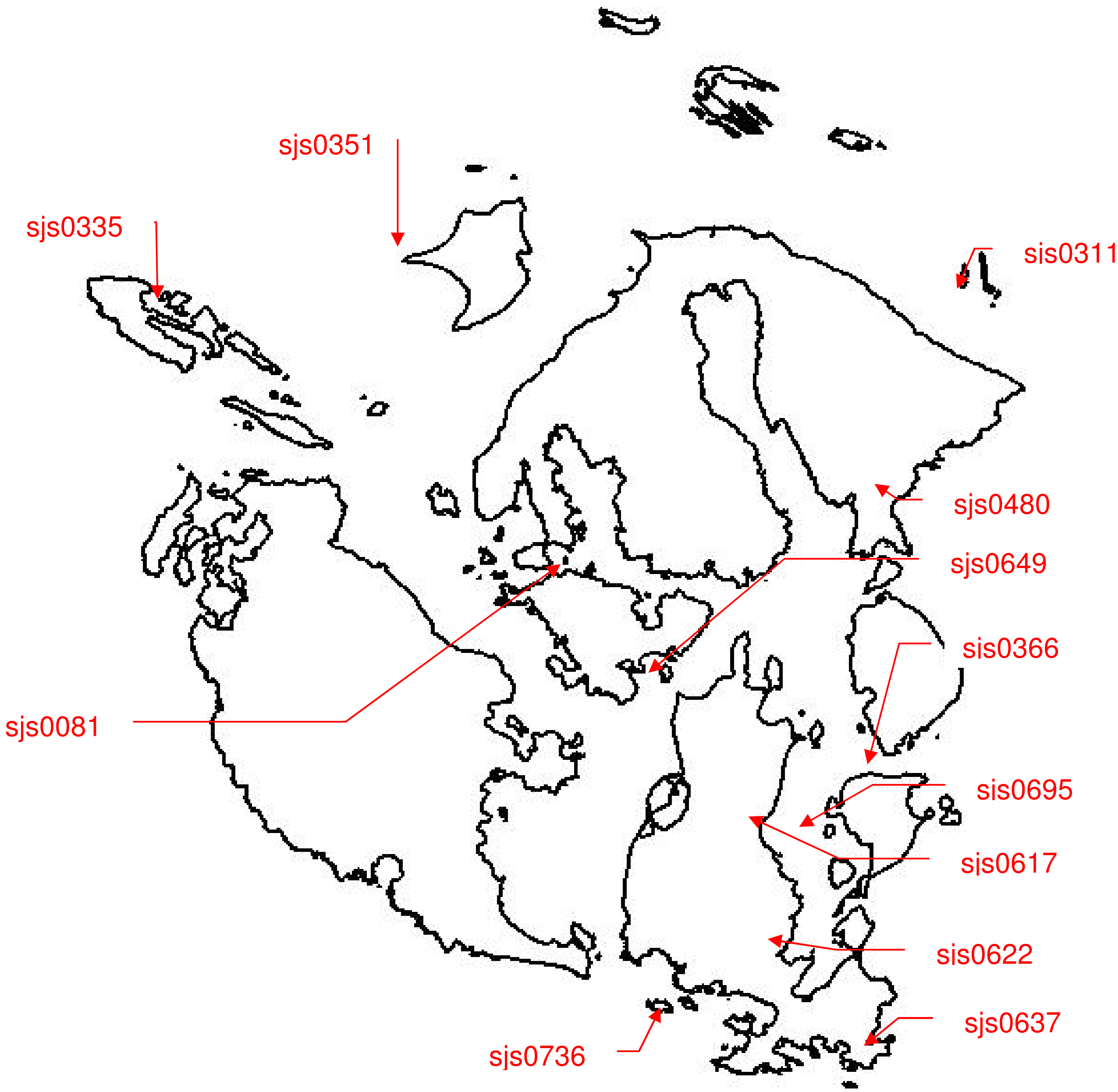

Figure 5. Fringe sites not surveyed because they were surveyed by the DNR SVMP during 2000 – 2003.

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.

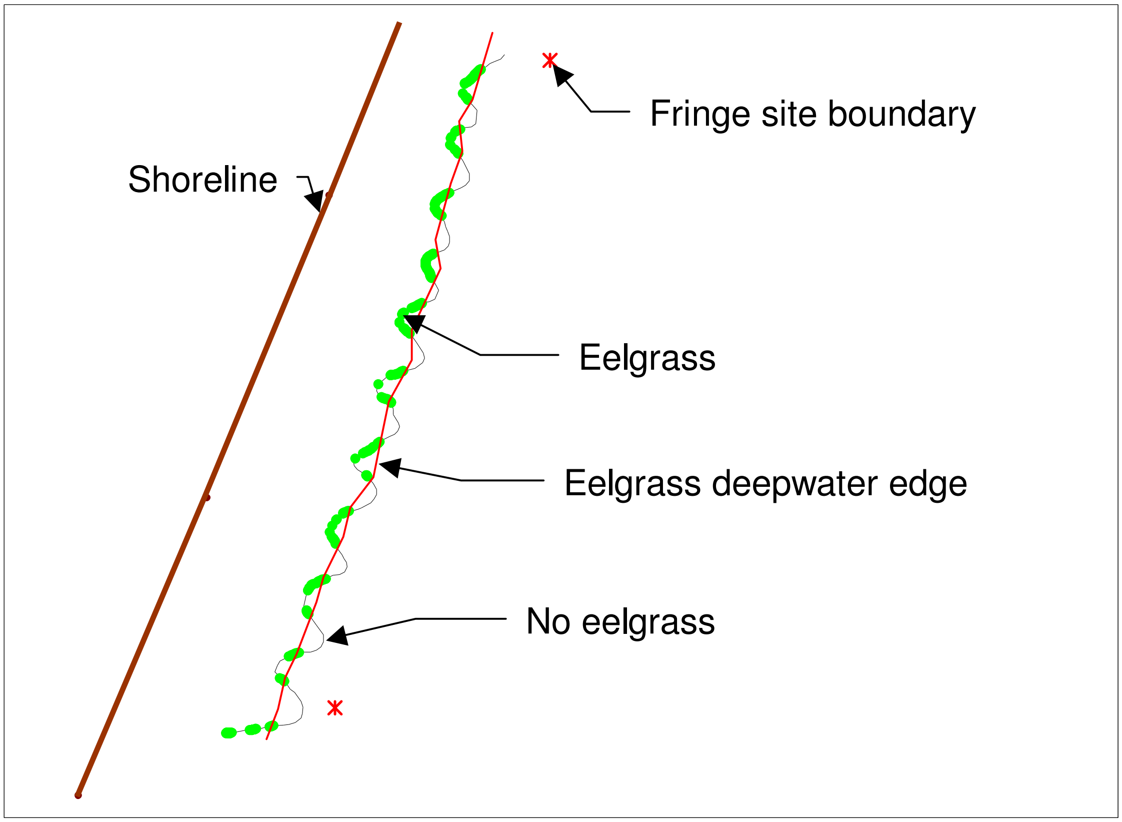

Figure 6. Sample zig-zag transect (site sjs0616).

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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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
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

APPENDIX B

GIS Methodology

San Juan County
Eelgrass (*Z. marina*) Survey
GIS Mapping Methodology

Survey data were received from Marine Resources Consultants and Washington Department of Natural Resources Submerged Vegetation Monitoring Program (SVMP).

Survey data received from Marine Resources Consultants were contained within separate files identified by the survey track ID, e.g. sjs0134. Survey data is in the form of points labeled with the presence or absence of Eelgrass (*Z. marina*). All point data have been reformatted in the following manner;

1. Database columns are labeled SiteCode, Track, Year, Month, Day, Hour, Min, Sec, Eelgrass, Video, Latitude, Longitude.
2. Latitude and Longitude have been converted to Washington State Plane North, Feet, High Precision Geodetic Network (HPGN).

All point data received from Marine Resources Consultants were consolidated into one monolithic table. Microsoft Access was used as the database manager for this project. Point data from Washington Department of Natural Resources, Submerged Vegetation Monitoring Program were combined with the data from Marine Resources Consultants in the Access database to create a database table named "Allpoints".

All points used in this project, regardless of source, can be found in the Eelgrass.mdb file in the table Allpoints. This table is the basis of and is the same as the arcview theme allpoints.shp

All source data, in it's original form, can be found in the directory "SourceData".

Depth statistics for this project were developed by Marine Resources Consultants. The database table "alldepth" in Eelgrass.mdb contains the depth analyses provided by Marine Resource Consultants. All depth data used in the project was provided by Marine Resource Consultants. No depth calculations or analyses were performed in the creation of the mapbook.

The ArcView GIS theme "outerline.shp" was created via interactive heads up digitizing directed by Marine Resources Consultants staff. Following their direction a line representing the outermost (deepest) edge of the surveyed eelgrass using the trackline points where eelgrass was observed. Following the digitizing process the "outerline" theme was segmented to correspond with the endpoints of the survey tracklines. These segments were labeled with the related trackline sitecode.

For purposes of linking depth or other analyses to the outerline theme, all linkage is performed on sitecodes.. Data received with place names as a site code were converted to the actual site code prior to linkage.

Depth data linked to the outerline theme were characterized in ArcView into three depth categories. These depth categories were colored magenta for depths between 2 and 13 feet, green for depths between 13 and 21 feet and blue for depths between 21 and 30 feet.

For display and presentation purposes the outerline theme, colored as described, has been overlayed over digital NOAA Nautical Charts and as a single color line over digital USGS Quad maps.

The GIS techniques used in this project are purely data assembly, coordinate conversion, retrieval and display. There are no analyses presented here.

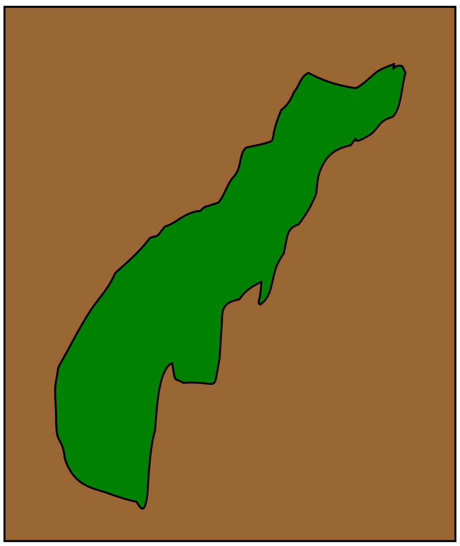
Appendix C:

Juvenile Salmonid Prey and Z. marina (Eelgrass) Landscapes: A Community-Based Monitoring Program

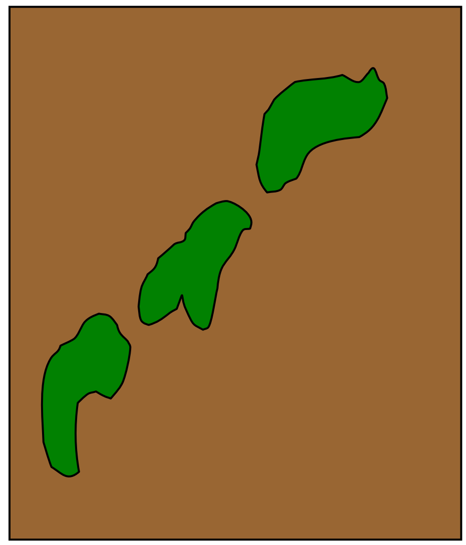
**Prepared by
the Friends of the San Juans**

The leaves of eelgrass (Zostera marina) provide habitat for invertebrates important in the diet of juvenile salmon (Oncorhynchus spp.). The objective of this program is to characterize the species diversity (richness and evenness), of these invertebrates associated with eelgrass landscape patterns.

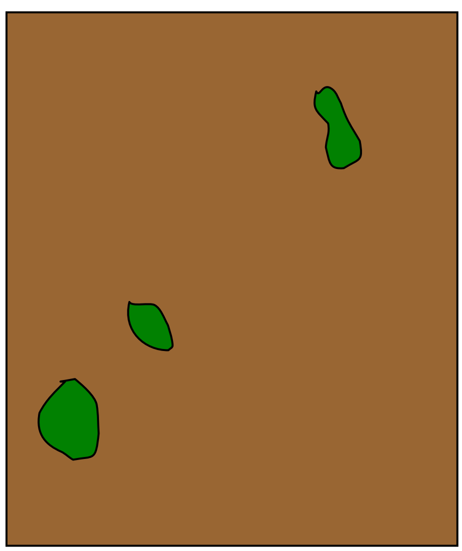
Eelgrass Landscape Patterns



Continuous Cover



Discontinuous Patches



Low Density Fragmented

Field sampling protocol

- Arrive at the location and proceed to a site defined by pre-selected GPS coordinates.

- Mark the site with a PVC stake and deploy a 30 m transect line. To minimize disturbance to the sampling site, unroll the line on shore above the site and then move the line to deeper water parallel with the shoreline. Eelgrass plants must be covered by at least 50 cm of water to effectively sample leaf dwelling invertebrates.

- Describe eelgrass landscape patterns along the transect, include location, time of day and notes on plant phenology using the forms provided.

- Sample 15 randomly selected stations along the transect by choosing the longest leaf from an individual eelgrass shoot at each station and cutting this leaf just above the leaf sheath (see diagram on form provided).

- Gently fold the excised leaf accordion-style, place it and a label (sample #, location and date) in a zip-lock bag.

- Fix all samples in formalin (5%) and seawater at the site. Insure samples are kept upright during transportation to the laboratory.

Sample preserved in the field.

Note that sample number, location and date are clearly visible.

Laboratory Processing

- Remove each excised leaf from the plastic bag, rinse the inside of the bag and leaf through a sieve.

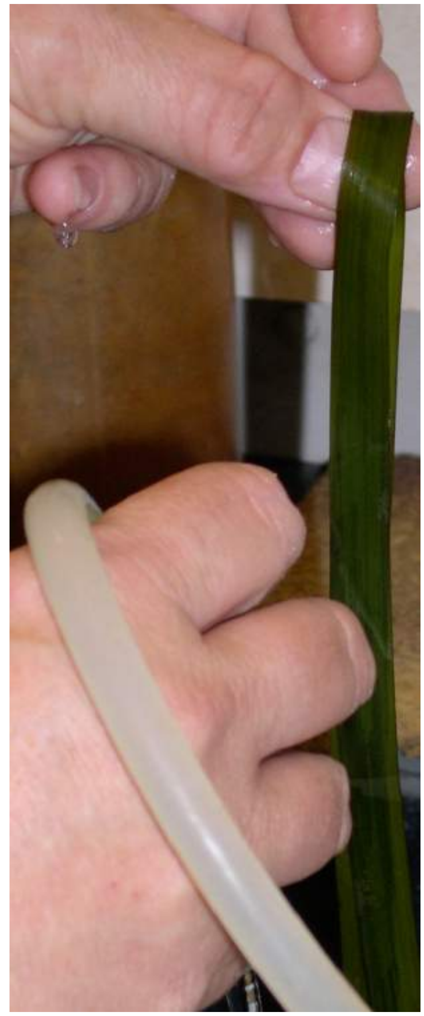
- Place the contents of the sieve into a leak-proof, labeled container.

- Process individual samples as follows:

  Leaves - Scrape off epiphytes, measure length and width, then dry and weigh.

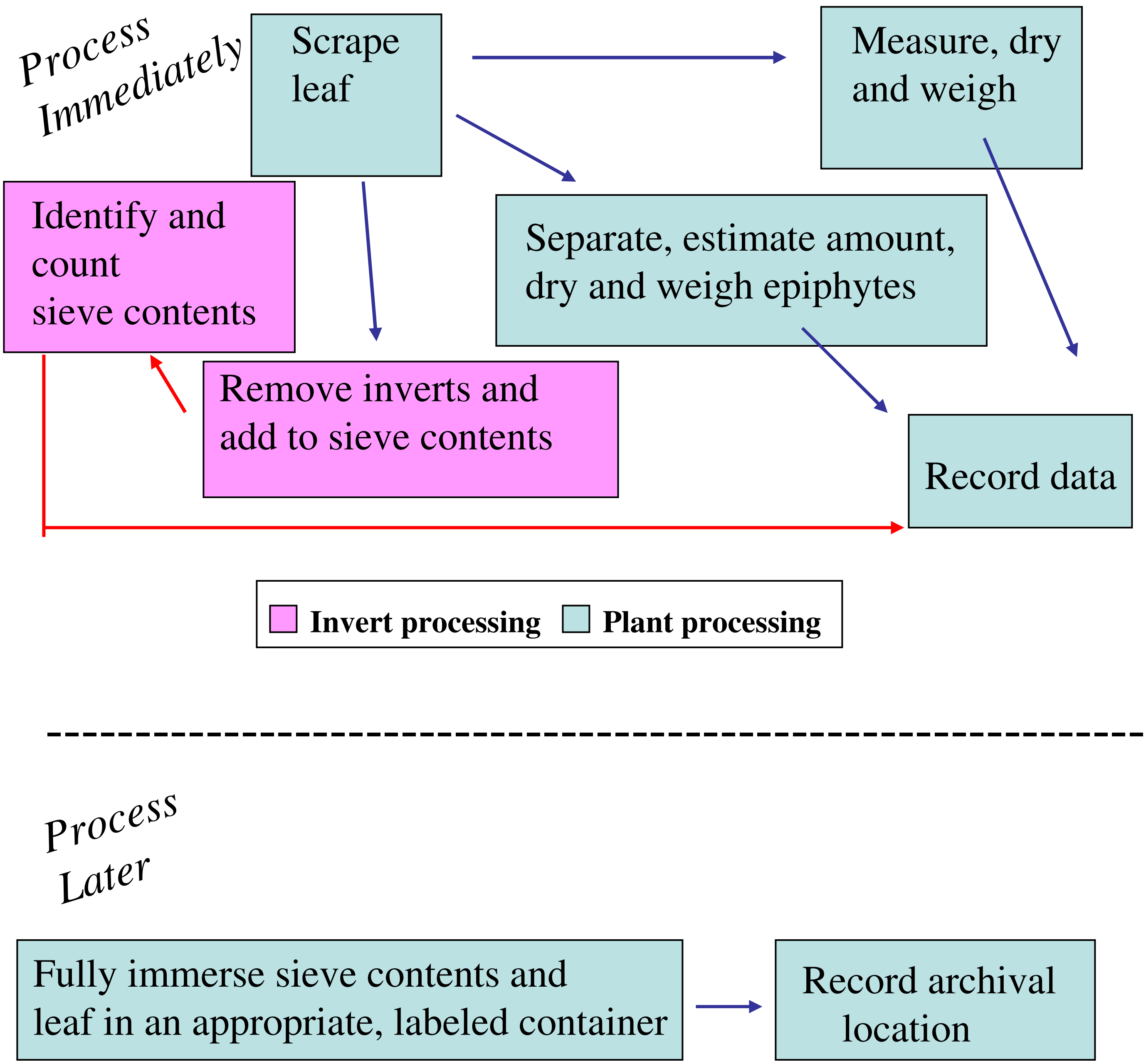
  Epiphytes - Separate into groups, estimate the percent abundance of each group, dry and weigh.

  Invertebrates - Separate into taxonomic groups for identification, key to species if possible, count and record data. Return specimens to sample container.

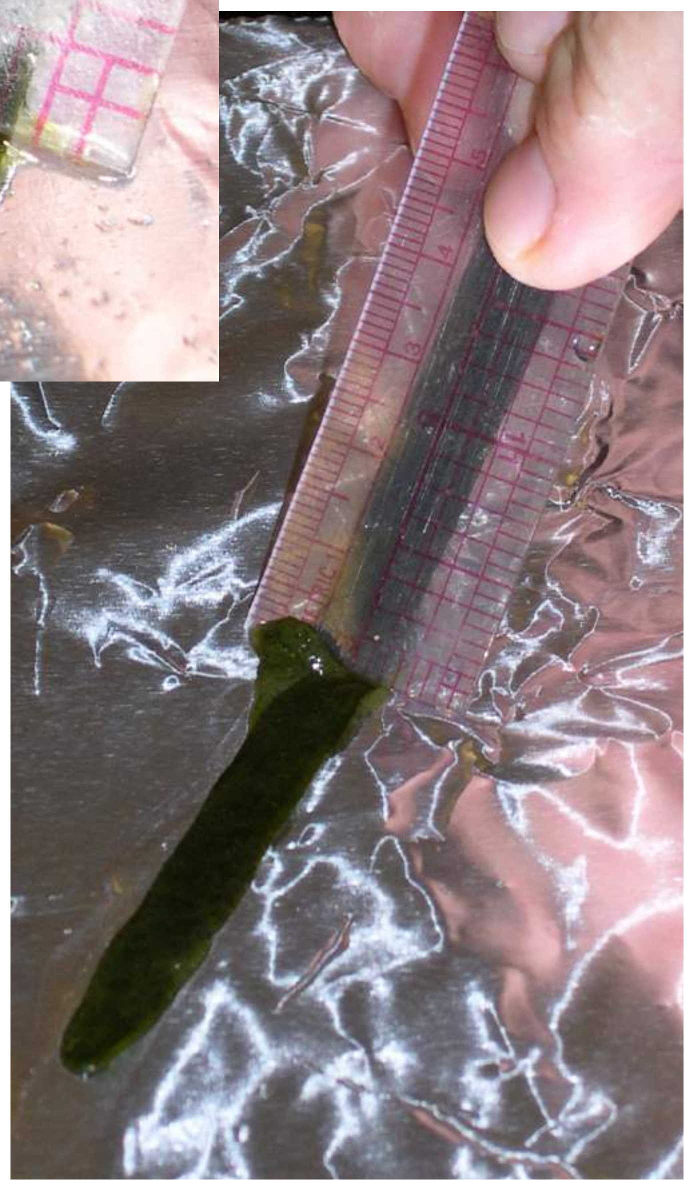


Washing the leaf into a sieve.

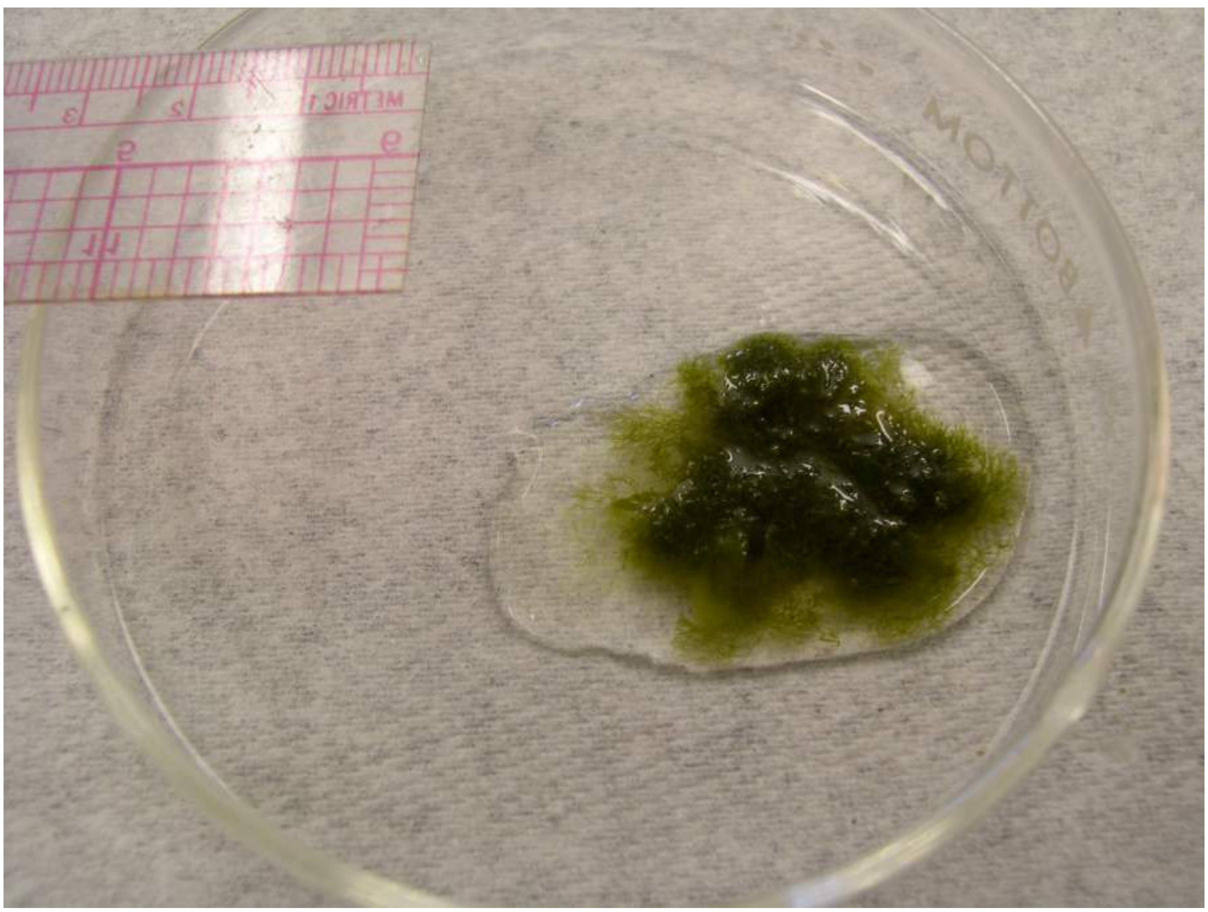
Processing Sequence



Use a straight-edge or ruler, at an angle, to gently scrape both sides of the leaf.

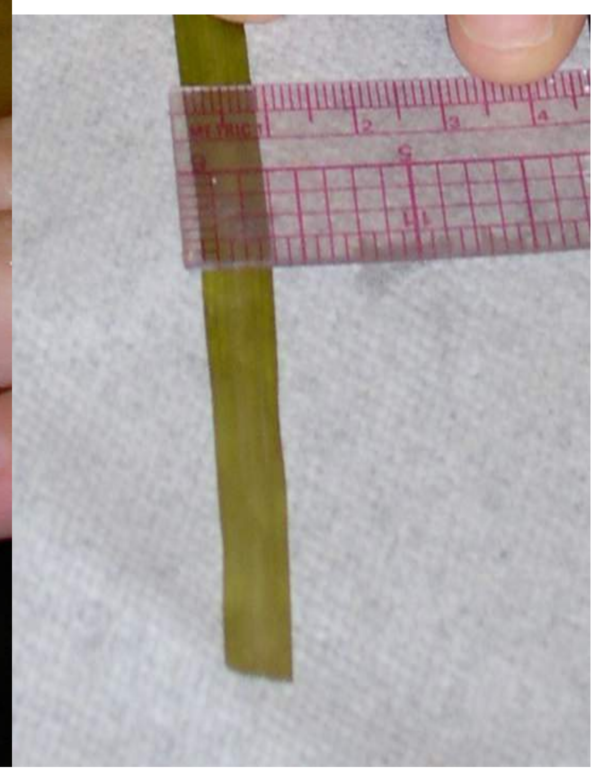


Place scrapings into petri dish and cover with seawater while you measure and prepare the leaf for drying.



Measure length from sheath to tip.

Measure width 5 cm above sheath.



Leaf Dry Weight

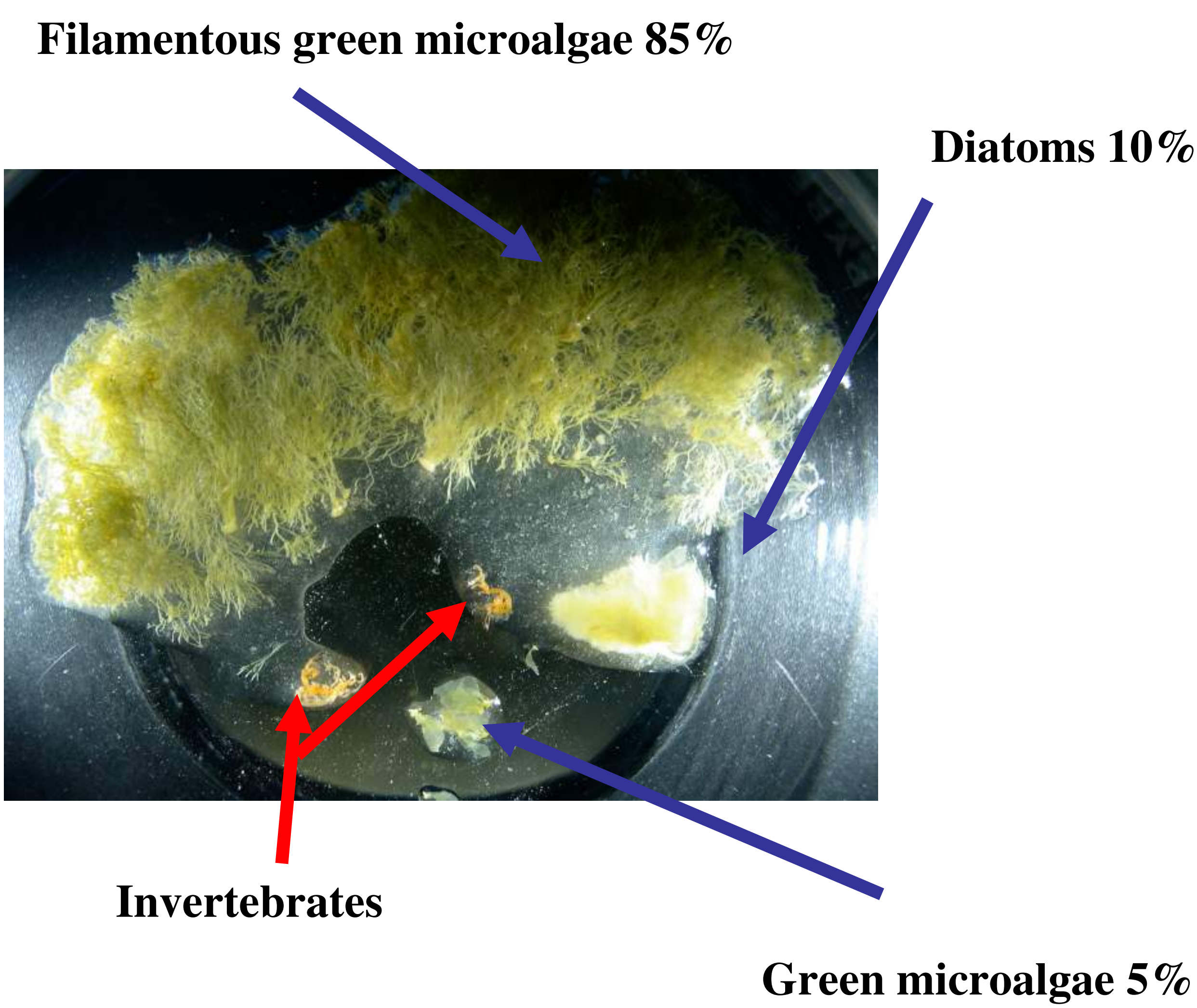
- Place leaf on pre-weighed foil in a pre- heated oven at 60° for 24 hours.

- Remove and weigh.

- Subtract the original (empty) foil weight from the total weight and record weight of the dry leaf.

<u>Epiphyte abundance</u>

Separate epiphytes into categories (e.g., microalgae and diatoms) and estimate amount. To estimate epiphytes first look at the whole amount as 100% then approximate the percentage of each component. Remove any invertebrates and place in the sample container.



Weighing the Epiphytes

- Weigh and record empty foil container.
- Place epiphytes on foil in a pre-heated oven at 60° for 24 hr.
- Remove and weigh.
- Subtract from the original (empty) foil weight from sample.
- Record dry weight.

Sorting and Counting Invertebrates

- Wash invertebrates through a fine-meshed (75 µm) sieve to remove formalin solution--save this solution in original sample jar.

- Wash invertebrates from sieve into a petri dish, with enough water to cover organisms.

- Sort invertebrates under medium power with a dissecting microscope, using fine forceps, and separate by major taxonomic group into puddles of water in another petri dish.

- After sorting, further separate groups in the petri dish, using higher microscope power if needed.

- Record numbers of each taxon.

- After enumeration, return invertebrates to original sample jar for archiving.

Invertebrates associated with eelgrass leaves and eaten by juvenile salmon

Zaus

Tisbe

Dactylopusia crassipes

Harpacticus uniremis

Caprellids, also commonly associated with eelgrass leaves, are not eaten by juvenile salmon

Juvenile stages

Adult male (top) / Female with eggs (bottom)

Process Later

Completely cover leaf with seawater and Formalin (5%).

Place sample label inside the container label the outside as well and archive.

Results from Pilot Project

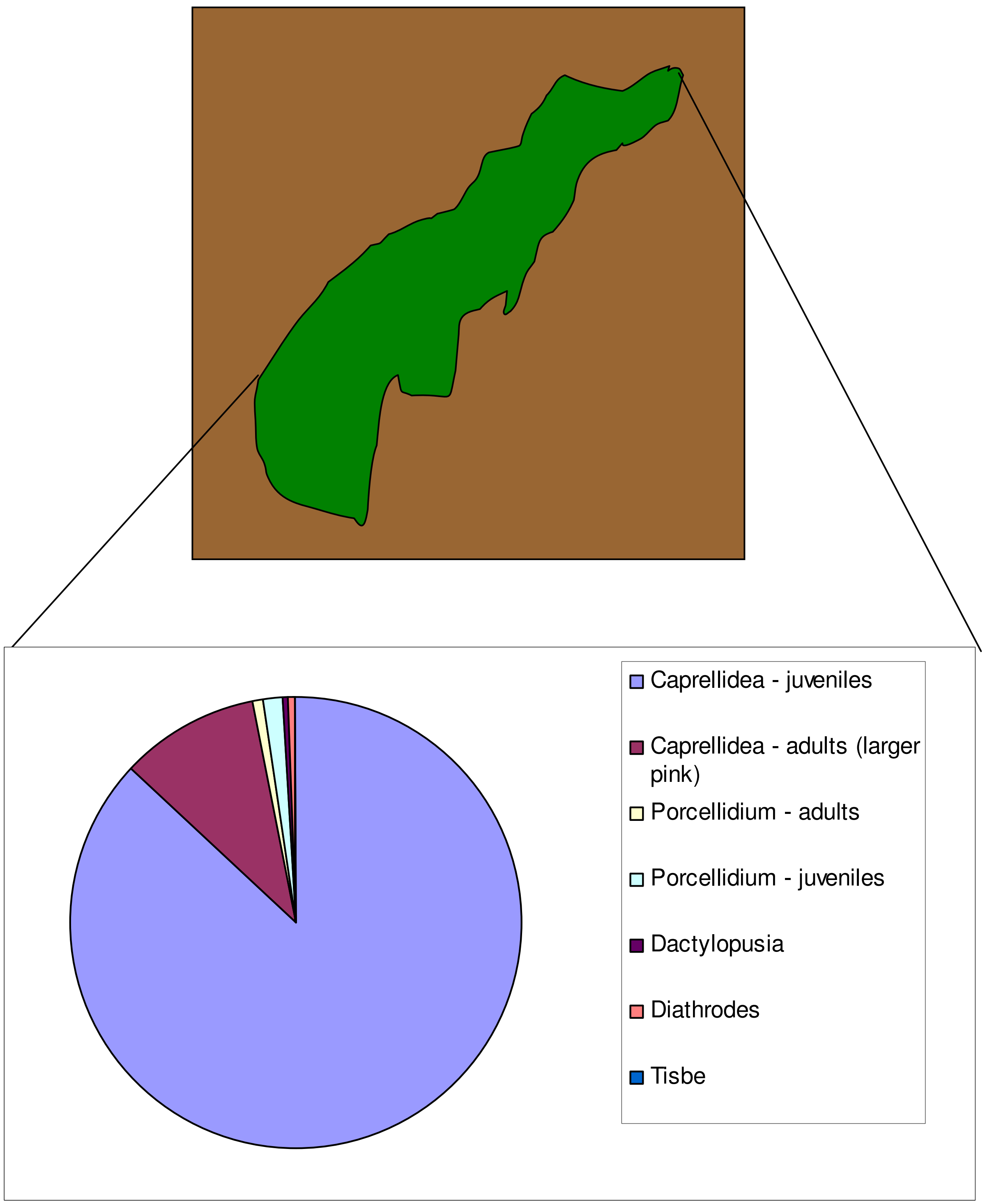
- Five locations sampled in San Juan County from 16 to 21 May 2003.

- All samples archived at the School of Fisheries, University of Washington.

- Five samples from three sites each with a unique eelgrass landscape pattern were processed. While the epibenthic community varied within the individual landscape patterns, differences in more general site level characteristics (e.g. wave exposure, fresh water input etc.) could also explain the variation we found. Having said this, these results are intriguing and suggest further investigation may be warranted.

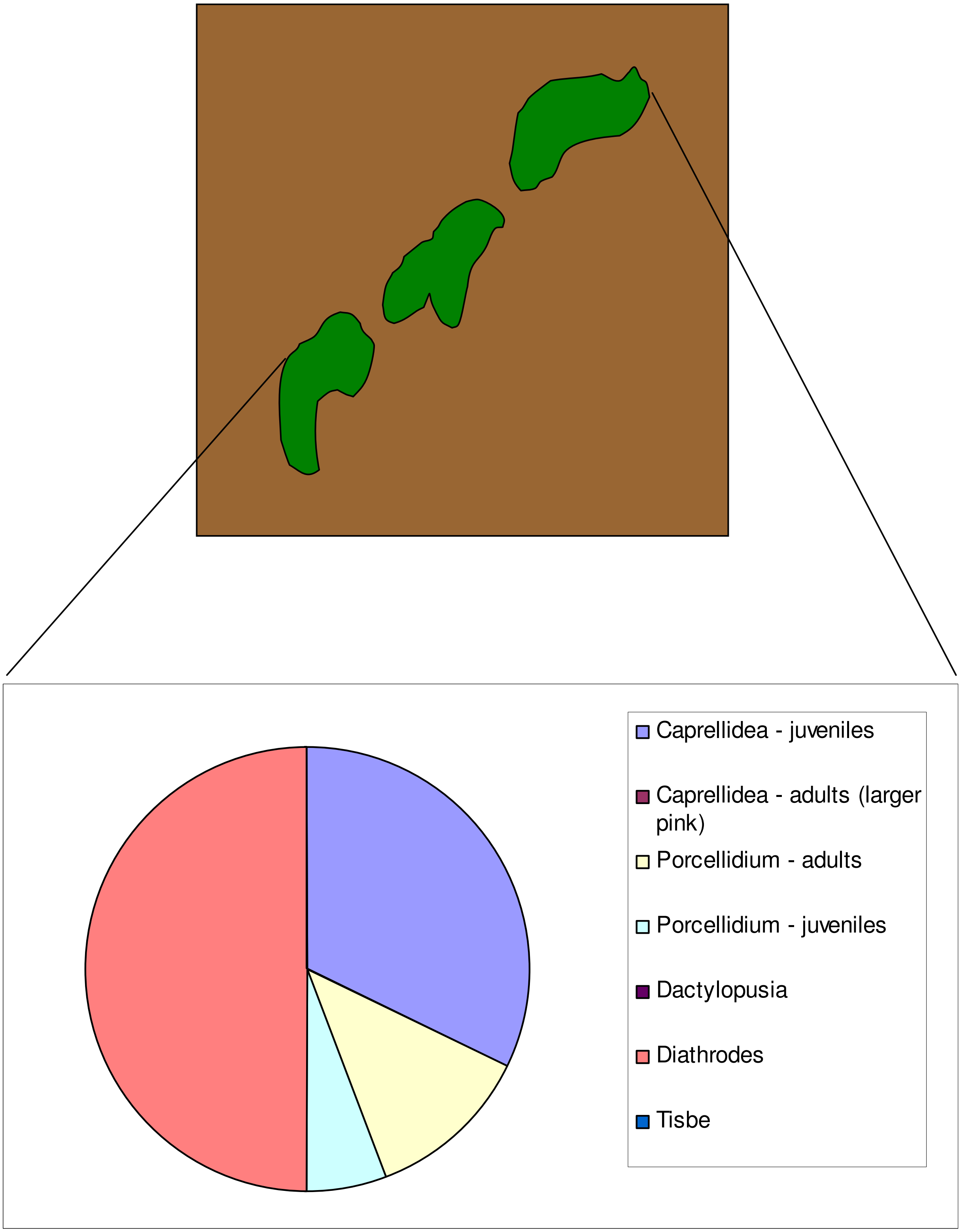
Indian Cove, Shaw Island

Continuous Cover



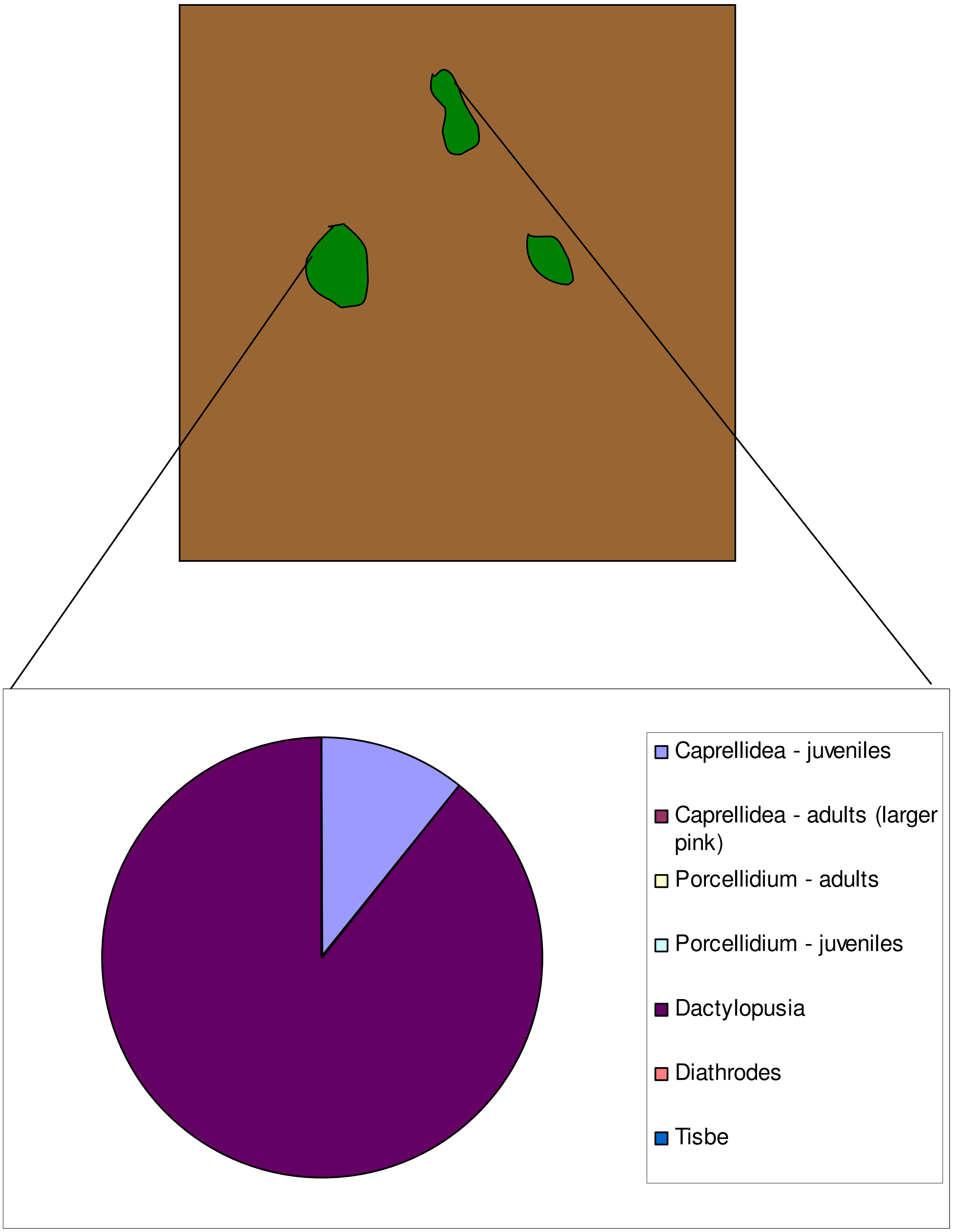
Odlin Park, Lopez Island

Discontinuous Patches



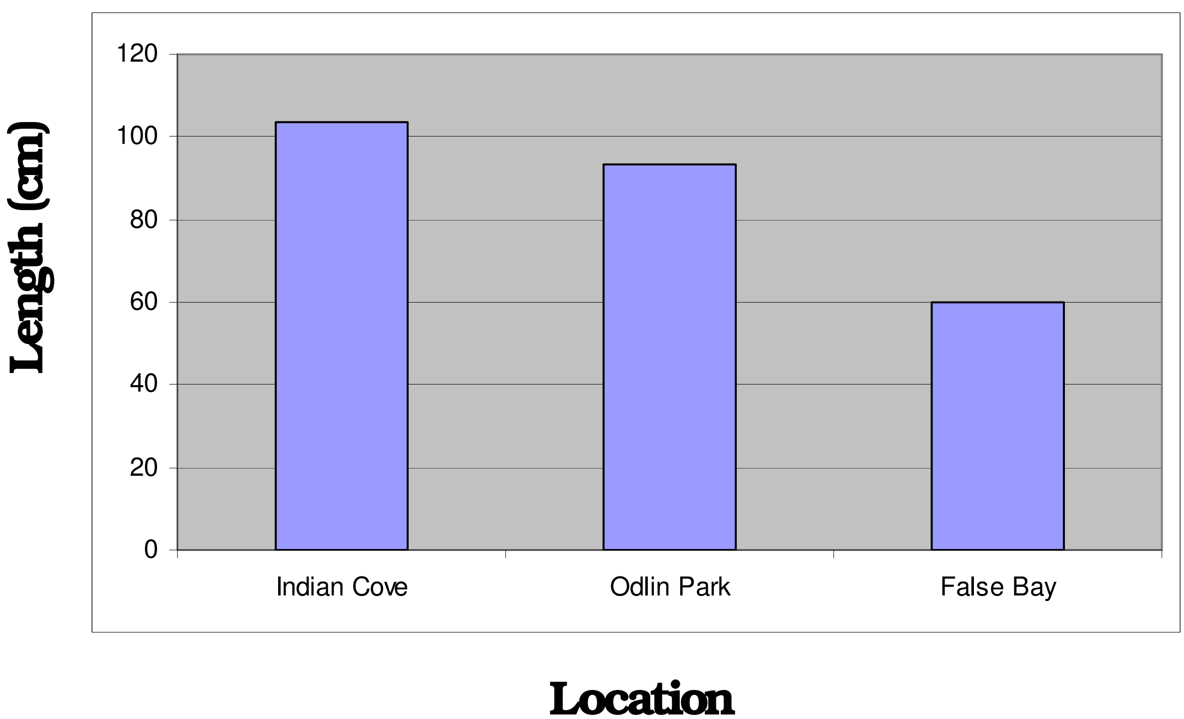
False Bay, San Juan Island

Low Density Fragmented

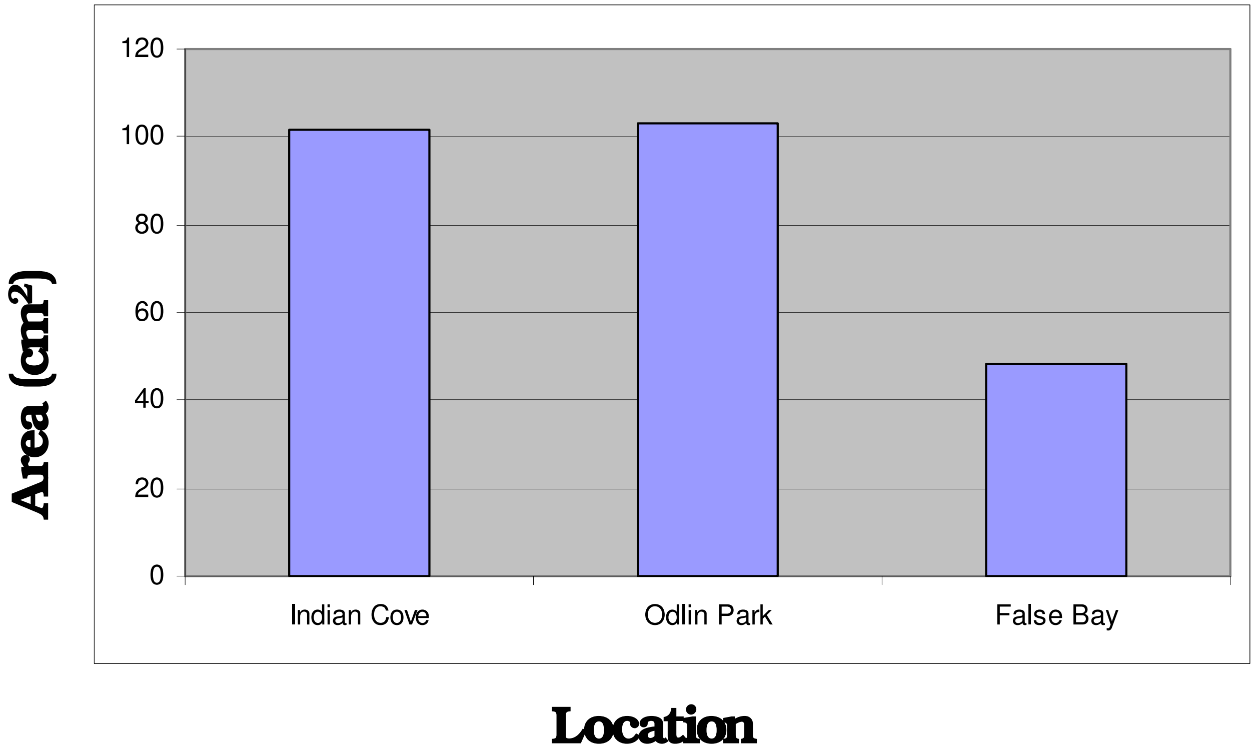


Leaf width (cm)

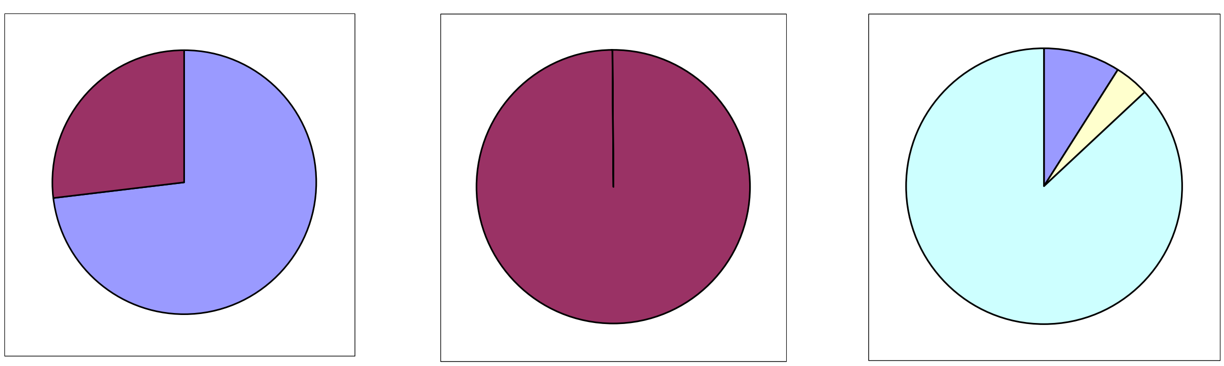
Leaf Length (cm)



Leaf Area (cm²)



% Epiphyte Abundance



Indian Cove **Odlin Park** **False Bay**

= Filamentous Green Algae
= Red Algae
= Green Algae
= Diatoms

Why should we monitor changes in eelgrass patch dynamics?

• Dense continuous stands and discontinuous patches formed by the spread of these clonal plants support a diverse assemblage of invertebrates that are important in the diets of juvenile salmon and other small fish.

•These same stands and patches also provide a refuge for small resident and migratory fish in the nearshore environment.

• Eelgrass landscape patterns can be negatively effected by human activities such as dock and float construction, shoreline modification, propeller
scarring, the swing and drag of anchor chains and nutrient and pollutant input.

Acknowledgements

Funding for this project was provided by Grant No. 01-1222 N from The Interagency Community Outdoor Recreation Salmon Recovery Funding Board

Special thanks to: T. Bidle, J.R. Cordell, S. Wyllie-Echeverria
University of Washington and Letica Hopper.

APPENDIX D

Z. marina Declines in San Juan County, WA Westcott Bay Taskforce Mini-Workshop

Z. marina Declines in San Juan County, WA
Westcott Bay Taskforce Mini-Workshop
26 July 2003

by

S. Wyllie-Echeverria
University of Washington

T. E. Mumford, Jr.
Washington State Department of Natural Resources

J. K. Gaydos
University of California, Davis

S. Buffum
Friends of the San Juans

Abstract

Zostera marina L. (eelgrass) is valuable nearshore resource that provides critical habitat for a number of marine and estuarine animals, including spawning substrate for Pacific herring, in the Puget Sound/ Georgia Basin. Washington State acknowledges this function and has established a policy of no net loss for eelgrass populations. Recent surveys indicate that more than 35 ac (14 ha) of this submerged habitat has disappeared from two documented Pacific herring spawn sties in northwest San Juan County, Washington. The conditions that caused the loss are presently unknown, however, there is concern that similar conditions could be occurring throughout the Puget Sound/ Georgia Basin. At both local and regional scales there is an immediate need to elucidate the reasons for the observed loss of habitat. The intent of this document is to (1) inform agencies and citizens on what is known about this loss of eelgrass stands and (2) assist in the development of a science-based program to identify the potential causes to ensure that similar losses, if preventable, do not occur throughout the region.

Introduction

Zostera marina L. (eelgrass) belongs to the group of submerged vascular plants collectively named seagrasses which grow in sub-arctic, temperate and tropical coastal marine and estuarine waters (den Hartog 1970; Phillips and Menez 1988). Depending on environmental conditions and the fitness of creeping rhizomes associated with sterile, vegetative shoots, *Z. marina* can form large prairies or stands in the Northern Hemisphere (den Hartog 1970; Tomlinson 1974). An annual seed rain from generative shoots also contributes to new growth within extant populations and allows these plants to colonize distant unvegetated "safe sites" in the near shore (Phillips et al. 1983; Harwell and Orth 2002). Perennial stands that include a yearly seed release are common in western North America (Phillips et al. 1983a; Wyllie-Echeverria and Ackerman 2003), however, annual stands are also present at some locations (Bayer 1979; Santamaria-Gallegos et al. 2000). In the Puget Sound Basin approximately 200 km^2 of *Z. marina* is distributed within coastal embayments or linearly along the shoreline (Berry et al, 2003). This vital habitat that sustains important migratory and resident animal species including Dungeness Crab (*Cancer magister*), black brant (*Branta bernicla*) and juvenile salmon (*Oncorhynchus* spp.) and is a spawning substrate for Pacific herring (*Clupea harengus pallasi*) (Phillips 1984; Simenstad 1994; Wilson and Atkinson 1995).

Owing to its overall importance to the ecosystem, Washington State has a no net loss provision to protect *Z. marina* resources (Fresh 1994; Hershman and Lind 1994). The State requires compensatory mitigation if proposed alteration of the near shore environment will result in an impact to extant *Z. marina* populations. The cost of restoring or mitigating seagrass within an impacted site is not trivial: Fonseca et al. (1998) estimate the average cost of restoring a damaged seagrass population to be approximately $91,000/acre. However, if the outcome of water or land-based human activity results in the removal or injury of a *Z. marina* stand, then a plan to restore habitat is mandated (Fresh 1994). If the loss cannot be explained, an inquiry must take place to determine if (1) human action contributed and therefore the responsible party or parties be held accountable and (2) the site can, once again, support healthy stands of *Z. marina*. The present document is the first step in an effort to determine the conditions that resulted in the relatively sudden loss of *Z. marina* resources at sites in San Juan County, Washington in 2003.

What Happened

The severe losses that occurred in Westcott and Garrison Bays (located on the northwest corner of San Juan Island; Figure 1) were discovered during the yearly Pacific herring spawn survey conducted by the Washington State Department of Fish and Wildlife (WDFW) in February 2003. The approximate location of these losses is shown in Figure 2. Because northern latitude populations (stands) of *Z. marina* begin to expand in late winter and early spring (Setchell 1929; Phillips et al 1983b), a second reconnaissance survey was undertaken in May 2003 to verify the February findings.

In preparation for this survey, results of the Washington State Department of Natural Resources, Submerged Vegetation Monitoring Project (SVMP) for the Westcott Bay site were reviewed. The Westcott Bay site was selected in the SVMP random sampling pool for 2000 and 2001 and bottom cover estimates and the mean maximum depth of plant growth are available for both years (Appendix A). Comparison between 2000 and 2001 reveals a decrease of approximately 24% in bottom cover and the depth at which plants were growing was reduced by approximately 2.3 m.

The survey team visited Westcott and Garrison Bays during maximum low water on 18 May (-1.0 m MLLW) and using aerial photos acquired by WDNR in 2001 searched for locations that formerly had *Z. marina* patches. In addition to inspecting sites from the surface by boat, the team also used a WDFW vegetation sampler. A small patch of *Z. marina* was located on the northwest side of Westcott Bay and patches were found on the northeast side of Garrison Bay. When compared to the number of patches visible in the 2001 aerial photo, bottom cover was much reduced. The team concluded that (1) an ongoing effort to census *Z. marina* in San Juan County, using similar protocol as the SVMP, include a survey of Westcott and Garrison Bays as soon as possible (2) other similar embayments in San Juan County should be surveyed in the same time frame and (3) effort be made to convene a scientific panel of experts to review the situation.

Significance of the Problem

Westcott Bay was re-sampled in June 2003 using the same protocol during 2000 and 2001 (see Berry et al. 2003) and preliminary results suggest that approximately 35 ac (14 ha) of *Z. marina* has disappeared (Figure 3). The loss in Garrison Bay is more difficult to quantify but when 2003 survey results are compared to WDNR's 1992 aerial photo of the site, *Z. marina* patches along the western side of the bay are absent (Figure 4).

While loss of valuable habitat results when *Z. marina* cover is reduced, conditions at Westcott and Garrison Bays are particularly troubling because known Pacific herring spawning sites are also lost (Lemberg et al 1997). On a larger scale, preliminary information from WDFW suggests that loss of *Z. marina* habitat may also be occurring at other documented herring spawn sites in San Juan County such as Blind Bay on the northern side of Shaw Island (Pentilla pers. com. 2003; Figure 5). It is also difficult to predict other impacts due to the cascade of changes in an ecosystem that could follow this rapid loss of *Z. marina* cover. Sudden loss of *Z. marina* cover following the wasting disease epidemic (i.e., lethal infection of the slime mold *Labyrinthula zosterae*) in the North Atlantic during the 1930's resulted in community shifts among benthic infauna in coastal embayments (e.g. Stauffer 1937). The impact to community structure caused by the loss of *Z. marina* in Westcott and Garrison Bays is unknown, but should be evaluated. An early warning signal of this shift might be the

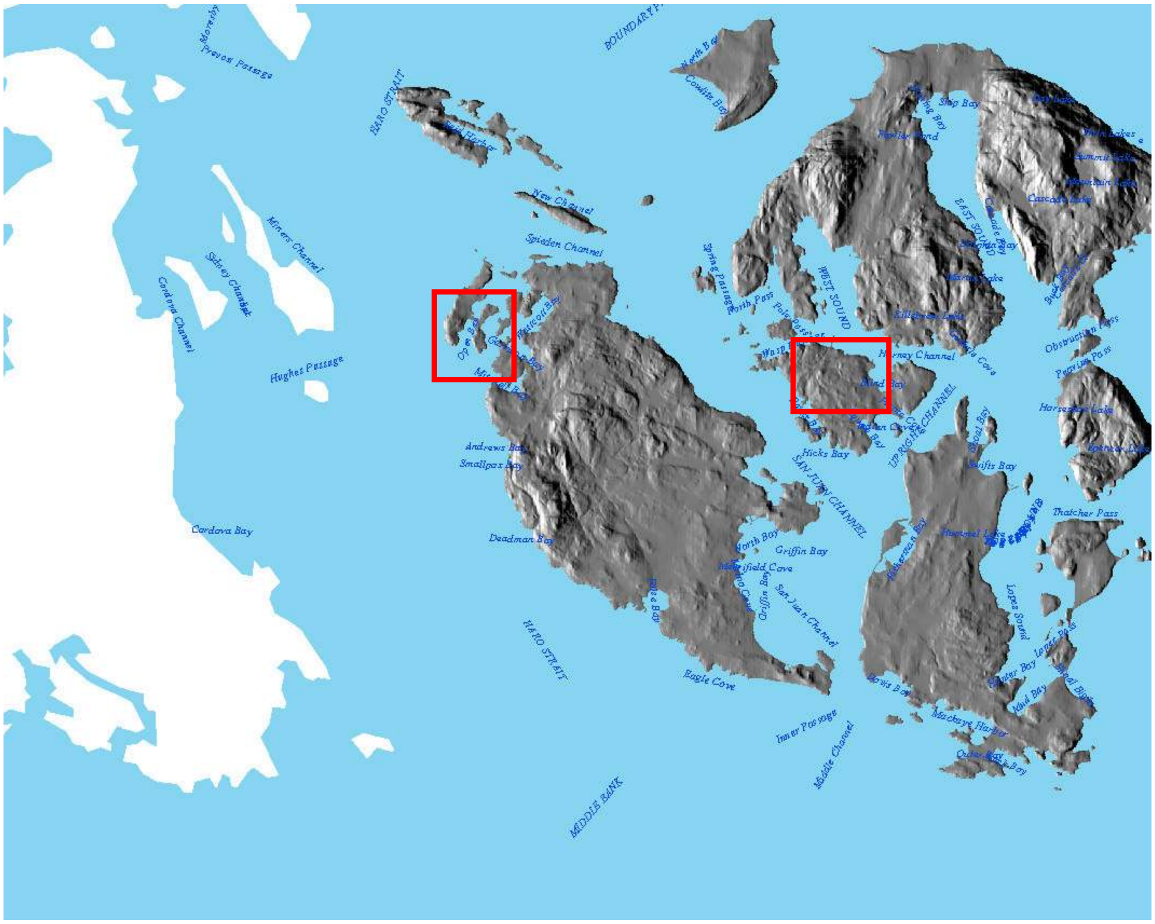


Figure 1. Westcott and Garrison Bays are located on the northwest corner of San Juan Island and Blind Bay is on the north side of Shaw Island, in San Juan County, Washington.

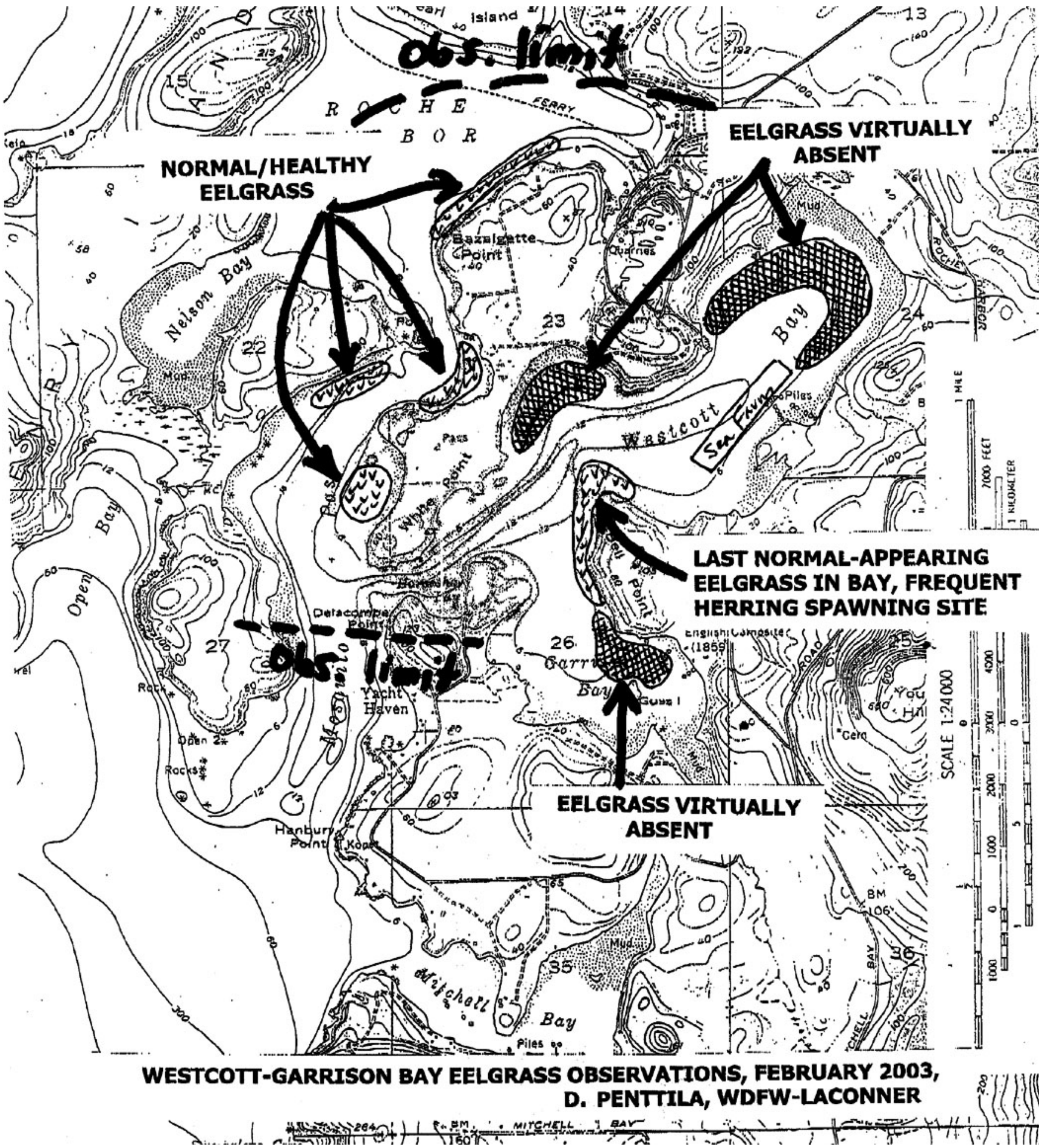


Figure 2. Hand-drawn map depicting the observations of *Z. marina* loss as noted by D. Pentilla, Washington State Department of Fish and Wildlife in February 2003.

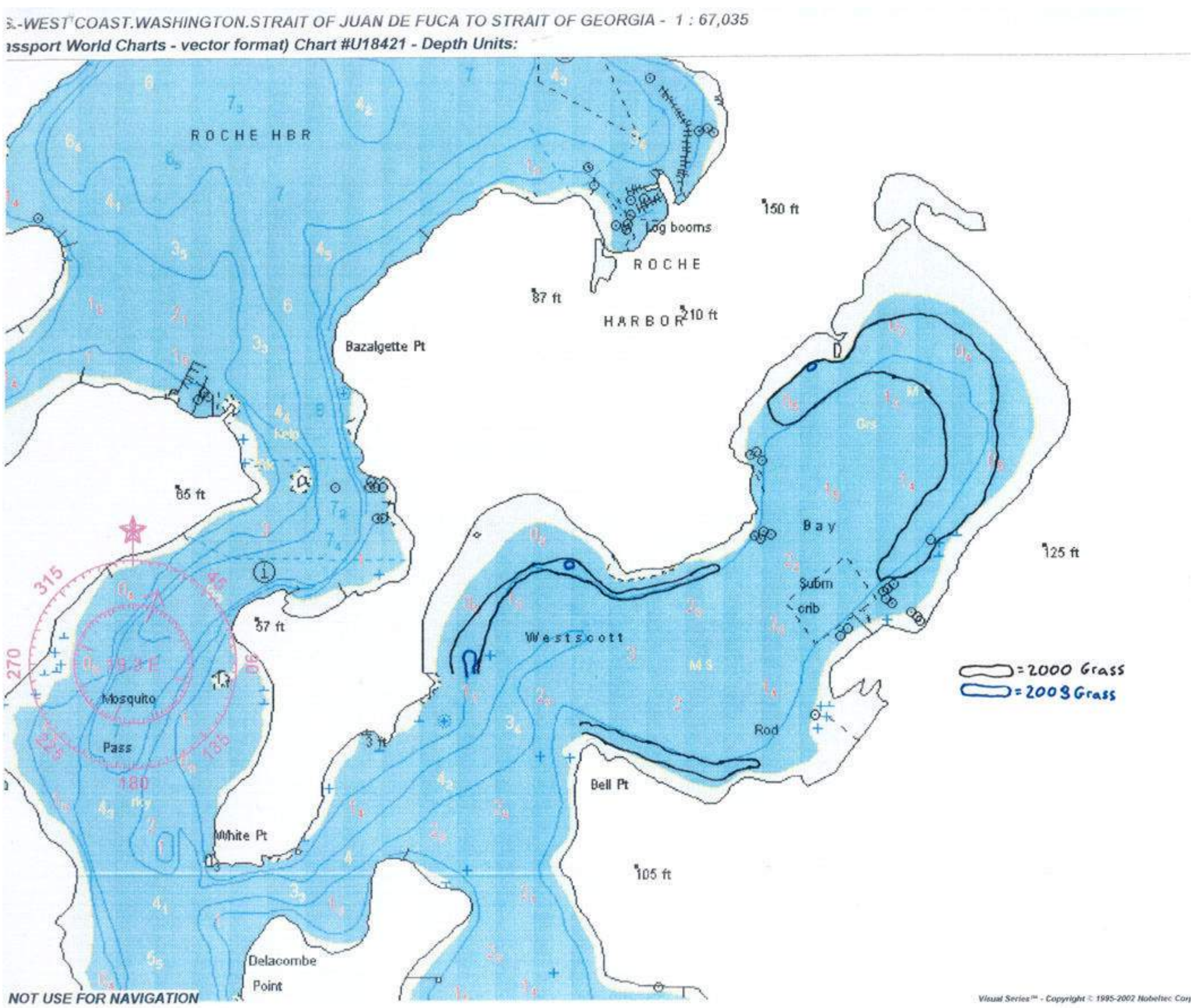


Figure 3. The preliminary hand-drawn polygons above compare the distribution of Z. marina Westcott Bay in 2000 and 2003. A final product will be available from the Friends of the San Juans by the third quarter of 2004.

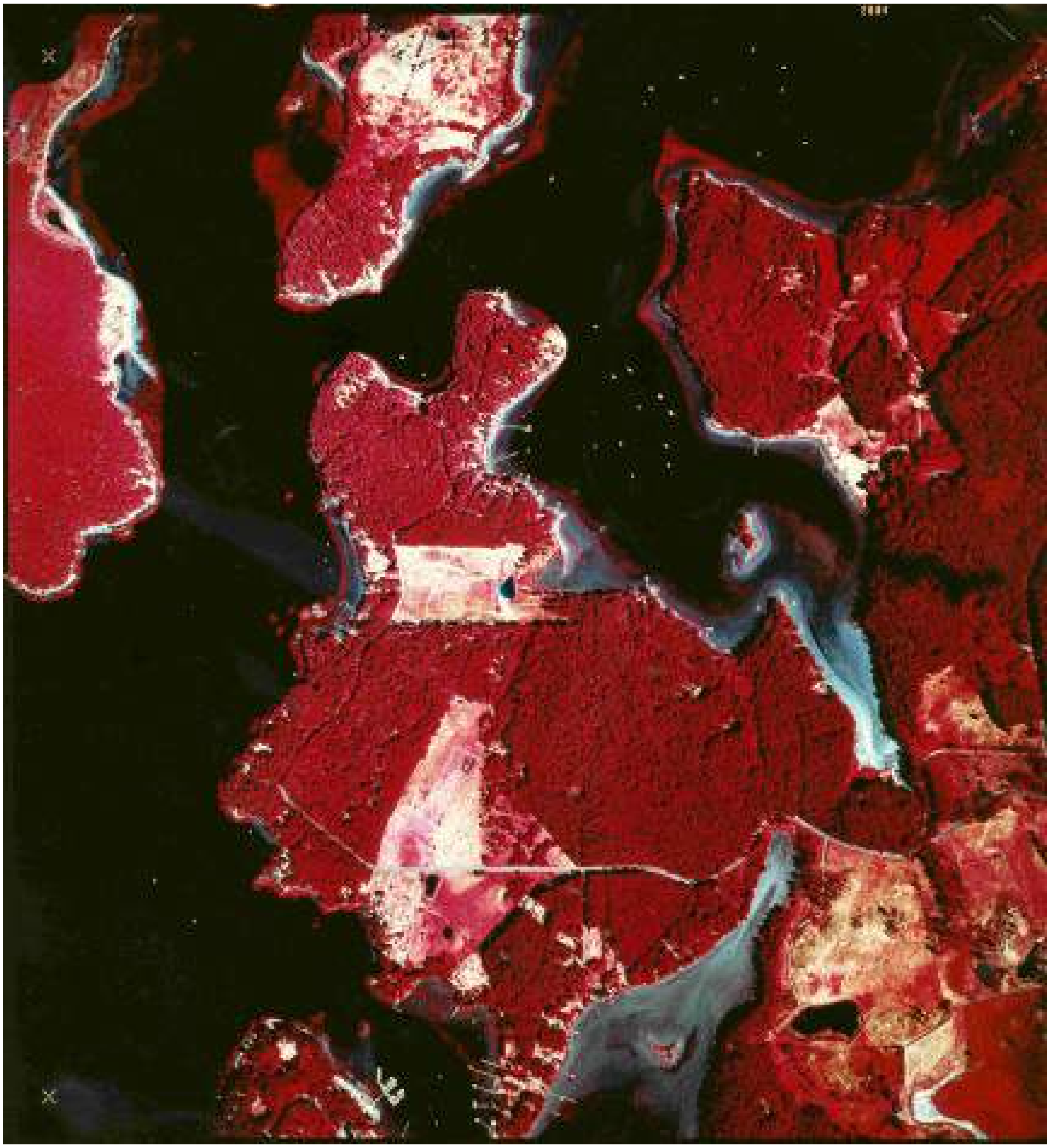


Figure 4. Color infrared aerial photo of Garrison Bay (the large bay in the center of the image) acquired in summer 1992 by the Washington State Department of Natural Resources. Patches of *Z. marina*, visible along the northern shore are absent in 2003 (See Figure 2).

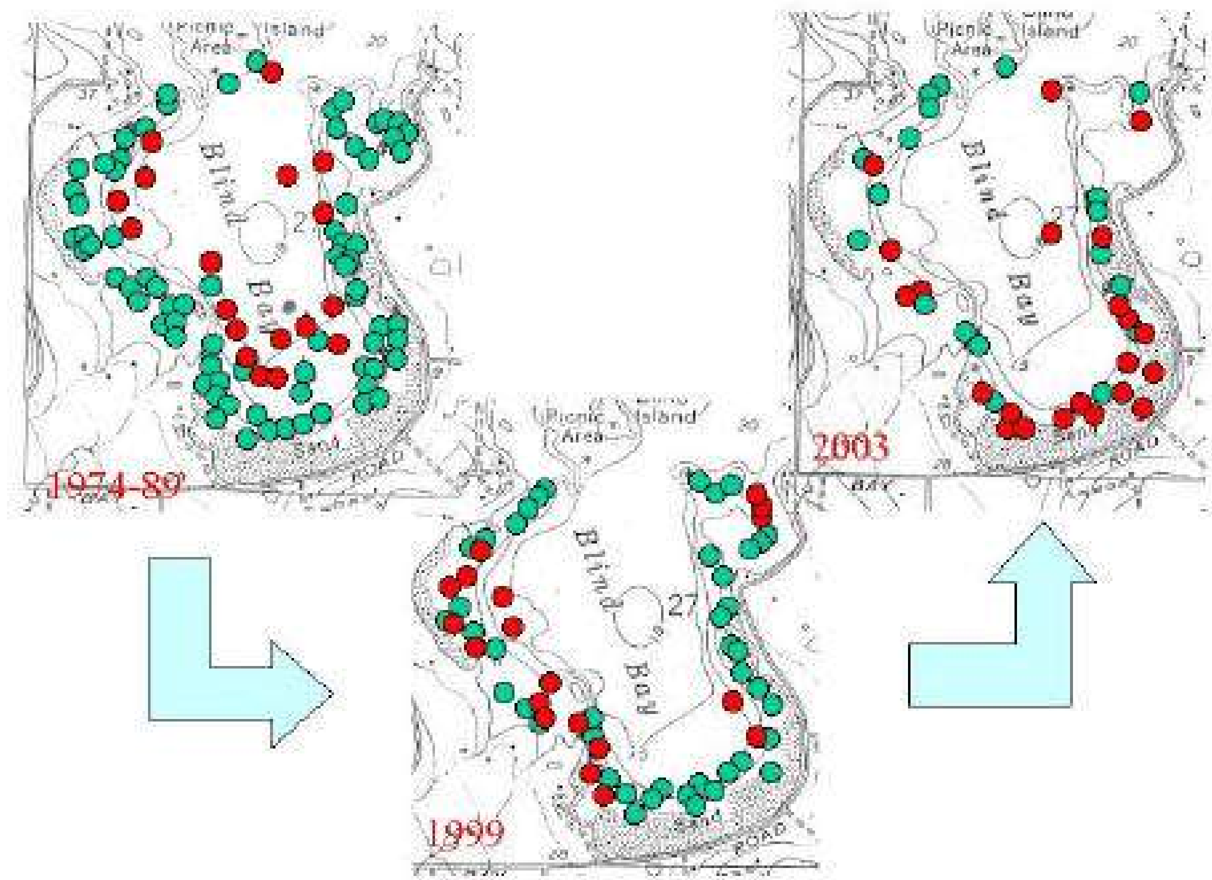


Figure 5. ***Z. marina*** **distribution in Blind Bay, north side of Shaw Island (Figure 1) as observed by the WDFW Pacific herring spawn survey (Green circles =** ***Z. marina*****; Red circles = No** ***Z. marina*****).**

observed loss of sea slugs (*Phyllaplysia taylorii*) which were once "thriving" on *Z. marina* leaves in both Westcott and Garrison Bays and are "not common elsewhere on San Juan Island" (Figure 1; Dethier and Ferguson 1998; Dethier pers. com. 2003). .

Possible Explanations

An array of human-induced and natural events can fragment or completely remove seagrass plants with the disappearance being either chronic or acute (Short and Wyllie-Echeverria 1996). Westcott and Garrison Bays are relatively sheltered embayments that are not often subjected to severe storms hence larger wave events known to destroy large areas of seagrass dominated sand in tropical regions (reviewed in Short and Wyllie-Echeverria 1996). Disturbance events such as disease and anoxia could have occurred and both are known to rapidly destroy and fragment *Z. marina* stands in northern temperate regions (Short et al. 1986; Muehlstein 1992; Plus et al. 2003). Human-induced events that produce sharp declines of the magnitude found in Westcott Bay can be related to the release of a toxic compound such as oil or eutrophication associated the watershed activities of farming and residential expansion along the waterfront (Short and Burdick 1996; Hemminga and Duarte 2000). The preliminary investigations on 18 May did not provide any clear explanation for the loss of *Z. marina* cover. Consequently, a mini-workshop involving regional experts was scheduled to discuss loss of *Z. marina* in Westcott and Garrison Bays and recommend a course of action.

Mini-Workshop

0n 26 July 2003, ten regional experts (Appendix B) met first for a survey of *Z. marina* conditions in Westcott and Garrison Bays during maximum low water (-0.4 m MLLW) and then for a workshop at Roche Harbor Resort on San Juan Island. In a discussion of the extent *Z. marina* of loss in Westcott and Garrison Bays, participants were informed that three detailed *Z. marina* surveys were conducted at Westcott Bay between 1998 and 2001 (Dethier and Ferguson 1998; Berry et al. 2003). When the results from these surveys are woven into a single theme the most plausible scenario is that of a gradual decline which then accelerated in 2002-03 and led to severe local depletion.

Dethier and Ferguson (1998) do not provide bottom cover estimates but their observations support the hypothesis of a gradually declining populations in both Westcott and Garrison Bays: (1) "Eelgrass was found in a virtually continuous band around the shallow subtidal zone of Westcott and Garrison Bays."; (2) Density "was patchy at fourteen of the twenty sites in which eelgrass was present."; (3) "..two property owners (one in Westcott and one in Garrison) independently commented that the eelgrass used to come further onto the shore than it does at this time." and (4) *Z. marina* "consistently" grew adjacent to the shadow cast by over-water structures in the bays. Taken in concert these observations suggest that while intertidal populations of *Z. marina* were declining, subtidal populations were thinning. The SVMP survey revealed that approximately 45 ac (18 ha) of *Z. marina* cover was growing in Westcott Bay in 2000 (Figure 3), an amount that was reduced a year later by 24% and then was virtually eliminated in 2003. This sequence strongly suggests that the *Z. marina* population in Westcott Bay ceased to be self-sustaining at some point between 1998 and 2000, began to thin, and then crashed in 2003.

Workshop participants agreed that (1) the above scenario requires further examination and verification and (2) detailed examination should begin at other locations, especially those with similar geomorphological features to determine the geographic scope and magnitude of other possible declines in the region. Toward this end the following tasks were given priority:

- Compare results from the ongoing 2003 survey at other sites in San Juan County to existing historical data.
- Define the consequences of *Z. marina* loss as it pertains to loss of ecological services for important resident and migratory species such as juvenile salmon, Dungeness crab, Pacific herring and black brant.
- Re-sample transects established by Nyblade (1977) and Dethier and Ferguson (1998) to characterize the potential change in infaunal communities since the decline accelerated.
- Characterize the present state of Westcott and Garrison Bays as habitable sites for *Z. marina* by sampling environmental parameters such as temperature, salinity, light, nutrients and water motion.
- Sample extant *Z. marina* within Westcott and Garrison Bays for the presence of "wasting" disease (e.g. lethal infection by the slime mold *Labyrinthula zosterae*) and plant tissue and sediment for the presence of toxins such as Mercury (Hg), Copper (Cu), Cadmium (Cd), Zinc (Zn), Chromium (Cr) and Lead (Pb) which are known to reduce *Z. marina* fitness (Lyngby and Brix 1984; Wyllie-Echeverria et al. 2001).
- Evaluate the possible effect of bioturbation, especially re-working the sediment by invertebrates (e.g. Dumbauld and Wyllie-Echeverria 2003) and grazing pressure by invertebrates (e.g. Zimmerman et al. 1996;) and birds (e.g. Tubbs and Tubbs 1983) as a mechanism for loss.
- Examine the potential effects of watershed alterations which may have increased nutrient input from compromised septic systems, sedimentation from tree and shrub removal upstream and the leaching of toxins and fertilizers associated with residential gardening and lawn care.
- Establish control sites (n =5) at locations in Puget Sound with a similar geomorphological features to Westcott and Garrison Bays but without the sharp decline of *Z. marina* cover. Such embayments could then serve as reference sites both in a program designed to track potential recovery and to track the status of *Z. marina* health on a regional scale. Include environmental parameters of temperature, salinity, submarine light, and water motion in the vegetation survey effort.
- Design and initiate a transplant experiment, taking into account appropriate genetic status (e. g. Williams 2001) and ensuring disease free status within the transplant program to determine if Westcott and Garrison Bays will support *Z. marina*.
- Develop a conceptual model to guide experimental designs and interpret data and information collected.

Because no obvious causative factor(s) was identified, workshop participants agreed that process studies designed to determine possible causes should be immediately developed in collaboration with colleagues attending the meeting and others in the region. Each participant was also urged to seek out and then communicate possible funding sources to others in the group, including the ability of state and federal agencies to support this research as mandated. To guide this effort, a brain-storming exercise revealed that approximately $100,000 per site was needed to sponsor the research agenda identified in the list above. Given that there is high value placed on the ecological services provided by *Z. marina* throughout the Puget Sound/Georgia Basin, it was decided a second meeting was warranted to bring others into the proposal writing process, discuss the status of fund raising efforts and bring to the public forum the scenario that initiated this workshop.

The loss of 35 ac of *Z. marina*, and possibly more, raises a red flag with respect to the health of the regional ecosystem. As such it requires immediate and decisive diagnosis and action by concerned citizens and agencies mandated with the protection of this crucial resource. Because the distribution of seagrass populations can respond rapidly to both natural and human induced disturbance (Short and Wyllie-Echeverria 1996; Fonseca et al in press), and regulatory authority can only influence human behavior, it is critical that a potential source of damaging human activity be identified and, to the extent possible, arrested to prevent further loss. It is hoped that this preliminary investigation and reported findings underscore the need to identify the sources of disturbance at Westcott and Garrison Bays, and other parts of Puget Sound/ Georgia Basin where a similar scenario might exist, so that appropriate administrative action can proceed.

Acknowledgements

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APPENDIX A

2000-2002 SVMP Westcott Bay Summary

2000

Monitoring was done July 13, 2000.

2001

Monitoring was done August 26, 2001.

2002

No monitoring was done in '02 – Dropped out of rotation

Trends

Table 1 shows a significant decrease in eelgrass coverage at Westcott Bay from 2000 to 2001 (@ 80%CI). The percent relative change was –23.8 ± 21.1 @ 80% CI (high within transect variance at site).

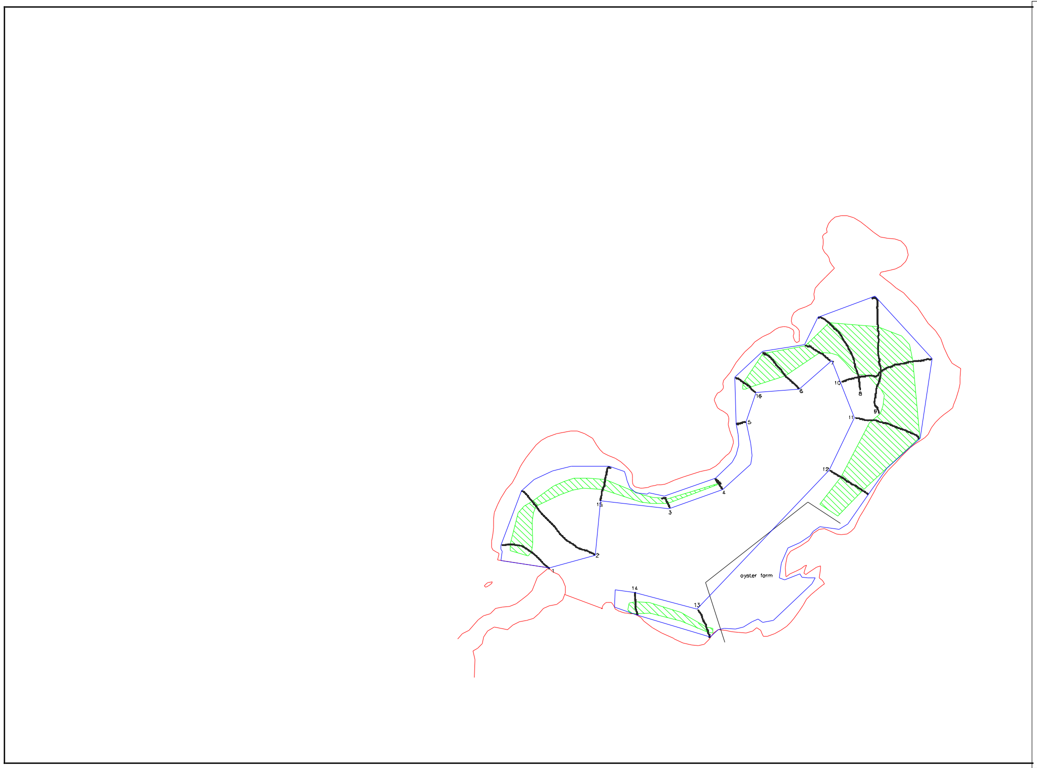
Table 1. Significant BAC change at Westcott Bay from 2000 to 2001

	2000 to 2001			2001 to 2002		
Reference area	**Signficant difference (m^2) at 80% CI**	**Relative % change at 80% CI**	**Relative % change at 95% CI**	**Signficant difference (m^2) at 80% CI**	**Relative % change at 80% CI**	**Relative % change at 95% CI**
Westcott Bay	yes	-23.8 ± 21.1	-23.8 ± 32.3	N/A	N/A	N/A

Site Maps and Transect Summaries

Figures 1 and 2 shows the transect sampling maps with statistics for 2000 and 2001 respectively.

Figure 1. 2000 SVMP Flats 53 (Westcott Bay)



Key:

Red Poly = GIS Polygon or Sample Site

Blue Poly = '00 Sample Polygon (everything outside assumed to have no grass present)

Black lines = transect locations

Green hatch = grass locations

General Summary: Tracks 1-16 were randomly selected from within sample polygon. Oyster Farm area was assumed to have grass present (included in sample poly)

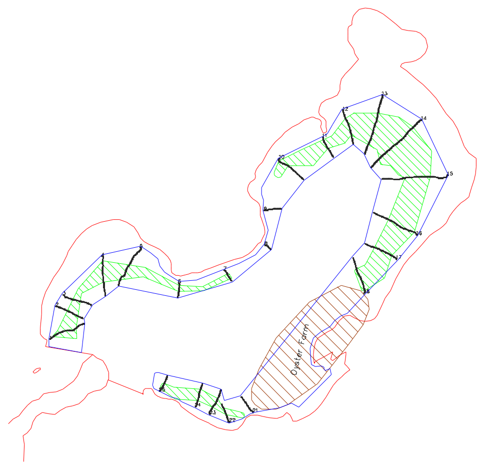
BAC Summary: Tracks 1-16 were used for analysis.

Depth Summary:
Used tracks 1-16 for minimum and maximum depth estimates

Site		Number of Transects	Eelgrass fraction	Estimated Basal Area (m^2)	Estimated Variance	Estimated Standard Error	cv	80% Lower Limit	80% Upper Limit	Patchiness Index
Flats53	**Westcott Bay**	**16**	**0.2555**	**185,270**	**813,367,970**	**28,520**	**0.15**	**148,765**	**221,775**	**5.11**

Site	n	Mean Minimum Depth	Estimated Standard Error	80% Lower Limit	80% Upper Limit	n	Mean Maximum Depth	Estimated Standard Error	80% Lower Limit	80% Upper Limit
Flats53	**15**	**-0.4**	**0.4**	**-1.4**	**0.5**	**15**	**-13.4**	**2.4**	**-18.6**	**-8.2**

Figure 2. 2001 SVMP Flats 53 (Westcott Bay)



Key:

Red Poly = GIS Polygon or Sample Site

Blue Poly = '00 Sample Polygon (everything outside assumed to have no grass present)

Black lines = transect locations

Green hatch = grass locations

General Summary: Tracks 1-25 were randomly selected from within sample polygon. Oyster Farm area was assumed to have grass present (included in sample poly)

BAC Summary: Tracks 1-25 (except 2, 19, 20 and 22 had technical problems or were not randomly chosen) were used for analysis.

Depth Summary:

Site		Number of Transects	Eelgrass fraction	Estimated Basal Area (m^2)	Estimated Variance	Estimated Standard Error	cv	80% Lower Limit	80% Upper Limit	Patchiness Index
Flats53	Westcott Bay	21	0.2389	141,178	457,925,731	21,399	0.15	113,787	168,569	4.17

Site	n	Mean Minimum Depth	Estimated Standard Error	80% Lower Limit	80% Upper Limit	n	Mean Maximum Depth	Estimated Standard Error	80% Lower Limit	80% Upper Limit
Flats53	16	0.0	0.4	-0.7	0.8	16	-5.7	0.3	-6.4	-5.1

APPENDIX B

Mini- Workshop Participants

26 July 2003

Laura Arnold
San Juan County Planning Department

Stephanie Buffum
Friends of the San Juans

Tom Mumford
Washington State Department of Natural Resources

Joe Gaydos
University of California at Davis

Jan Newton
Washington State Department of Ecology

Dan Pentilla
Washington State Department of Fish and Wildlife

Craig Sandgren
University of Wisconsin-Milwaukee

Two Crow Schumacher (*aka* J.D. Schumacher, Ph.D.)
Two Crow Environmental, Inc.

Ron Thom
Battelle Marine Sciences Laboratory

Sandy Wyllie-Echeverria
University of Washington

Rebecca Wyllie-Echeverria
High School Intern