Flora Bank Eelgrass Survey

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Table of Contents

Executive Summary

A DGPS-positioned, towed video camera system was used to collect imagery of eelgrass on Flora Bank. Some experimental eelgrass survey work was also carried out with a Humminbird 997c SI sidescan unit.

A data record of substrate and biota classes was produced for each second of video imagery using a substrate and biotic classification similar to that used by the British Columbia Land Use Coordination Office (LUCO).

All classification data was entered into a relational database. Maps of observed eelgrass distribution were produced using ArcGIS. A library of linked and searchable video annotations was produced.

The following observations regarding the eelgrass survey can be made:

1. A combination of very shallow water depths, strong tidal currents, high turbidity, and large woody debris made conditions for towed video work difficult, and significantly limited the amount of video footage that was collected.
2. Approximately 97% of the observed eelgrass was intertidal, and appeared to be *Zostera marina typica* based on the blade width and plant height as seen in the video images.
3. Approximately 96% of the observed eelgrass is either within, or in very close proximity to, those areas where the 1997 Borstad CASI survey indicated eelgrass to be present. This provides further ground-truthing for the CASI technology, and confirms its capacity to correctly identify eelgrass based on spectral analysis. Also, the fact that there was very little eelgrass observed in areas at a distance from the previously identified beds seems to suggest that the eelgrass has not spread very much since 1997.
4. Given the high turbidity of the site, it is quite possible that any eelgrass growing in the subtidal environment might be severely light limited. Thus, the Flora Bank eelgrass bed is most likely limited to only those regions where the depth is shallow enough to allow good light penetration.
5. Since the Skeena River plume appears to play an important role in controlling the growth of eelgrass on Flora Bank (e.g., through changes in turbidity), further studies on the relationship between the volume, timing, and sediment load of the Skeena River freshet and the growth of eelgrass on Flora Bank should be undertaken, particularly in light of possible changes in the river’s seasonal patterns as a result of global climate change.
6. Based on the intertidal nature of the Flora Bank eelgrass bed, and the significant navigational hazards associated with Flora Bank, it is suggested that future surveys of the eelgrass bed be undertaken at low tide using light-weight, highly mobile craft, such as kayaks, which can be carried along the bed as the survey progresses, thus reducing the risk of stranding. Utilizing experienced paddlers would also be highly recommended.
7. Eelgrass was successfully visualized using the Humminbird 997c SI sidescan unit. In the sidescan image, the eelgrass is seen as rough-textured areas. In the downward-looking sonar image, the eelgrass is seen as “feathery” crests on the sand waves. The image quality of the sidescan data produced by the Humminbird 997c SI unit was comparable with that of images produced by more expensive systems. In light of the significant difference in set-up costs between the Humminbird system and other systems used in scientific research, this may make it possible for small organizations with limited funding to be able to collect high quality sidescan data.
8. The use of the downward-looking sonar to quantify eelgrass height may prove potentially valuable in deeper waters, although this method needs significantly further ground-truthing.

Introduction

The Skeena River originates high in the coastal mountains of northwestern British Columbia, at the edge of the Spatsizi Plateau, and flows 570 km to reach the Pacific Ocean. Draining a total area of 54,400 km^2, the Skeena is the second largest river in the province, and one of the longest un-dammed rivers in the world.

The Skeena River estuary is a unique system in that it does not have a single distinct intertidal delta typical of most estuary systems. Suspended sediments from the Skeena River are deposited in shoals along the lower river and the channels which connect the estuary to the open ocean.[1] This creates a region of extensive mudflats and shallow, intertidal passages around DeHorsey Island, through Inverness Passage, and between Kitson Island and Lelu Island (Flora Bank). Figure 1 shows the Skeena River plume, with its heavy sediment load, in the area around Flora Bank.

These mudflats and intertidal areas have been identified by the North Coast Wetlands Program as important migratory/wintering waterfowl habitat. Several rare species, including the red-listed western grebe and the blue-listed trumpeter swan, brant, oldsquaw and great blue heron have all been recorded in the wetlands. A Department of Fisheries and Oceans fisheries habitat study identified Inverness Passage, Flora Bank, and DeHorsey Passage, in that order, as critical habitats for Skeena River juvenile salmon, as well as important eulachon habitat.[2]

While Flora Bank is recognized as one of the largest eelgrass beds in British Columbia and a region of high habitat value, relatively few studies have been done on the nature and extent of the eelgrass in this area. During August, 1996, Borstad Associates Ltd. of Sidney, B.C. were commissioned to conduct a CASI (Compact Airborne Spectrographic Imager) survey of Prince Rupert Harbour and vicinity. The study was timed to correspond with maximum vegetation development at the end of the summer, extreme low tides and high sun angle to allow for optimum observation conditions. Habitats to be mapped included kelp and eelgrass beds, sandflats, and intertidal vegetation. Bad weather prevented acquisition of useful data in 1996, and the area was reflown in August, 1997 during the next extreme daytime low tide.[3] Figure 2 shows the distribution of eelgrass on Flora Bank as determined by the CASI survey. The amount of eelgrass present on Flora Bank during 1997 as estimated from the CASI study is approximately 0.80 km^2. Note that almost all of the reported eelgrass is located in the intertidal zone.

In 2002, an Eelgrass Stewardship Project was initiated in Prince Rupert by the Prince Rupert Community Fisheries Development Centre (CFDC) in partnership with local First Nations Band Councils, Fisheries and Oceans Canada's Habitat Enhancement Branch, SeaChange Marine Conservation Society, and local World Wildlife Fund (WWF) representatives. During that year, mapping and monitoring of intertidal eelgrass was undertaken by boat and underwater camera at Delusion Bay (Lat N54 15.54", Long W130 23.060"), Casey Cove (Lat N54 16.775", Long W130 23.063"), and Dodge Cove (Lat N54 17.303", Long W130 22.848"). In following years, WWF took the lead role in eelgrass mapping in Prince Rupert, and data was submitted to the Community Mapping Network (CMN) as part of their Eelgrass Bed Mapping project. However, little additional information was gathered on the Flora Bank eelgrass bed.

[1] Hoos, L.M. 1975. The Skeena River estuary status of environmental knowledge to 1975. Special Estuary Series No. 3. Environment Canada, Vancouver, BC, 418 pp.

[2] Higgins, R.J. & Schouwenburg, W.J. 1973. A biological assessment of fish utilization of the Skeena River estuary, with special reference to port development in Prince Rupert. Dept. of Envir., Fish. & Mar. Ser. Tech. Rep. 1973-1.

[3] Forsyth, F., Borstad, G., Horniak, W., & Brown, L. 1998. Prince Rupert intertidal habitat inventory project. Unpublished report to the Prince Rupert Port Corporation, the Canadian Department of Fisheries and Oceans, and the City of Prince Rupert. 33 pp.

In 2008, WWF had discussions with Ocean Ecology regarding the use of a towed video camera system to observe eelgrass on Flora Bank. In particular, since subtidal eelgrass occurs commonly in the North Coast area, and since the CASI study was limited to eelgrass in the intertidal region, there was a keen interest to see if the Flora Bank eelgrass bed extended any significant distance subtidally. After several attempts in 2008 to collect video from the site, a successful set of video data was collected during May, 2009.

Flora Bank Eelgrass Survey Methodology

Towed Benthic Video Survey Design

Towed Video System

A DGPS-positioned, towed video system was used to collect imagery of the seabed (similar to the Seabed Imaging and Mapping System [SIMS] used by CORI). This system was a custom-built model designed for use in the steep, rugged terrain characteristic of British Columbia fjords. Typical tow speed was 0.9 knots. The towed video system had two video cameras - one in a forward-looking orientation and one in a downward-looking orientation. Both cameras have a Sony 1/3" super HAD color CCD with 480 lines horizontal resolution (768 x 494 pixels) and 0.5 lux @ F 2.0. These cameras provided composite video signals to an overlay unit that stamped the DGPS position data (latitude/longitude), together with date and time, on each video frame. The video signal was also displayed in real-time on the vessel, where it was used to adapt the survey to particular features that were seen while underway. High intensity white LEDs were mounted on the camera to provide additional illumination when it was required.

The altitude of the underwater camera was controlled using a hydraulic winch which was operated from the bridge while monitoring the real-time video feed from the camera. Typically, the camera was towed approximately 1 m above the seabed.

Video Recording System

The dual analog camera signals were recorded using a digital video recorder directly onto a hard drive. After the survey was completed, the raw video data was copied onto DVDs. As the digital video recorder creates video files in a proprietary format, software to view and convert the video data into other formats was also provided on each raw video DVD.

Survey Design

Originally, a grid survey of the Flora Bank area was planned in 2008. However, after attempting to do several of the planned transects across Flora Bank, it became apparent that even at high spring tides, the water was too shallow (less than 2 m) to allow safe passage across the highest part of the bank. Additionally, strong tidal currents and uprooted trees and other debris deposited by the Skeena freshet made navigation in the very shallow water hazardous.

In 2009, a new survey plan was devised. Six transects were performed along bearings which radiated out from the center of the highest part of Flora Bank (see Figure 3). The transects started as close to the center of Flora Bank as was possible, generally in the lower intertidal zone or to the limit of safe navigation. While the ship's draft is approximately 2 m, the actual minimum safe operational depth varies depending on the topography (e.g., are there rocks or other obstacles which could create hazards to navigation), tidal height (e.g., is the tide rising or falling), winds (e.g., is the wind blowing the ship into shore), and tidal currents during the survey. Safety of the ship and personnel are the primary considerations when navigating in shallow water. The transects then progressed radially away from the center of Flora Bank along the designated bearing until a depth was reached beyond which no further eelgrass was observed.

Bathymetric Survey Design

Depth and Hardness Data

Seafloor hardness and depth data were collected using a 50 kHz hull-mounted transducer while carrying out the video survey. Sounding data were recorded every second and logged on a computer.

Sidescan Sonar Data

Sidescan sonar images of the eelgrass were collected using a Humminbird 997c SI sonar unit operating at 455 kHz. Simultaneously, the Humminbird unit also collected seafloor depth data using downward-looking sonar operating at 200 kHz. The transducer for the Humminbird unit was mounted in a towfish which was towed from the stern of the vessel at 2 m depth. Sidescan and downward-looking sonar data were recorded to an SD card in the proprietary Humminbird SON file format.

Classification and Mapping

Database of Species and Substrate Classifications

Raw video of the transects was reviewed and classified using a substrate and biotic classification similar to that used by the British Columbia Land Use Coordination Office (LUCO). A data record of substrate and biota classes was produced for each second of video imagery.

The geology database contains information on substrate type (Table A1 in the Appendix) and percentage substrate cover (Table A2 in the Appendix). Anthropogenic features were mapped as part of the geological inventory.

The biological database captured detail on seabed biota within two general categories, vegetation (Table A3 in the Appendix) and fauna (Table A5 in the Appendix). Up to three faunal and floral types were evaluated for each second of video and given distribution codes. Vegetation coverage classes (Table A4 in the Appendix) and faunal distribution classes (Table A6 in the Appendix) were also recorded. Note that very small species (e.g., barnacles, small tube worms, small algal species), infauna (e.g., clams), cryptic fauna (e.g., flatfish, decorator crabs), or hidden fauna (e.g., under kelp fronds) were often not identified in the video footage, and were therefore not included in the database.

Video annotation created a linked, random-access database of all the video data which can be readily searched using keywords from the classification scheme. Additionally, the provided “Transect Player” software links video and GPS data, allowing simultaneous viewing of the camera’s geographical position on a map and the video images captured by the camera at that location.

All classification data was also entered into a relational Access database, which was then used to generate the data for mapping. This database contains a “Filter by Video” function which allows the user to browse through the data for each transect as a series of data recording forms.

ArcGIS Mapping

Maps of the observed eelgrass distribution were produced using ArcGIS. These maps have been provided as an ArcGIS project which can be viewed using the supplied ArcReader.

Transect Profiles

Cross-sectional profiles of Flora Bank along the transect lines were generated using SigmaPlot. The location of observed eelgrass is recorded on these profiles, thus allowing the relationship between depth and eelgrass abundance to be observed.

Processing of Sidescan Data

Raw sidescan data from the Humminbird 997c SI unit was visualized directly using the HumViewer freeware created by Martin Johansen. For further image processing, the raw data file was converted into a format which could be imported into the Mini Image Processing System (MIPS), an open source image processing software developed by the United States Geological Survey (USGS).

Calculation of Eelgrass Height

Experimental software written by Ocean Ecology was used to extract eelgrass height information from the downward-looking sonar data recorded by the Humminbird 997c SI unit. A plot of eelgrass height along the sidescan transect line was then generated using SigmaPlot.

Flora Bank Eelgrass Survey Results

Benthic Video Survey

The transect lines for the survey as carried out are shown in Figure 4. The transects ranged in depth from -1.31 m (e.g., 1.31 m above the chart datum, which is the Lowest Normal Tide [LNT]) to 3.22 m. The minimum depth below the keel of the boat was 1.7 m. Coverage for the site was quite limited as a result of a number of factors:

1. ***high turbidity*** – the site is located directly in the plume of the Skeena River (see Figure 1), resulting in normally high turbidity. As a result, the visibility at the site seldom exceeded 1 m. High intensity LEDs were used to provide light during the video runs; however back-scattering of light from the silt particles often created a “halo effect”, causing additional visibility issues. This reduced the resolution of the video camera, producing a grainy image quality. In spite of these problems, the image quality was deemed sufficient for organism identification. Due to the limited visibility, the camera was often towed less than 1 m above the bottom, resulting in a relatively small field of view and a low towing speed (0.5 knots).
2. ***very shallow water*** - much of the Flora Bank region had water depths too shallow to be safely accessed by the ship towing the video camera system.
3. ***strong currents*** – due to the shallow nature of Flora Bank and the large tidal range of the Prince Rupert area, very strong tidal currents were experienced during the survey. These strong currents made course-holding difficult and increased potential safety issues where hazardous obstacles were present.
4. ***freshet debris*** - the Skeena River freshet had deposited a number of trees and logs in the shallow waters of Flora Bank. This was a particular problem around transect 2-1, and made navigation in that region very hazardous.

One DVD of raw video data were generated from the survey. Processing and annotation of the video data produced one DVD containing the clipped and converted videos and viewers to visualize the data.

Eelgrass Distribution

Figure 5 shows the distribution of eelgrass as observed by the benthic video survey. Some observations regarding the eelgrass present at Flora Bank are:

1. Approximately 97% of the observed eelgrass was in the intertidal region.
2. Approximately 50% of the observed eelgrass was in the regions where the Borstad CASI survey had recorded eelgrass in 1997. Furthermore, approximately 96% of the observed eelgrass was within 65 m (e.g., relatively close proximity) of these regions.
3. Most likely the observed eelgrass on Flora Bank consists largely of the ecotype *Zostera marina typica* (primarily intertidal with low tolerance to current; has shorter, narrower blades).

The minimum depth at which eelgrass was observed was -0.82 m (e.g., 0.82 m above LNT). The maximum depth at which eelgrass was observed was 1.75 m. The average depth of all eelgrass observations was 0.46 m.

A series of cross-sectional profiles of Flora Bank along the transect lines was created (see Figure 6, Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11). On transects 1-1, 2-1, and 4-1, eelgrass was moderately abundant, but was only observed in the intertidal regions. On transects 5-1 and 6-1 (on the west side of Flora Bank), only a small amount of eelgrass was observed, and this eelgrass was located below the intertidal region. No eelgrass was observed on transect 3-1.

Sidescan Imaging of Eelgrass

Figure 12 shows the position of an experimental sidescan track. The purpose of this experiment was to see if it was possible to visualize eelgrass using a Humminbird 997c SI system. Figure 13 shows a screen capture from the raw sidescan data. The right-hand window shows a sidescan image of eelgrass, and the left-hand window shows a downward-looking sonar image of eelgrass. In the sidescan image, the eelgrass is seen as rough-textured areas. In the downward-looking sonar image, the eelgrass is seen as "feathery" crests on the sand waves. Figure 14 shows the complete sidescan record after processing with the Mini Image Processing System (MIPS). Again, rough-textured areas are eelgrass. The wavy pattern is produced by small sand waves.

Calculation of Eelgrass Height

Figure 15 shows a plot of eelgrass height, as calculated from the Humminbird 997c SI downward-looking sonar, along the length of the experimental sidescan track. Maximum eelgrass height was approximately 45 cm, and occurred near the beginning of the transect. This corresponds to the rough-textured patch at the center bottom of Figure 14. Generally, eelgrass ranges in height from 20 cm to 200 cm. There are three ecotypes of eelgrass (*Zostera marina*) occurring in British Columbia:

(1) *Z. marina typica* - primarily intertidal with low tolerance to current; has shorter, narrower blades
(2) *Z. marina phillipsi* - found between 0 and 4 m depth with moderate tolerance to current; has intermediate blade length and width
(3) *Z. marina latifolia* - found between 0.5 and 10 m depth with strongest tolerance to current; has larger, wider blades

A height of 45 cm or less corresponds to *Z. marina typica*, which agrees with the observations from the video survey.

Fauna

Overall, fauna observations during the Flora Bank survey were relatively sparse. The majority of the observations were unmounded holes. Unmounded holes represent the observed surface disturbances caused by a number of unidentified infauna, including burrowing polychaetes, some bivalve species, and mud shrimp. Table 1 lists the various groups of fauna identified at the site, and their abundances in terms of total number of observations.

Table 1. Abundances of various fauna groups.

Fauna identification	Number of Observations
Unmounded hole	1381
Butter clam	79
Mounded hole	51
Orange sea pen	14
Unidentified fish	4
Geoduck clam	2
Nuttall's cockle	2
Spot prawn	2

Discussion and Recommendations

The Flora Bank eelgrass survey can be divided into two distinct sets of observations, each of which has significant outcomes: (1) an examination of the current state of the eelgrass bed in terms of distribution; and (2) a study on the use of some new approaches for monitoring eelgrass.

Distribution of Eelgrass on Flora Bank

A fairly well-known and frequently used eelgrass monitoring technique, towed underwater video imagery, was used to survey the Flora Bank eelgrass bed. While the combination of very shallow water depths, strong tidal currents, high turbidity, and large woody debris made conditions for towed video work difficult, and significantly limited the amount of video footage that was collected, several important observations of the eelgrass bed were made.

Firstly, approximately 97% of the observed eelgrass was intertidal, and appeared to be *Zostera marina typica* based on the blade width and plant height as seen in the video images. Originally, there had been some expectation that subtidal eelgrass might be found at the site, since subtidal eelgrass is fairly common in the North Coast region. However, given the high turbidity of the site (see Figure 1), it is quite possible that any plants growing in the subtidal environment might be severely light limited. Thus, the Flora Bank eelgrass bed is most likely limited to only those regions where the depth is shallow enough to allow good light penetration.

Recommendation: Since it is clear that the Skeena River plume plays an important role in controlling the growth of eelgrass on Flora Bank (e.g., through changes in turbidity), further studies on the relationship between the volume, timing, and sediment load of the Skeena River freshet and the growth of eelgrass on Flora Bank should be undertaken, particularly in light of possible changes in the river's seasonal patterns as a result of global climate change.

Recommendation: Based on the intertidal nature of the Flora Bank eelgrass bed, and the significant navigational hazards associated with Flora Bank, it is suggested that future surveys of the eelgrass bed be undertaken at low tide using light-weight, highly mobile craft, such as kayaks, which can be carried along the bed as the survey progresses, thus reducing the risk of stranding. Utilizing experienced paddlers would also be highly recommended.

Secondly, approximately 96% of the observed eelgrass is either within, or in very close proximity to, those areas where the 1997 Borstad CASI survey indicated eelgrass to be present. This provides further ground-truthing for the CASI technology, and confirms its capacity to correctly identify eelgrass based on spectral analysis. Also, the fact that there was very little eelgrass observed in areas at a distance from the previously identified beds seems to suggest that the eelgrass has not spread very much since 1997 (e.g., the bed is not actively expanding).

New Approaches for Monitoring Eelgrass

Although still a developing technology, the use of sidescan sonar to delimit the extent of eelgrass beds is not in and of itself a novel technique. However, the experimental equipment deployed by Ocean Ecology is unique in several ways:

(1) The Humminbird 997c SI sidescan unit is a commercially available recreational unit which sells for approximately $2000 as compared to the $20,000 or more for most sidescan units used for scientific research. A simple towfish can be constructed for under $200 which allows the Humminbird unit to be used in a number of applications.

(2) Ocean Ecology has written software which converts the Humminbird proprietary data format into a form which can be read by an open source sidescan image processing software. This further reduces the costs of setting up a sidescan system, as much of the commercial sidescan mosaicing software is in excess of $5000 to purchase.

(3) Ocean Ecology has also designed some experimental software which uses data from the downward-looking sonar of the Humminbird 997c SI unit to measure the height of the eelgrass. This may be useful in quantifying as well as delimiting eelgrass beds using sidescan sonar.

The image quality of the sidescan data produced by the Humminbird 997c SI unit (see Figure 14) was comparable with that of images produced by more expensive systems.[4,5] In light of the significant difference in set-up costs between the Humminbird system and other systems used in scientific research, this is a very significant outcome. It may make it possible for small organizations with limited funding to be able to collect high quality sidescan data.

While the sidescan technique was of limited use on Flora Bank, due to the shallow nature of the eelgrass bed, it may well come into its full realization when used on deeper, subtidal beds where some of the more traditional eelgrass quadrat surveys will not be possible. The use of the downward-looking sonar to quantify eelgrass height may also prove potentially valuable in deeper waters, although this method needs significantly further ground-truthing, particularly under a variety of current conditions which may cause the eelgrass to be flattened, and thus not record a true height value.

Recommendation: Based on the positive results obtained so far with the Humminbird 997c SI sidescan unit, it is recommended that further experimental trials be carried out on subtidal eelgrass beds.

[4] Bailey, A., Norris, J., Fraser, I., & Petrillo, T. 2007. Snohomish County, Washington County-Wide Eelgrass Inventory. Snohomish County Surface Water Management Marine Resources Committee.

[5] Woodruff, D. L., Kohn, N.P., Borde, A. B., Evans, N. R., Southard, J. A., & Thom, R.M. 2006. First Annual Report: 2004 Pre-Construction Eelgrass Monitoring and Propagation for King County Outfall Mitigation. Marine Sciences Laboratory.

Project Deliverables

In addition to this report, the following materials have also been provided from the subtidal survey:

1. One DVDs containing raw georeferenced seabed video imagery* (overlaid with time, latitude, and longitude) of the survey site.
2. One DVD containing:
    a. a georeferenced, classified Access database* for biological and physical features of the seabed.
    b. an electronic ArcGIS project* containing maps of analyzed video data.
    c. a report describing and explaining the results of the video survey.
    d. java-based software which links video* and GPS data, allowing simultaneous viewing of the camera's geographical position on a map and the video images captured by the camera at that location.
    e. a library of video* annotations

*Note: time on the video imagery, in the database, and in the ArcGIS project is given in PST (Pacific Standard Time).

Figures

Flora Bank Eelgrass Survey

Figure 1. Skeena River plume and Flora Bank.

Projection: WGS 1984 UTM Zone 9N

Scale: 1:54,000

Legend

Flora Bank

0 375 750 1,500 Meters

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Flora Bank Eelgrass Survey

Figure 2. Eelgrass distribution as reported by the Borstad CASI study.

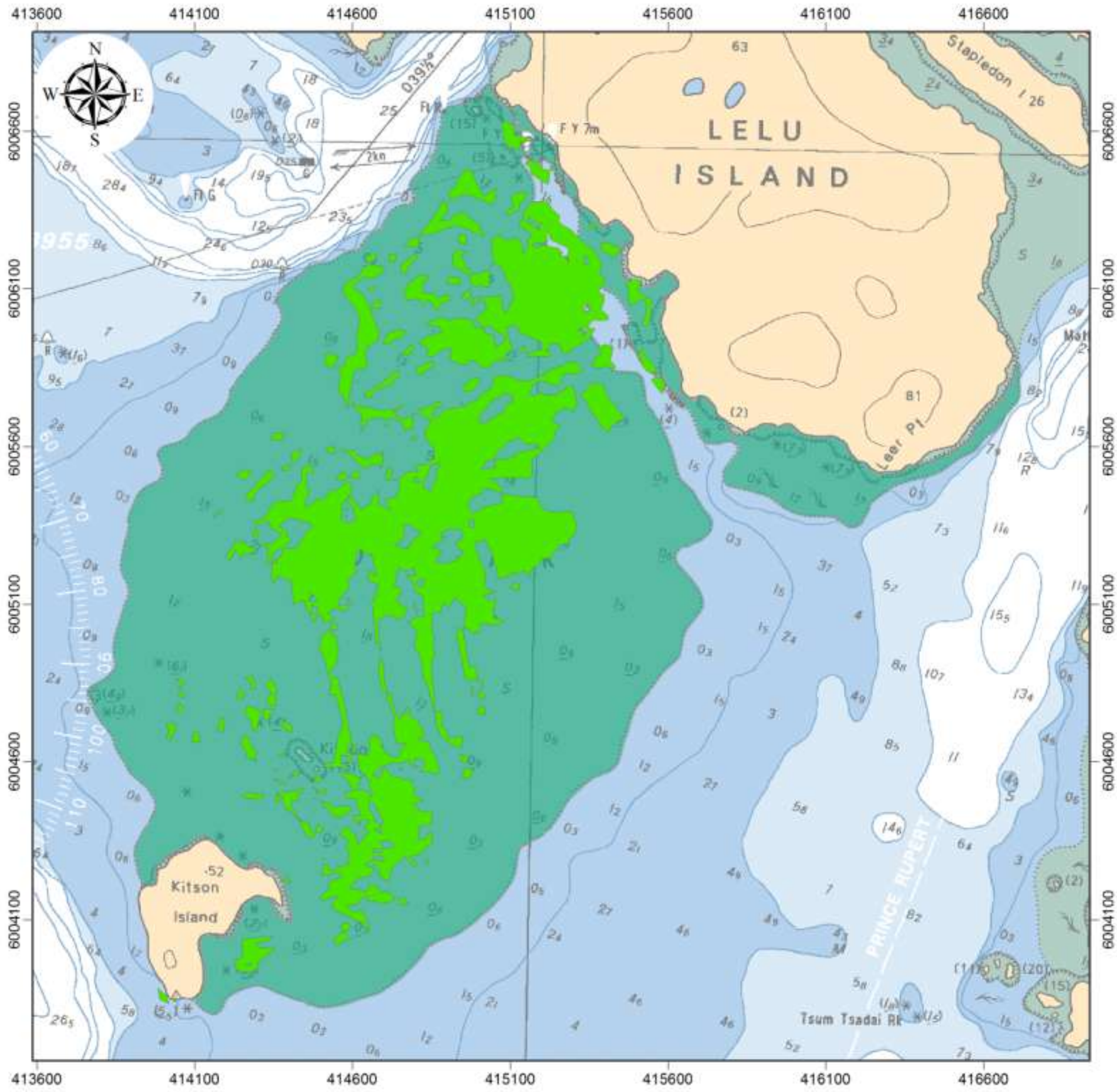


Chart used for navigation:
CHS 395502
(Porpoise Harbour)

Chart datum: LNT

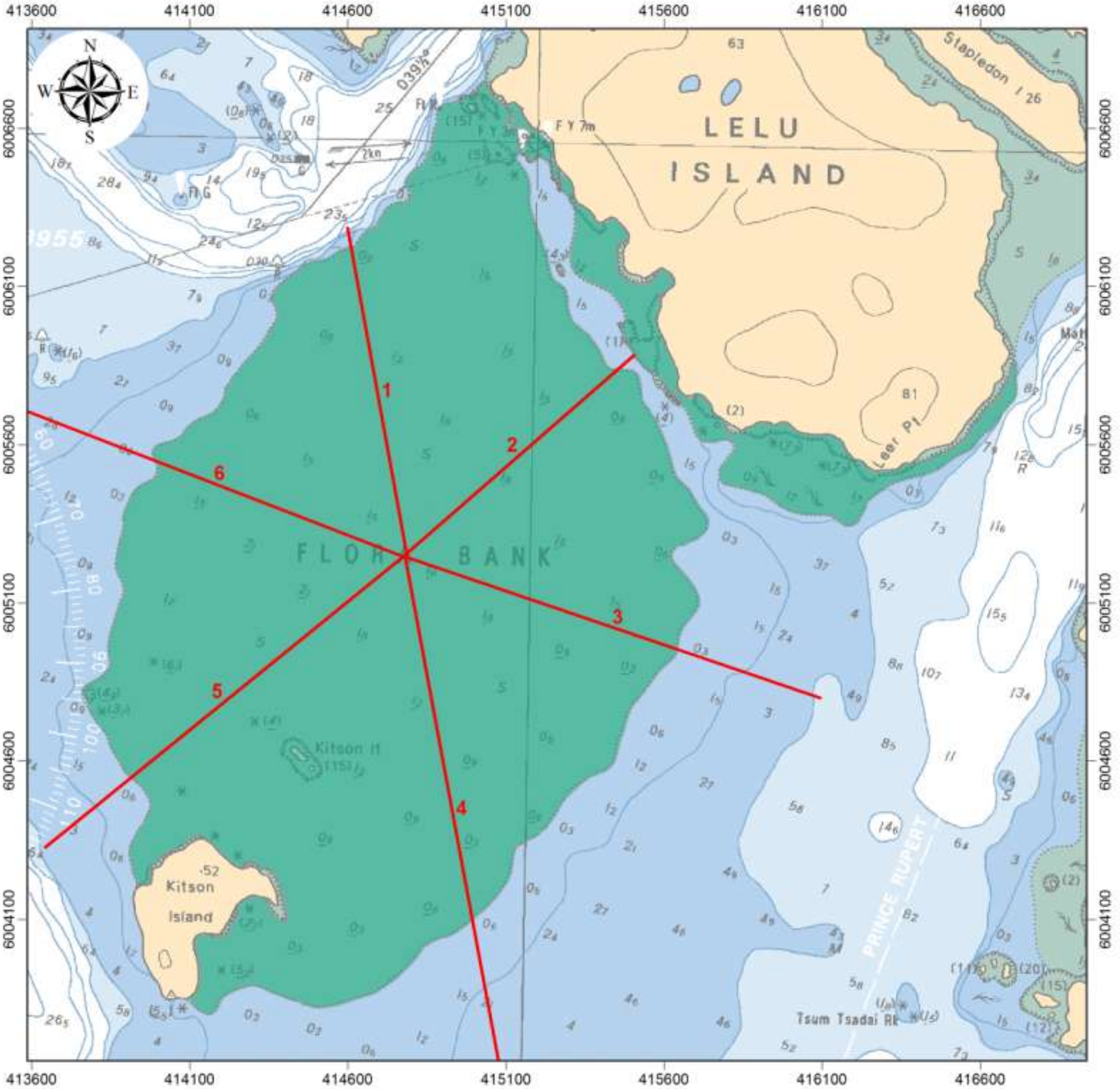
Projection: WGS 1984 UTM Zone 9N

Scale: 1:17,000

Legend

- Borstad eelgrass extent
- Intertidal regions

0 125 250 500 Meters



Flora Bank Eelgrass Survey

Figure 3. Survey design showing transect bearings.

Chart used for navigation:
CHS 395502
(Porpoise Harbour)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:17,000

Legend

Proposed transect bearings

Intertidal regions

0 125 250 500 Meters

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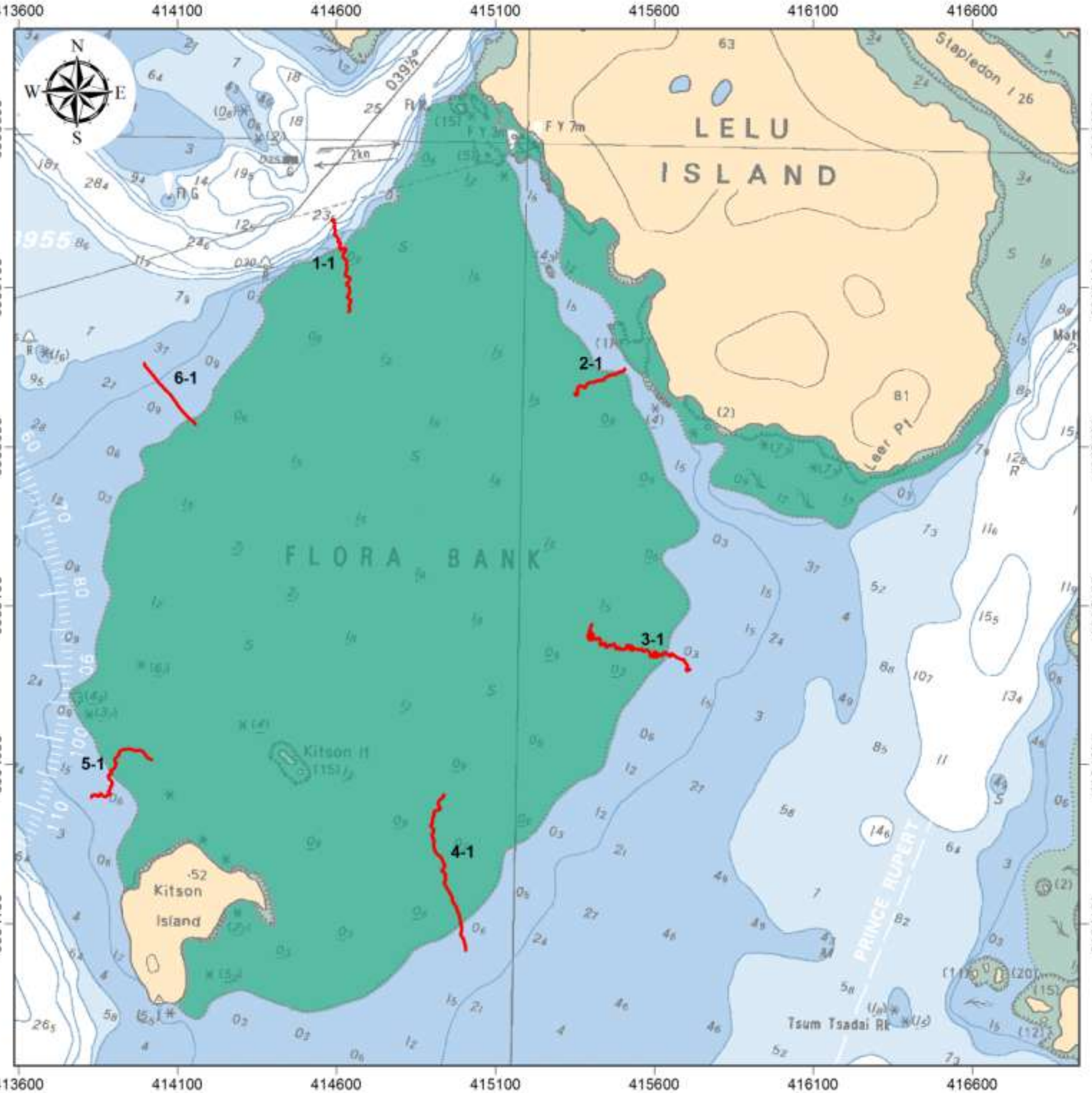

Flora Bank Eelgrass Survey

Figure 4. Completed survey showing transects.

Chart used for navigation: CHS 395502 (Porpoise Harbour)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:17,000

Legend

Transect lines

Intertidal regions

0 125 250 500 Meters

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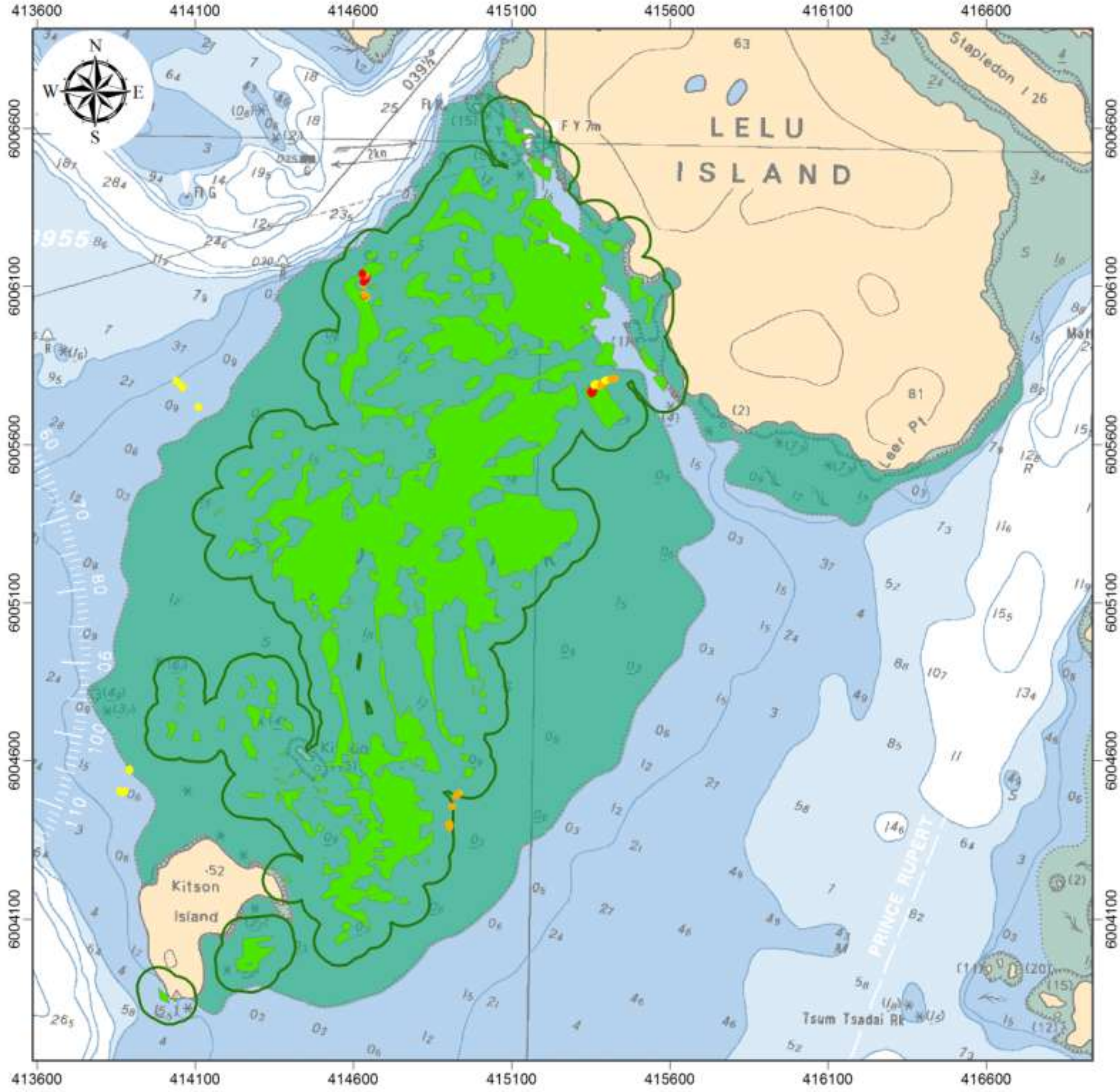

Flora Bank Eelgrass Survey

Figure 5. Eelgrass observations.

Bathymetric system:
JRC 130 single-beam echosounder

Transducer:
50 kHz operating at 1 kW power

Beam angle: 9 degrees

Positioning system:
Electronic charting software using DGPS

Station for tide height corrections:
Port Edward,
CHS reference station 10933

Chart used for navigation:
CHS 395502
(Porpoise Harbour)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:17,000

Legend

Eelgrass observations

Percent cover

- < 5%
- 5% - 25%
- 26% - 75%

Borstad eelgrass extent

65 m buffer

Intertidal regions

0 125 250 500 Meters

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Figure 6. Distribution of eelgrass with depth along transect 1-1.

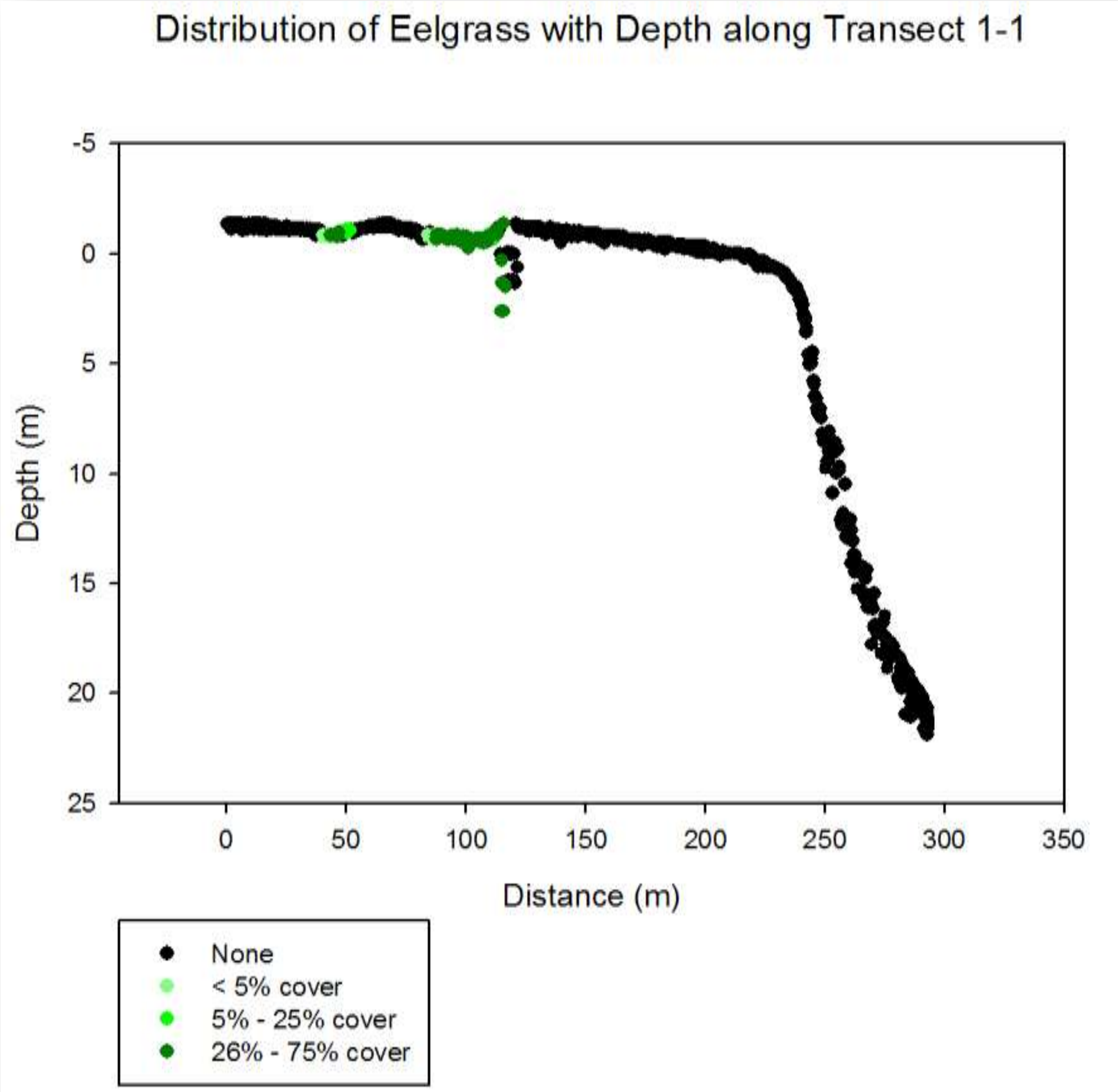


Figure 7. Distribution of eelgrass with depth along transect 2-1.

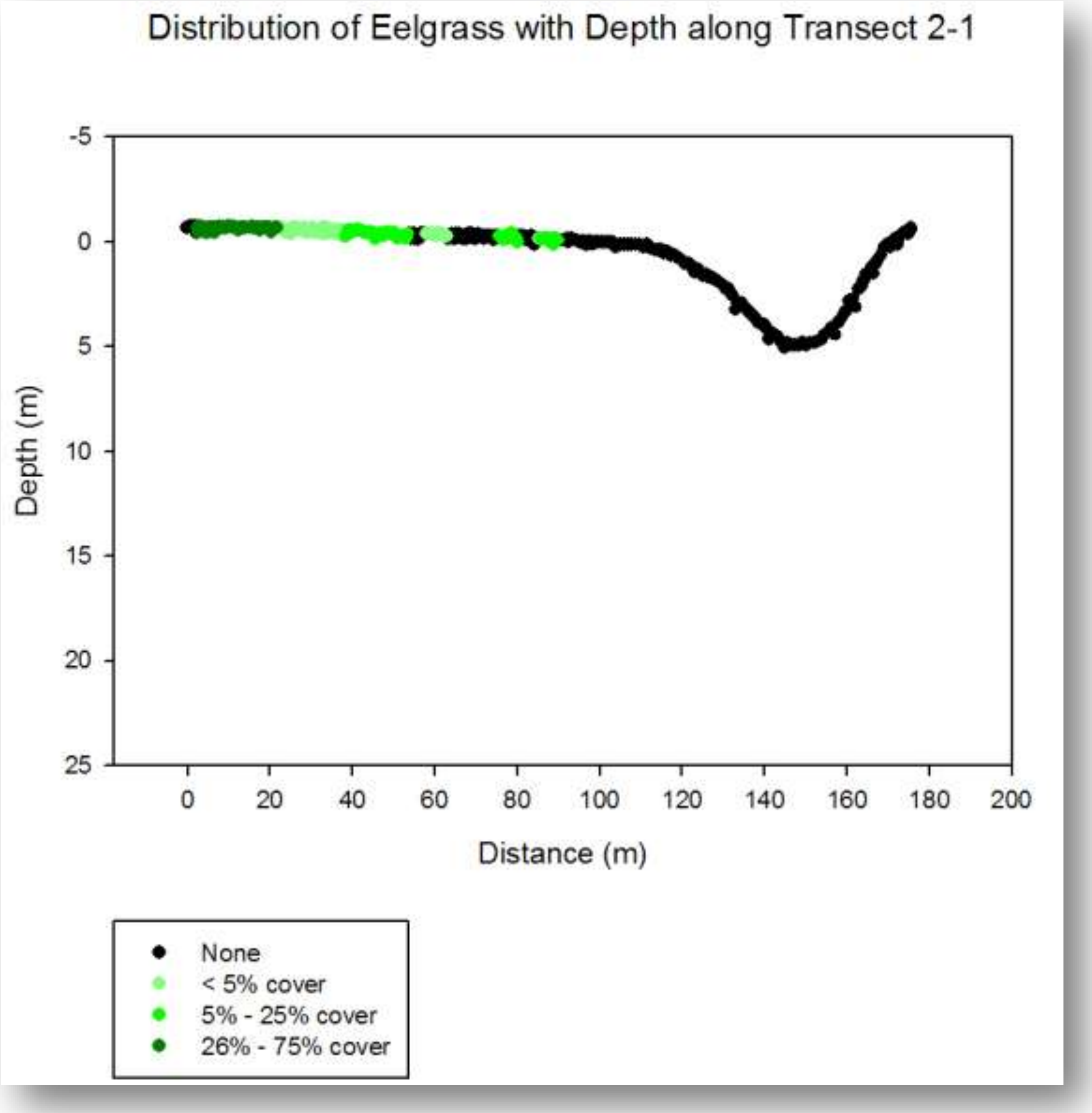


Figure 8. Distribution of eelgrass with depth along transect 3-1.

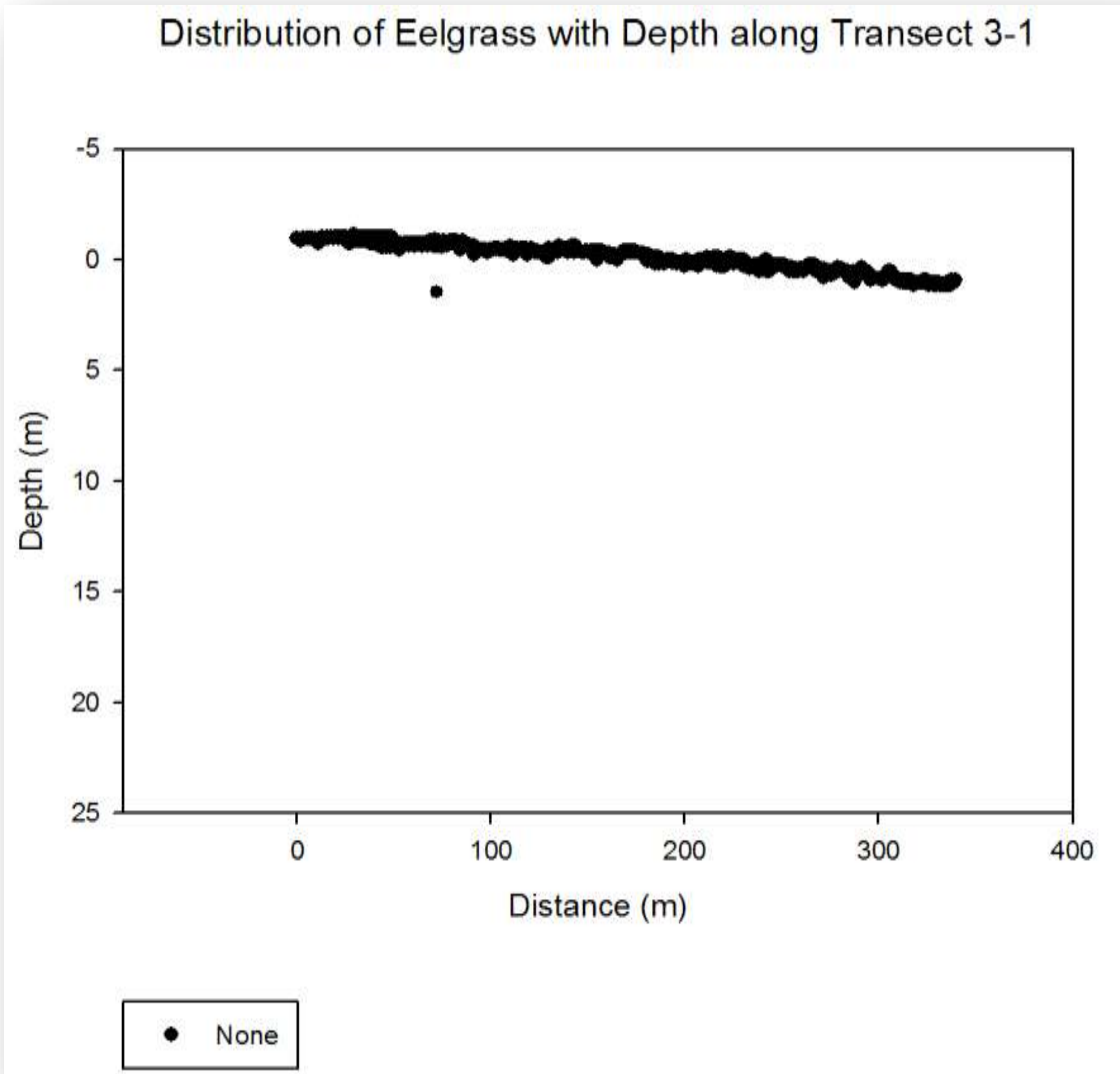


Figure 9. Distribution of eelgrass with depth along transect 4-1.

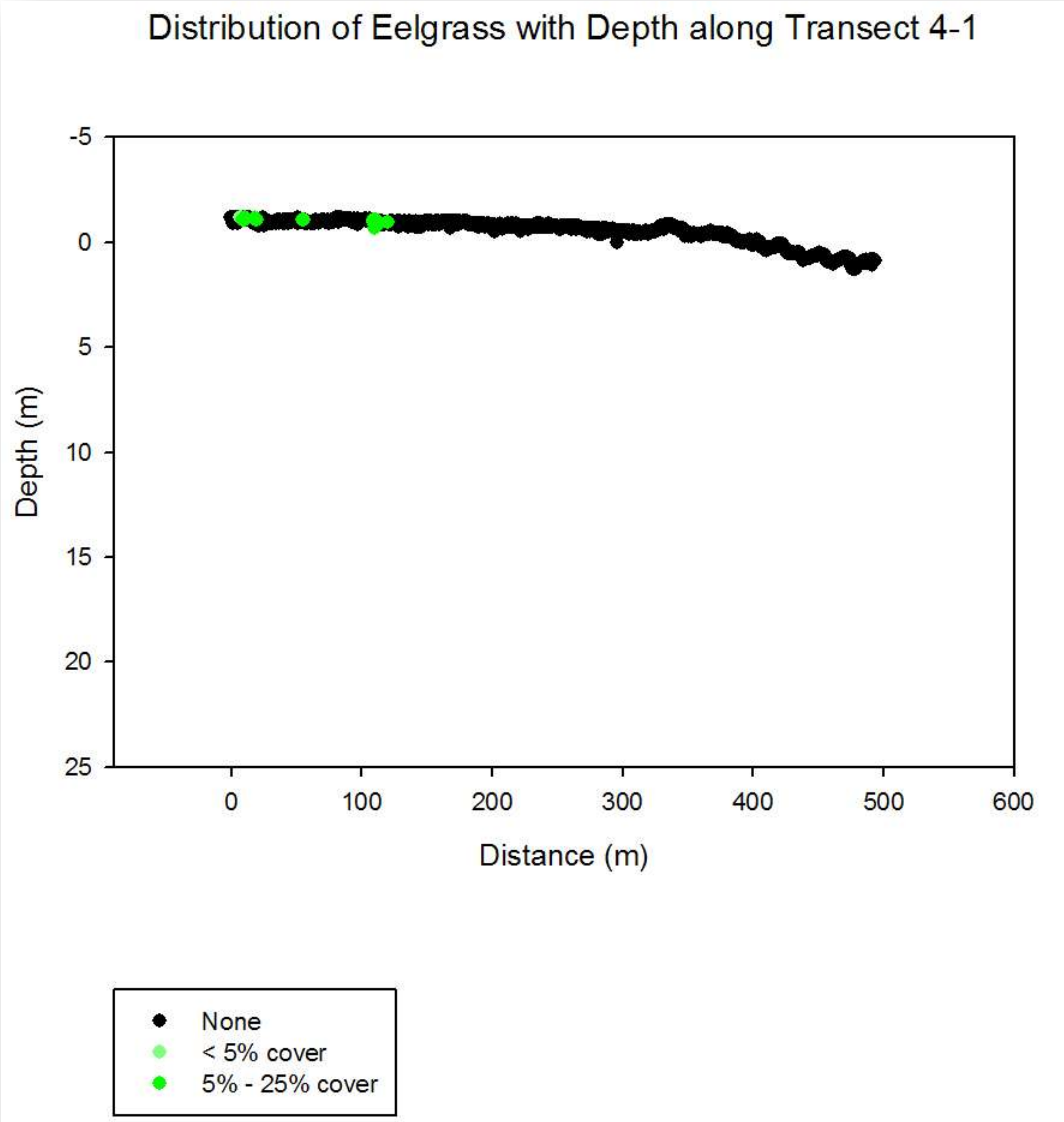


Figure 10. Distribution of eelgrass with depth along transect 5-1.

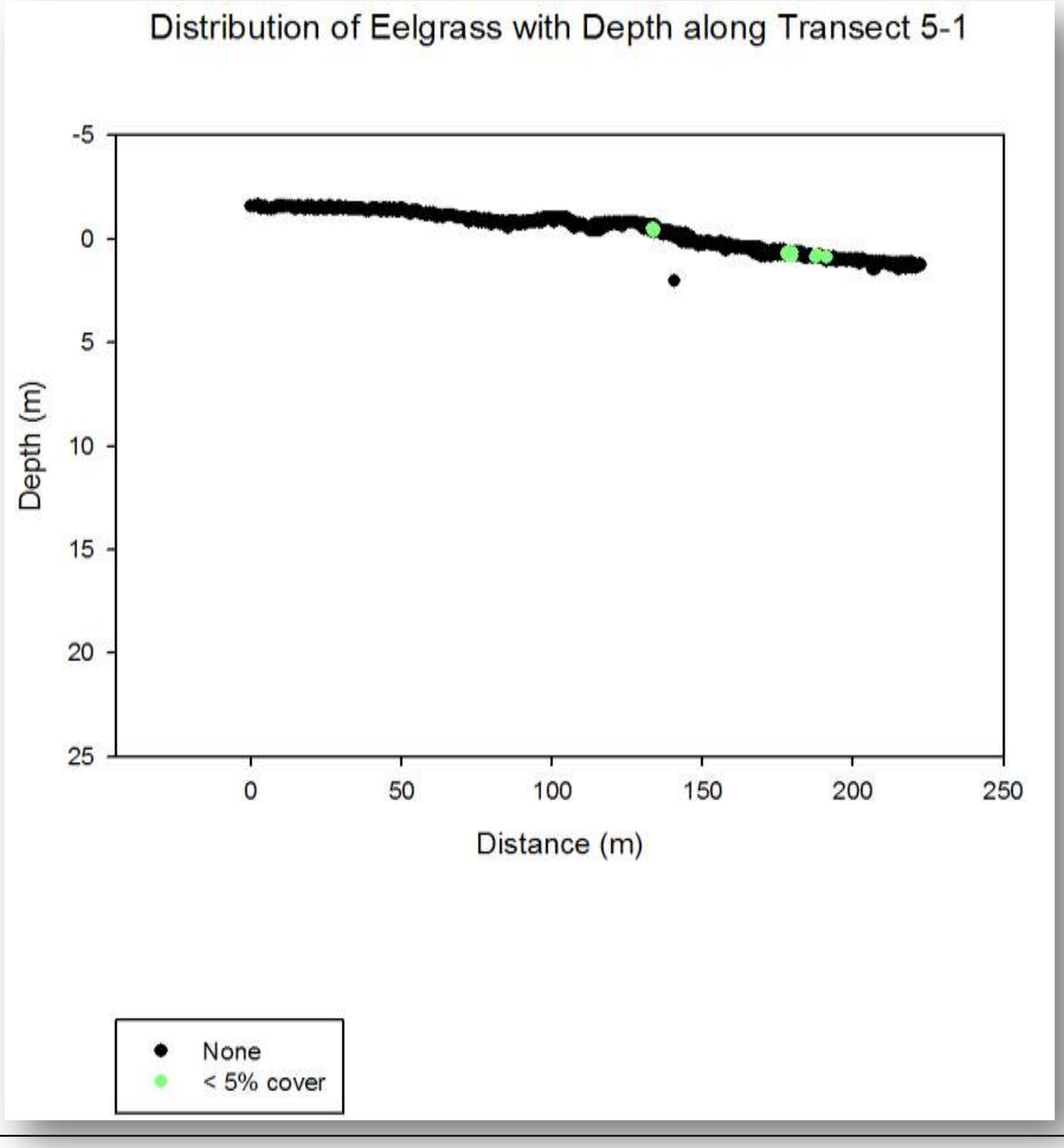
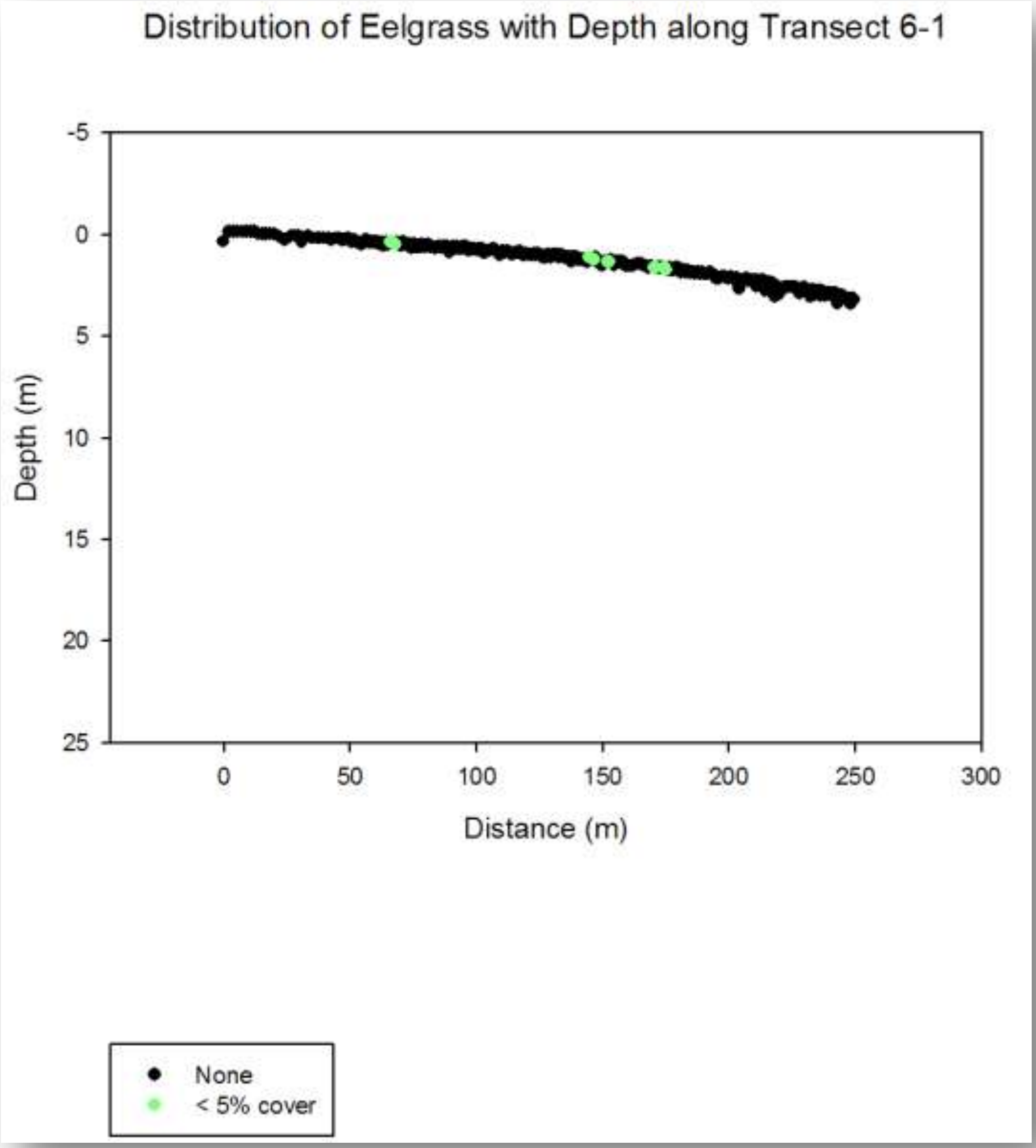
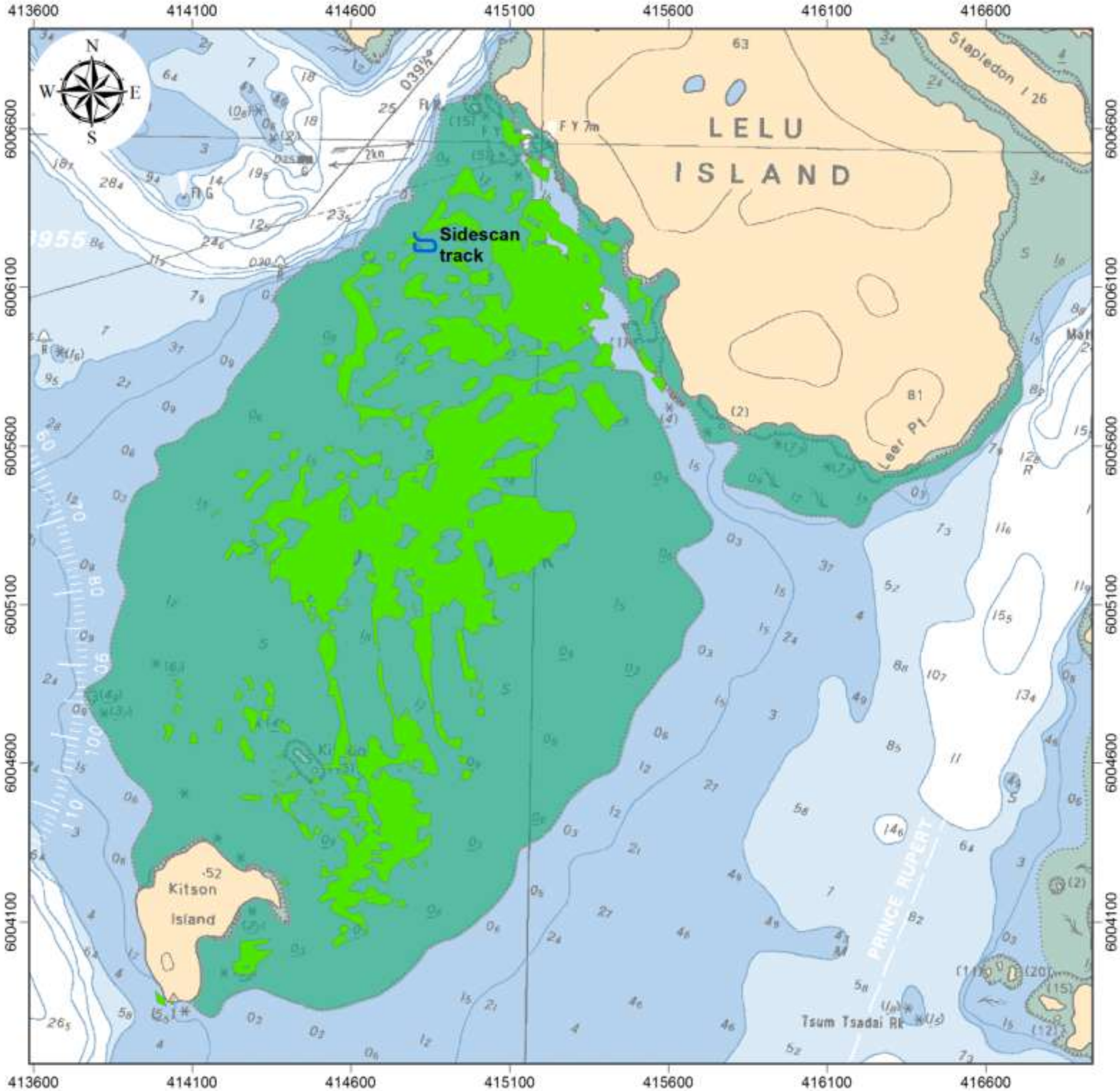


Figure 11. Distribution of eelgrass with depth along transect 6-1.





Flora Bank Eelgrass Survey

Figure 12. Location of experimental sidescan track.

Bathymetric system:
Humminbird 997c SI

Transducer:
455 kHz and 200 kHz
operating at 1 kW power

Positioning system:
Electronic charting software using DGPS

Station for tide height corrections:
Port Edward,
CHS reference station 10933

Chart used for navigation:
CHS 395502
(Porpoise Harbour)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:17,000

Legend

Sidescan track

Borstad eelgrass extent

Intertidal regions

0 125 250 500 Meters

OCEAN ECOLOGY

Figure 13. Screen capture of raw sidescan data using the HumViewer software.

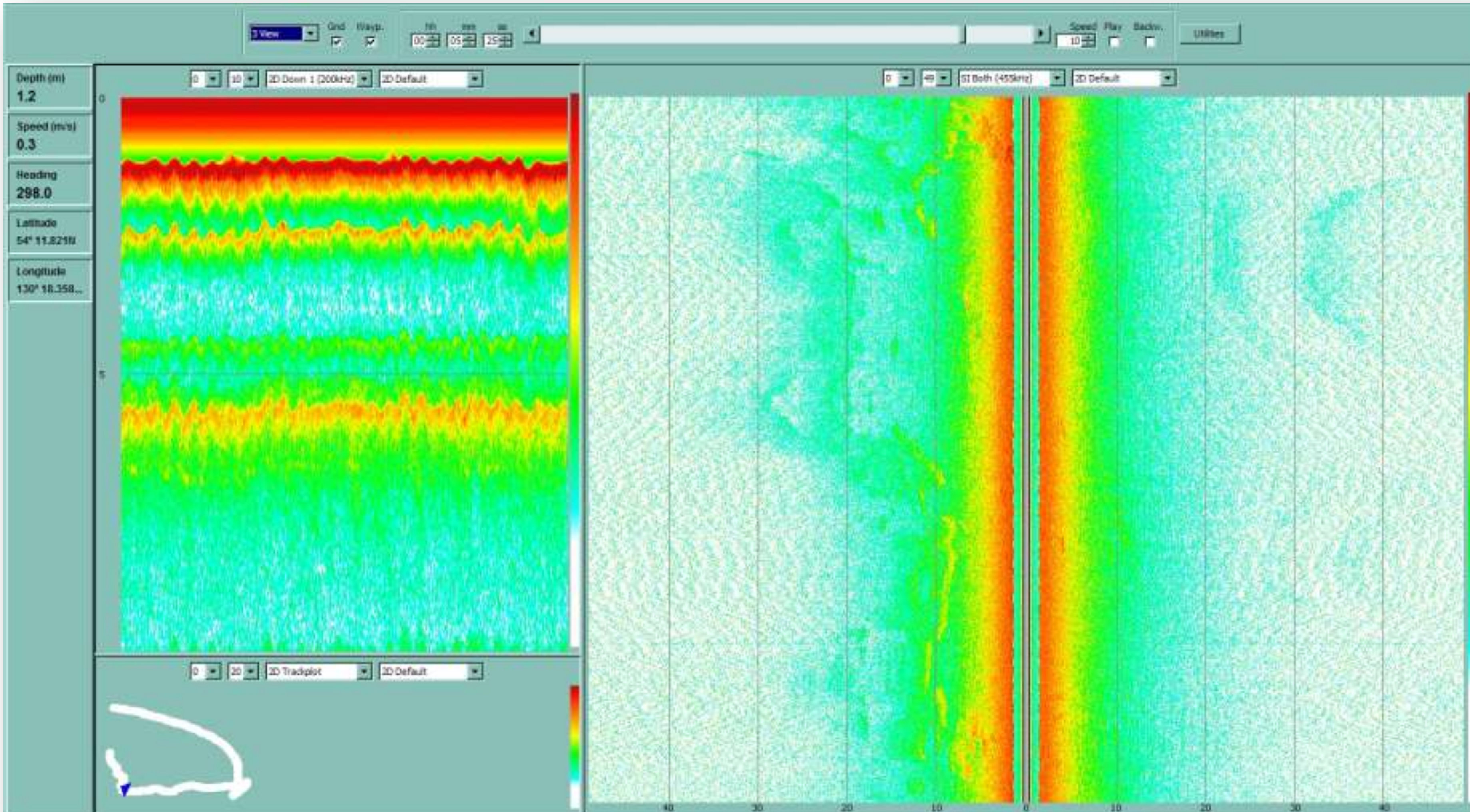


Figure 14. Sidescan data after processing with Mini Image Processing System (MIPS).

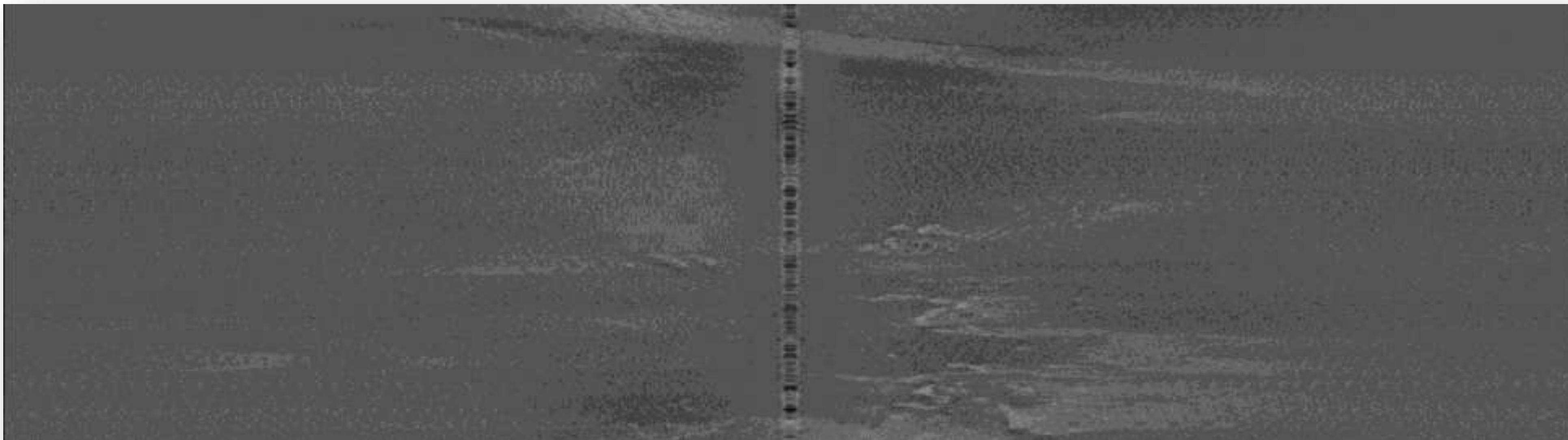
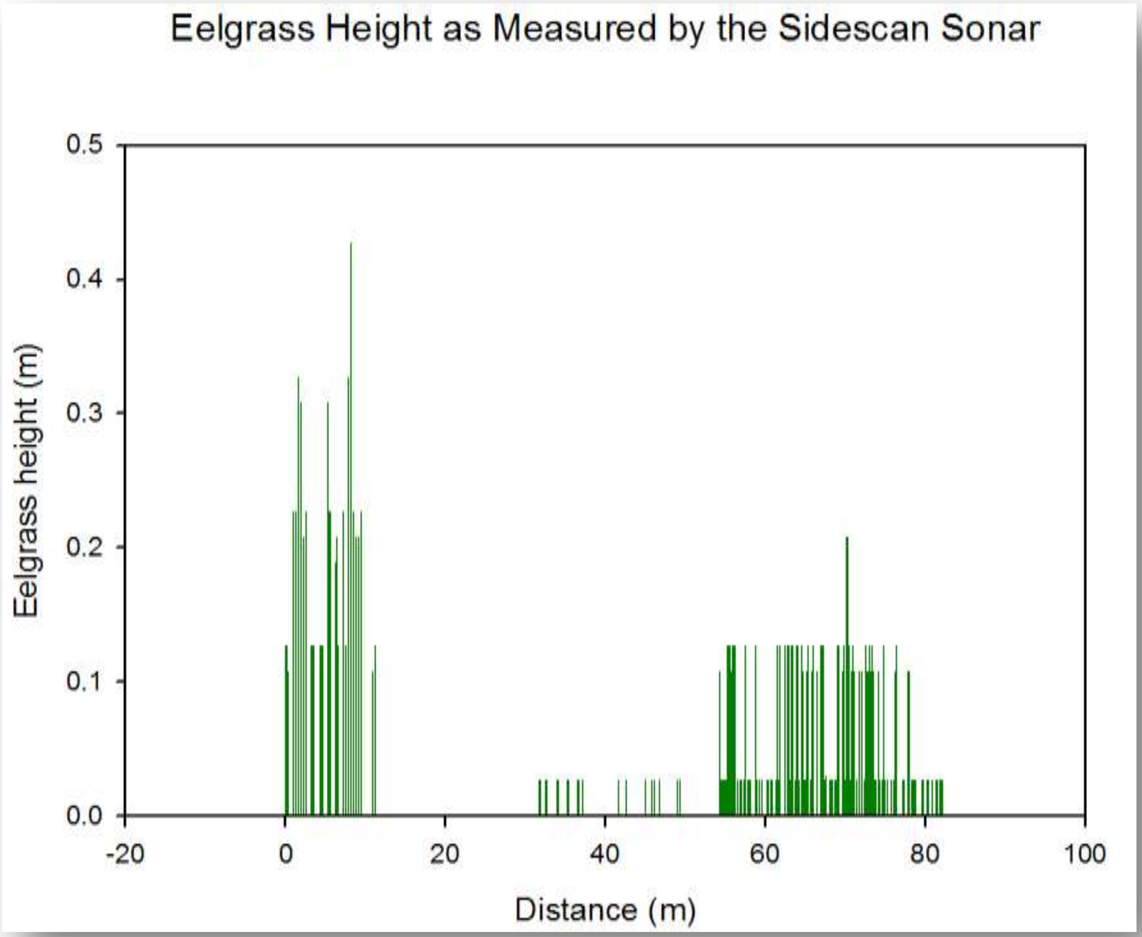


Figure 15. Plot of eelgrass height against distance along experimental sidescan track.



Appendix

Table A1. Substrate type codes.

Substrate Composition	Class	Subclass	Description
Rock (R)			Bedrock outcrop; may be partially covered with a veneer of sediment.
Veneer over bedrock (vR)			Intermittently visible bedrock covered with a thin veneer of clastic sediments.
Clastic (C)			Seabed comprised of mineral grains of gravel-, sand- or mud-sized material.
	Gravel (G)	Boulder (B)	Percentage boulder (>25.6 cm in size) on seabed.
		Cobble (CO)	Percentage cobble (6.4 to 25.6 cm in size) on seabed.
		Pebble (P)	Percentage pebble (4 mm to 6.4 cm in size) on seabed.
		Granules (GR)	Percentage granules (2-4 mm in size) on seabed.
	Sand (S)	Sand (S)	Percentage sand (0.062 to 2 mm in size) on seabed.
	Silt-mud (M)	Silt-mud (M)	Percentage silt-mud (<0.62 mm in size) on seabed.
Biogenic (B)			Surface of seabed comprised of material of biogenic origin, such as vegetation.
	Organics (O)	Shell (SH)	Percentage coarse (> 2 mm in size) shell debris on seabed.
		Organic debris (OD)	Percentage organic debris on seabed.
		Wood debris (WD)	Percentage wood debris on seabed.
Anthropogenic (A)			Features of man-made origin, such as trawl marks, anchor drag marks, or cable drag marks.

Table A2. Percentage substrate cover codes.

Class Code	Percentage Cover
1	T-5%
2	5-30%
3	30-50%
4	50-80%
5	>80%

Table A3. Vegetation codes.

Algal Class	Subclass	Code	Description
Green Algae (GRA)	Foliose greens	FOG	Primarily *Ulva*, but also including *Enteromorpha* and *Monostroma.*
	Filamentous greens	FIG	The various filamentous green/red assemblages (*Spongomorpha/Cladophora* types).
Brown Algae (BA)	Fucus	FUC	*Fucus* and *Pelvetiopsis* species groups.
	Sargassum	SAR	*Sargassum* is the dominant and primary algal species.
	Nemalion	NEM	Filamentous *Nemalion* sp. is the dominant species.
	Soft brown kelps	BKS	Large laminarian bladed kelps, including *L. saccharina* and *groenlandica*, *Costaria costata, Cymathere triplicata.*
	Seersucker kelp	SEE	*Costaria costata.*
	Split kelp	SPL	*Laminaria setchellii.*
	Sugar wrack kelp	SWK	*Laminaria saccharina.*
	Suction-cup kelp	SUC	*Laminaria yezoensis*.
	Dark brown kelps	BKD	The LUCO chocolate brown group,. *L. setchelli, Pterygophora, Lessoniopis. Alaria* and *Egregia* may also be present. Generally more exposed than soft browns.
	Alaria	ALA	*Alaria* sp.
	Agarum	AGR	*Agarum* is the dominant species, but other laminarians may also occur. Generally found deeper than Laminarian subgroup.
	Fringed sea colander kelp	FSC	*Agarum fimbriatum*.
	Stringy acid weed	STW	*Desmarestia viridis.*
	Broad acid weed	BRW	*Desmarestia lingulata.*
	Macrocystis	MAC	Beds of canopy forming giant kelp.
	Nereocystis	NER	Beds of canopy forming bull kelp.

Table A3. Continued.

Algal Class	Subclass	Code	Description
Red Algae (RED)	Foliose reds	FOR	A diverse species mix of foliose red algae (*Gigartina*, *Iridea, Rhodymenia, Constantinia*) which may be found from the lower intertidal to depths of 10 m primarily on rocky substrate.
	Filamentous reds	FIR1	A diverse species mix of filamentous red algae (including *Gastroclonium, Odonthalia, Prionitis*) which may be found from the lower intertidal to depths of 10 m, often co-occurring with the foliose red group described above.
	Filamentous reds	FIR2	A mix of red algae (primarily *Neoagardhiella*and *Gracilaria*) which grow on "submerged" cobble and pebble in fine sand and silt bottoms.
	Coralline reds	COR	Rocky areas with growths of encrusting and foliose forms of coralline algae.
	Halosaccion	HAL	*Halosaccion glandiforme.*
Seagrasses (SGR)	Eelgrass	ZOS	Eelgrass beds.
	Surfgrass	PHY	Areas of surfgrasses (*Phyllospadix*), which may co-occur with subgroup BKS or BKD above.
No Vegetation		NOV	No vegetation observed.
Cannot Classify		X	Vegetation present by cannot be identified. Imagery is not clear, classification not possible.

Table A4. Vegetation coverage codes.

Code	Class	Abundance
1	Sparse	Less than 5% cover.
2	Low	5 to 25% cover.
3	Moderate	26 to 75% cover.
4	Dense	>75% cover.

Table A5. Fauna codes.

Species or Species Complex	Code	Description
Bacterial mat	BCM	Unidentified bacterial mat; sulfuretum.
Sponges	USP	Unidentified sponge.
	CLD	Cloud sponge (*Aphrocallistes vastus*).
	SBS	Sharp lipped boot sponge (*Rhabdocalyptus dawsoni*).
	RSB	Round lipped boot sponge (*Staurocalyptus dowlingi*).
	SVS	Stalked vase sponge (*Leucilla nuttingi*).
	BRS	Breast sponge (*Eumastia sitiens*).
Jellyfish	MJF	Moon jellyfish (*Aurelia labiata*).
	CYC	Lion's mane jellyfish (*Cyanea capillata*).
Hydroids	HYD	Unidentified hydroids.
	HYM	Hydromedusa sp.
Anemones	PAF	Tube-dwelling anemone (*Pachycerianthes fimbriatus)*.
	MET	Plumose anemone (*Metridium* sp.).
	URT	Sea anemone (*Urticina* sp.).
	XAN	Giant green anemone (*Anthopleura xanthogrammica*).
	CRI	Snake lock anemone (*Cribrinopsis* sp.).
	ANT	Sea anemone (*Anthopleura* sp.).
	STR	Strawberry anemone (*Corynactis californica*).
Corals/Hydrocorals	SPO	Orange sea pen (*Ptilosarcus gurneyi*).
	SPW	White sea pen (*Virgularia* sp.).
	CUP	Orange cup coral (*Balanophyllia elegans*).
	SWP	Sea whip (*Balticina septentrionalis*).
	STY	Pink hydrocoral (*Stylaster* sp.).
Worms	TUB	Parchment tube dwelling polychaete worms.
	TUC	Calcareous tube dwelling polychaete worms.
	LUG	Pacific lugworm (*Abarenicola pacifica*).

Table A5. Continued.

Species or Species Complex	Code	Description
Crabs	CRB	Unidentified crab.
	CAN	*Cancer* sp.
	DUN	Dungeness crab (*Cancer magister*).
	TAN	Tanner crab (*Chionoecetes* sp.).
	KCR	Kelp crab (*Pugettia* sp.).
	BXC	Box crab (*Lopholithodes foraminatus*).
	ORE	Decorator crab (*Oregonia gracilis*).
	SQT	Squat lobster (*Munida quadraspina*).
Shrimps (Pandalid)	PAN	Unidentified pandalid.
	PRN	Spot prawn (*Pandalus platyceros*).
	PNB	Spiny pink shrimp (*Pandalus borealis*).
	PNH	Humpback shrimp (*Pandulus hypsinotus*).
Ghost and mud shrimps	GHS	Ghost shrimp (*Callianassa californiensis*).
	MDS	Mud shrimp (*Upogebia pugettensis*).
Gastropods	WHK	Unidentified whelk.
	NUC	Dogwinkle (*Nucella* sp.).
	WLN	White-lined nudibranch (*Dirona albolineata*).
	TOT	Orange-peel nudibranch (*Tochuina tetraquetra*).
Bivalves	MUS	Mussel bed (*Mytilus trossulus*).
	GCL	Geoduck clam (*Panopea abrupta*).
	HCL	Horseclam (*Tresus* sp.).
	PCL	Piddock clam.
	BCL	Butter clam (*Saxidomas gigantea*).
	COC	Nuttall's cockle (*Clinocardium nuttallii*).
	SFC	Softshell clam (*Mya* sp.).
	OYS	Oyster.
	OCL	Other clam species.
	SCA	Scallop (*Chlamys* sp.)
	TER	Teredo worm (*Bankia setacea*).
Octopus	OCT	Pacific octopus (*Octopus*).
Bryozoan Complex	BRY	Bryozoans, ascidians, sponges - generally on rock substrate.
Brachiopods	BRA	Unidentified brachiopod.
	LAM	California lamp shell (*Laqueus californicus*).

Table A5. Continued.

Species or Species Complex	Code	Description
Seastars	BRE	Short-spined seastar (*Pisaster brevispinus*).
	EVA	False ochre seastar (*Evasterias troschelli*).
	PYC	Sunflower seastar (*Pycnopodia helianthoides*).
	POR	Ochre seastar (*Pisaster ochraceus*).
	DER	Leather star (*Dermasterias imbricata*).
	GEP	Gunpowder star (*Gephyreaster swifti*).
	WRS	Wrinkled star (*Pteraster militaris*).
	PTT	Slime star (*Pteraster tesselatus*).
	VER	Vermilion star (*Mediaster aequalis*).
	HEN	Seastar (*Henricia* sp.).
	SOL	Seastar (*Solaster* sp.).
	COO	Cookie star (*Ceremaster patagonius*).
	PLS	Pale star (*Leptychaster pacificus*).
	SMS	Spiny mudstar (*Luidia foliolata*).
	ORT	Painted star (*Orthasterias koehleri*).
	STF	Long ray star (*Stylasteria forreri*).
	SIX	Six-armed star (*Leptasterias* sp.).
	ROS	Rose star (*Crossaster papposus*).
	STR	Unidentified seastar.
Brittle Stars	BRT	Unidentified brittle star.
	GYB	Gray brittle star (*Ophiura lütkeni*).
Basket Stars	BSK	Basket star (*Gorgonocephalus* sp.).
Feather Stars	FST	Feather star (*Florometra serratissima*).
Sand Dollars	SDD	Sand dollar (*Dendraster excentricus*).
Sea Urchins	RSU	Red sea urchin (*Strongylocentrotus franciscanus*).
	GSU	Green sea urchin (*Strongylocentrotus droebachiensis*).
	WSU	White sea urchin (*Strongylocentrotus pallidus*).
	PSU	Purple sea urchin (*Strongylocentrotus purpuratus*).
Sea Cucumbers	RCU	Rea sea cucumber (*Cucumaria miniata*).
	WCU	White sea cucumber (*Psolus squamatus*).
	PAR	California sea cucumber (*Parastichopus californicus*).
	ASC	Aggregating sea cucumber (*Pseudocnus* sp.).
Tunicates	TUN	Unidentified tunicate.
	CIO	Tunicate (*Ciona* sp.).
	PEA	Pacific sea peach (*Halocynthia aurantium*)
In fauna "holes"	HLM	Mounded worm, clam or crustacean hole, but species or species group cannot be distinguished.
	HLF	Unmounded (flat) worm or clam hole, but species or species group cannot be distinguished.

Table A5. Continued.

Species or Species Complex	Code	Description
Fish	FSH	Unidentified fish.
	SAL	Unidentified salmonid.
	ELP	Unidentified eelpout (Zoarcidae).
	POA	Unidentified poacher.
	GBE	Black-eyed goby (*Coryphoterus nicholsi*).
	PLP	Pile perch (*Rhacochilus vacca*).
	PST	Striped perch (*Embiotica lateralis*).
	FTF	Unidentified flatfish.
	RFS	Unidentified rockfish.
	BRF	Black rockfish (*Sebastes melanops*).
	NRK	China rockfish (*Sebastes nebulosus*).
	CRK	Copper rockfish (*Sebastes caurinus*).
	QRF	Quillback rockfish (*Sebastes maliger*).
	TRF	Tiger rockfish (*Sebastes nigrocinctus*).
	YRF	Yelloweye rockfish (*Sebastes ruberrimus*).
	GLG	Unidentified greenling (Hexagrammid).
	KGR	Kelp greenling (*Hexagrammos decagrammus*).
	LNG	Lingcod (*Ophiodon elongatus*).
	SCU	Unidentified sculpin (Cottidae).
	NRN	Northern ronquil (*Ronquilus jordani*).
	RAT	Ratfish (*Hydrolagus colliei*).
	LSK	Longnose skate (*Raja rhina*)
Unknown	UNK	Macro fauna visible but cannot be identified.
No Fauna	**NOF**	No fauna observed.

Table A6. Faunal distribution classes.

Code	Descriptor	Distribution
1	Few	Rare (single) or a few sporadic individuals.
2	Patchy	A single patch, several individuals or a few patches.
3	Uniform	Continuous uniform occurrence.
4	Continuous	Continuous occurrence with a few gaps.
5	Dense	Continuous dense occurrence.
6		Code specific for school of fish.

Disclaimer

The findings presented in this report are based upon data collected during the period May 21st, 2009 using the methodology described in the Survey Methodology section of this report. Ocean Ecology has exercised reasonable skill, care, and diligence to collect and interpret the data, but makes no guarantees or warranties as to the accuracy or completeness of this data.

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Any questions concerning the information or its interpretation should be directed to the undersigned.

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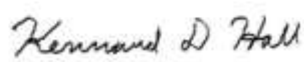
Oceanographer, R.P.Biol.

Reviewed By:



Kennard Hall, Captain
Partner, Ocean Ecology