2010 Experimental Herring Video Survey Final Report

December 2010

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Executive Summary

A DGPS-positioned, towed video camera system was used to carry out an experimental video survey of herring spawn at Hornby Island. Nominal shore-normal transect line spacing was 350 m. Surveys were carried out in water depths from -0.6 m to 96.2 m depth.

A spawn intensity rating system was developed using categories (e.g. “sparse”, “light”, “medium”, “heavy”). A data record of substrate, vegetation type, and herring spawn density was produced for each second of video.

All classification data was entered into a relational database. Maps of depth, bottom hardness, distribution of observed spawn intensity, and vegetation distributions were produced using ArcGIS. A library of linked and searchable video annotations was produced.

A DGPS-positioned, high definition drop camera system was used to collect high resolution still photographs of herring spawn. Forty-three high definition camera drops were carried out along 6 transects on the west coast of Hornby Island.

The following observations were made regarding the experimental herring surveys of the 2010 season:

1) A variety of habitats were surveyed using the towed video system. Surveyed substrates included mud, sand, cobble, boulder, and rock. Surveyed ecosystems included *Sargassum* beds, flat-kelp dominated rocky habitats, sea urchin barrens, eelgrass beds, and *Macrocystis* forests. The towed video system operated with equal ease in both flat, obstacle-free habitats and steep, rocky habitats. It was also readily maneuvered through subsurface beds of *Macrocystis*, and entire *Macrocystis* plants could be surveyed by raising and lowering the camera as it was slowly towed through the bed.
2) A comparison of the video survey with the dive survey at Hornby Island was attempted. The following preliminary observations were made:
    a. Video transects went farther offshore than dive transects. This is not unexpected, as one of the objectives of the video survey was to search for herring spawn in deeper (and thus farther offshore) waters.
    b. In the northern part of the survey area, the location of the dive transects correlated reasonably well with the location of the regions of high spawn density as observed by the video survey.
    c. In some areas, significant amounts of herring spawn (e.g., densities of 1 to 2 egg layers) appeared to occur in regions outside of the dive survey transects.

   A direct comparison was attempted between the dive survey data and the video survey data, but was largely unsuccessful as very few of the dive data quadrats were less than 20 m from a video survey transect. As a result, an indirect comparison using a grid interpolated from the video survey data was performed. The results of this comparison were rated as “fair”.
3) The following observations were made regarding the high definition drop camera survey:
    a. Images were crisp and clear, and could be enlarged sufficiently to see small organisms.
    b. Individual eggs could be seen clearly and should be identifiable to species.
    c. The amount of vegetation covered by eggs could be estimated.
4) The main limitations of using the towed video system to assess herring spawn were:
    a. Unable to operate in gale force winds.
    b. Unable to operate in very shallow or rocky regions.
    c. A significant amount of operator expertise is required.
    d. The capacity of the system to quantify spawn has yet to be fully assessed.
5) The main benefits of using the towed video system to assess herring spawn were:
    a. High levels of speed and efficiency.
    b. Able to operate in water depths up to 100 m.
    c. Able to operate in rougher water than dive teams.
    d. Able to operate in the presence of sea lions.

6) The main limitations of using the high definition drop camera system to assess herring spawn were:
    a. System is slower to deploy than the towed video system.
    b. Camera deployment time was limited by the size of the on board memory.
    c. Operation in "low light" conditions resulted in a small depth of field.
    d. Water turbidity had a significant impact on the drop camera"s resolution.
7) The main benefits of using the high definition drop camera system to assess herring spawn were:
    a. High resolution images.
    b. Constant field of view.
    c. No motion blur.
8) Ocean Ecology recommended that the high definition drop camera system be used with a stratified random sampling design, and that the images by analyzed using an areal coverage methodology.
9) Ocean Ecology recommended the following possible future directions for HCRS to consider:
    a. Using the video survey as a pre-assessment tool to quickly assess the presence/absence of spawn in an area, and determine its location and extent, with the possibility of sending divers in at a later time to carry out a quantitative survey.
    b. Carry out further calibration experiments with the high definition drop camera system.
    c. Develop a protocol for the collection of GPS data by dive survey teams and train the dive teams in the use of this protocol.
10) The following questions were posed during the 2010 experimental herring surveys, and could form the basis for future research:
    a. Do herring require contact with the substrate in order to deposit their eggs, or do they release them just above the substrate?
    b. Does the presence of sediment cause the herring to release their eggs in the water?
    c. Is it possible that the herring "broadcast" spawn in the absence of suitable substrate? How long can female herring retain their eggs before they must spawn or the retained eggs loose viability?
    d. Do urchin barrens, which result in loss of suitable spawning substrate, have an effect on where and how the herring spawn?
    e. Can we improve our ability to track herring schools?
    f. What are the effects of oceanographic conditions (e.g., currents, tides, wind) on the spawning locations?
    g. Do herring have a vegetation type preference when spawning?
    h. What effect does selective fishing pressure have on herring spawning behavior?
    i. Are global climate changes affecting the locations and patterns of herring spawning? Do we need to be taking large scale climate changes into account when modeling herring?

1. Introduction

In 2008, at the Fall Meeting of the Herring Industry Advisory Board (HIAB), a collaborative project between DFO and the Herring Conservation and Research Society (HCRS) to investigate the capability of a towed video camera and/or ROV to measure herring spawn was proposed. The rationale for this study was twofold:

1) If camera survey technology can be developed and proven, it may be useful in the future to supplement and complement present survey techniques by examining early, late, or deep herring spawns.
2) Camera survey technology may also be useful in circumstances where DFO divers are not available or unable to survey specific sites.

However, HIAB noted that for potential future applications, camera surveys would only be useful if they could be conducted at a reasonable cost, and provide data that are compatible with the existing herring spawn surveys.

During the spring of 2009, Ocean Ecology was contacted by HCRS, and an experimental design for the assessment of a towed video camera survey of herring spawn was developed. In April, 2009, the experimental herring video survey was carried out in Big Bay, after DFO dive surveys determined that herring spawn was present.

Comparisons of the 2009 results between the dive and camera surveys found both similarities and differences in the assessment of the areas surveyed. Some of the discrepancies between the surveys may have been related to uncertainty about the exact positioning of the DFO transect stations. Other differences may have been related to survey timing. For example, since the camera survey occurred several days after the dive survey, natural egg loss from predation or the possibility of a new spawning event may have altered the amount of spawn present as compared with that observed by the dive survey.

The focus areas of the 2010 survey were:

1) to conduct surveys and collect information which would allow adequate geographical comparison of the dive and video surveyed spawning areas
2) to develop a camera survey protocol using a towed video camera to assess spawning bed boundaries in conjunction with a high definition camera taking still photographs to assist in the interpretation of the video data.
3) to develop a spawn intensity rating system using categories (e.g. “trace”, “light”, “medium”)

2. Survey Equipment

2.1 Towed Benthic Video Survey System

A DGPS-positioned, towed video system was used to collect imagery of the seabed (similar to the Seabed Imaging and Mapping System used by CORI). This system was a custom-built model (e.g., not commercially available) designed for use in the steep, rugged terrain characteristic of British Columbia fjords. Typical tow speed for the system was 0.7 knots. The towed video system has 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 downward-looking camera was also equipped with a pair of scaling lasers with a center-to-center distance of 4 cm.

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.

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.

2.2 Video Recording System

The dual analog camera signals from the towed benthic video system 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.

2.3 High Definition Drop Camera System

A DGPS-positioned, high definition drop camera system was used to collect high resolution still photographs of the seabed. This system consisted of a dual Ethernet/analog output high definition video camera in a water tight housing mounted in a “lander” frame. The lander frame was designed to hold the camera at a specific elevation above the sea floor with a known field of view, and to minimize movement of the camera system so that blurring of the photographs was reduced. The lander frame had a 0.25 m^2 base footprint, which matches the standard quadrat size used by the herring dive survey. The height of the camera was adjusted in the frame such that the field of view of the camera matched the lander footprint, and was thus also 0.25 m^2.

The camera used in the video system was a 5.0 MP IQeye 755 with a maximum resolution of 2560 x 1920 pixels. It operates very well in low-light conditions, with a 0.3 lux sensitivity for color images and < 0.05 lux sensitivity for black and white images. Power consumption is less than 2.5 W, which made the camera ideally suited for a remotely-powered system. The camera has both a full time analog video output (NTSC/PAL standard) and an Ethernet output which allows live streaming of high definition video and images as well as control over the various camera settings. Since it was not possible to have an Ethernet connection to the camera while it was underwater, the camera was set up to record high definition images to an onboard CF card every 2 seconds. Live video from the camera was viewed real-time on the vessel during deployment using the analog output. When the camera was brought to the surface, the Ethernet cable was attached, and the recorded images were downloaded to a computer.

High intensity white LEDs were mounted on the camera to provide additional illumination when it was required. Both the camera and the light ring were powered remotely using a POC (power over coaxial) system.

3. Survey Methodology

3.1 Towed Benthic Video Surveys of Dive Transects

Video surveys of the dive transects were designed to duplicate the dive survey as closely as possible in order to permit meaningful comparison between the results of the two surveys. Thus, for each location the survey consisted of a series of shore-perpendicular transects along the dive transects as defined by the start and end GPS points provided by DFO. These transects were continued inshore to 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.

3.2 Exploratory Video Surveys

In several locations, the towed video system was used as an exploratory tool to determine whether or not herring spawn was present. In these surveys, no attempt was made to follow existing dive transects. Instead, the video system was towed in a manner which attempted to provide a rapid assessment with both shore-parallel and shore-perpendicular coverage.

3.3 Drop Camera Surveys

Upon completion of the towed video survey for a location, several representative transects where herring spawn had been observed were selected. Ten evenly-spaced drop locations were then plotted along each of the selected transects using ArcMap. The ship was positioned as close as possible to each of the plotted drop locations, and the high definition drop camera was lowered to the bottom. Using the live analog signal received from the camera, the position of the lander frame was checked for stability. After a waiting period to allow all stirred up sediment to drift away, the video system was held in position for approximately 10 seconds to provide sufficient time for a number of 5.0 MP images of the bottom to be recorded by the system. The drop camera was then raised to the surface for redeployment at the next drop location.

3.4 Bathymetric Surveys

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

3.5 Classification and Mapping

3.5.1 Depth and Bottom Hardness Contour Plots

The bathymetry data (depth and bottom hardness) collected from the site were corrected for transducer position relative to the GPS antennae and for tidal height in ArcGIS. The corrected data was exported from ArcGIS, and used to generate contour plots in Surfer (a more specialized contouring and 3D surface mapping program than ArcGIS). These contour plots were then imported back into ArcGIS to be used in further GIS analyses. The chart datum for these plots is Lowest Normal Tide (LNT), which is consistent with the Canadian Hydrographic Service"s nautical charts.

3.5.2 Databases of Herring Video Data Observations

For ease of data management, the raw video of the transects was clipped into segments of generally less than 30 minutes length, and saved as .avi files (XVID format). These video segments were then reviewed and annotated using the "Anvil" annotation software. The annotation process consisted of coding each second of raw video for substrate, vegetation, and herring spawn density. From the video annotations, a database was generated containing the following information:

1) ***Substrate data***. Substrate type (Table A1 in Appendix 1) and percentage substrate cover (Table A2 in Appendix 1) were recorded.
2) ***Vegetation data***. Vegetation type (Table A3 in Appendix 1) and vegetation coverage classes (Table A4 in Appendix 1) were recorded. Up to three vegetation types were evaluated for each second of video and given distribution codes.
3) ***Herring spawn density data***. The average egg layers per field of view per second were recorded (Table A5 in Appendix 1). From the DFO Herring Spawn Survey Manual[1] protocol, "A layer of eggs one egg thick over the entire spawned surface is recorded as one layer. An additional layer over half of the spawned surface is 0.5 layers." For the analysis of the video data, this was modified as follows: "A layer of eggs one egg thick over the entire video field of view is recorded as one layer. An additional layer over half of the video field of view is 0.5 layers." For the video analysis, there are only four herring spawn density categories, with the last one being egg layers >2, as the camera is unable to differentiate anything greater than this.

Video annotation creates 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 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.

[1] Fort, C., Daniel, K., and Thompson, M. 2009. Herring Spawn Survey Manual. Fisheries and Oceans. Science.

3.5.3 ArcGIS Mapping

All data for the project were visualized as a series of maps in ArcGIS. These maps have been provided as an ArcGIS project which can be viewed using the supplied ArcReader.

3.5.4 Substrate Maps

Substrate observations were mapped as a series of points in ArcMap. A hexagonal grid (composed of hexagonal polygons with widths of 90 m) was overlaid on the observation points. Each polygon was assigned a substrate code based on the code of the majority of the data points within that polygon. Polygons which contained no data points were assigned the code of the nearest neighbouring polygon.

3.5.5 Vegetation Range Maps

Range maps for vegetation were generated using the fixed kernel density estimation procedure. Vegetation observations were weighted by abundance (see Table A4 in Appendix 1). In order to allow overlap of polygons between transects, the search radius (a.k.a. the smoothing factor) was set to the distance between shore-normal transects (e.g., 350 m). For each organism, a 95% volume contour was generated. This consisted of a polygon covering a geographical area in which 95% of the estimated population was expected to be found.

3.5.6 Dominant Vegetation Maps

Observations for vegetation were mapped as a series of points in ArcMap. A hexagonal grid (composed of hexagonal polygons with widths of 90 m) was overlaid on the observation points. Each polygon was assigned a species code based on the most abundant species within that polygon, weighted by abundance. Polygons which contained no data points were assigned the code of the nearest neighbouring polygon.

3.5.7 Herring Spawn Maps

A herring spawn contour map was generated from the “Herring spawn density” value using Surfer. A raster image in ArcGIS with a cell size of 10 m x 10 m was created from this contour map.

For further information on the software and calculations used in developing the herring spawn maps, see Appendix 2.

4. Survey Results

4.1 High Definition Drop Camera Design

Ocean Ecology successfully designed and deployed a high definition drop camera during the video survey work on Hornby Island. However, as described during our preliminary discussions with HCRS, the system was something of a compromise, as much of the technology used in the system is “leading edge” and not yet designed for deployment in a marine environment. During the design and development phase of the high definition drop camera system, a number of issues were encountered and resolved. These included the following:

1) ***Short time frame for design and development***. Ocean Ecology was given approval to start the design of the high definition camera system at the beginning of January with completion scheduled for the end of February. This was an extremely short time frame for what evolved into a very complex design project.
2) ***Importing and border security***. Much of the electronics used in the high definition camera system are not available in Canada, and must be imported. During the design phase of the system, the Winter Olympics were taking place in Vancouver, resulting in increased border security and delays of up to 2 weeks on imports. This increased the difficulties associated with the already short time frame for the project.
3) ***Camera size***. The IQeye 755 was purchased “sight unseen” based on its specifications. High definition cameras are generally much larger than the normal analog cameras which Ocean Ecology uses in its towed video system. Originally, it was hoped that the IQeye, which is one of the smallest high definition cameras available, would fit in Ocean Ecology‟s pre-existing water tight housing. When the camera arrived, it became quickly apparent that a new housing would have to be constructed to accommodate the larger size of the high definition camera.
4) ***Availability of armored Ethernet cables***. Currently, Ocean Ecology uses an 11 mm electromechanical oceanographic cable which consists of a two conductor coaxial core protected by two layers of helically wound plough steel strands. Ethernet cable has 8 conductors (rather that two, as in a coaxial cable). An armored 8 conductor cable is not available “off the shelf”, although possibly one could be specially ordered and constructed, at some expense. As a result, it was not possible to run “live” Ethernet to the high definition camera system using the tradition 8 conductor approach.
5) ***POC (power over coaxial) vs. POE (power over Ethernet)***. The IQeye 755 can be powered either directly through a 12 V power supply, or indirectly by supplying power through the Ethernet cable in a system referred to as POE (power over Ethernet). Since an armored Ethernet cable was not available, the POE option could not be used. Supplying the camera directly with 12 V can be accomplished by using a battery pack; however, this would make the system large and bulky, and greatly limiting the recording time of the camera. Ocean Ecology has chosen a different approach to this problem. Since the current tow cable is coaxial, a system termed POC (power over coaxial) has been used. This system uses a pair of “video modems” which simultaneously transmit power from the ship to the camera and analog video from the camera back to the ship over a single coaxial cable.

6) ***EOC (Ethernet over coaxial)***. A new technology is becoming available which allows the transmission of Internet Protocol (IP) signals (e.g., computer or Ethernet data signals) over coaxial cables. This technology is referred to as EOC (Ethernet over coaxial). It has the advantage of allowing the use of cheaper, more readily available coaxial cables for data transmission between computers and other electronic equipment rather than using 8 conductor Ethernet cables. However, this technology suffers from several disadvantages. Passive EOC (e.g., no power supply) can only be used over relatively short coaxial cable runs (generally shorter than the length of Ocean Ecology"s tow cable). Active EOC (e.g., with a power supply) can be used over longer cable runs, but requires power at both the receiving (computer) end and the remote (camera) end. No currently available EOC system in North America can supply power to the remote end while simultaneously transmitting an IP signal. Thus, Ocean Ecology was unable to use the EOC technology to provide a "live" Ethernet link to the high definition camera over the current coaxial cable. EOC was deployed for the short cable run which is used to download data from the camera"s CF card when the camera is out of water.
7) ***Cable impedance***. Most commercially available video equipment and coaxial cables have an impedance of 75 Ω. However, oceanographic coaxial cables have an impedance of 50 Ω. Impedance mismatches in a system will cause a portion of the signal power traveling from source to the load to be reflected back to the source. DC current is not affected by impedance mismatches; however video and computer signals may be affected. The degree of the effect is related to the frequency of the signal and the length of the cable. The lower the frequency of the signal, the longer its wavelength will be. If the wavelength of the signal exceeds the length of the cable run, there will be no impedance problems. If the wavelength of the signal is shorter than the cable run, impedance mismatch is possible. Video signals, which rarely exceed a frequency of 10 MHz, have an approximate wavelength of 20 meters. Thus, impedance mismatch may become a factor in cable runs over 20 meters in length. High resolution computer video signals and fast digital signals easily exceed a frequency of 100 MHz, so the proper impedance matching is needed even in short cable runs. Impedance mismatch is significantly increased by dirty or corroded connectors between cables, thus requiring meticulous maintenance of all the connections in the video system. Impedance mismatch can cause "ghosting", "ringing" or other interference patterns to occur in the video signal. The impedance mismatch between the video equipment and the oceanographic cable was another factor which made EOC in the high definition drop camera system unviable.

4.2 Survey Limitations

The following factors had potential impacts on the survey, and should be considered as possible limitations of the survey:

1) ***Poor weather conditions.*** Work in the Strait of Georgia was impeded by both southeast and northwest gales. This made it difficult to carry out the video survey, as often the ship would be wind-bound for part of each day. High winds also increased the water turbidity, thus decreasing the resolution and clarity of the video. In Big Bay, work was brought to a complete standstill during a southeast storm.
2) ***High water turbidity.*** High water turbidity was caused by wind-stirred sediment, as well as herring milt (especially in Big Bay). High turbidity not only reduces the quality of the video footage, it also slows the video survey down, as the camera must be towed closer to the seafloor at a slower speed in order to clearly record the presence of the herring spawn.
3) ***Spawn timing and pattern.*** In both the Strait of Georgia and the Big Bay area, herring spawning started early and occurred in small patches, rather than in long stretches (as is the normal pattern). Furthermore, the herring spawned repeatedly over time in the same area. The patchiness of the spawn made it difficult to locate. The repeated spawning events meant that the time elapsed between the dive survey and the video survey had to be very short, as even a period of 12 hours could lead to a significant difference between the observations of the two surveys.
4) ***Ground wire break in the video tow cable.*** Midway through the survey work in the Strait of Georgia, the video camera system started experiencing temporary power losses and degradation of signal on one channel (the forward-looking camera). Initially, this was diagnosed as water ingression into the cable termination plug. The plug was cleaned and dried, and silicone applied to the suspect area where the leak occurred. This appeared to temporarily correct the problem, and video work continued. However, the problem re-emerged during the Big Bay survey, and ultimately, near the end of the survey, the system completely lost power. At this point, it was discovered that seawater had entered the cable, possibly from the poorly-sealed plug, and had caused corrosion of the ground wire in the electrical cable, finally resulting in a complete break of the ground wire. Although repairs were not possible in the field, the cable was readily repaired once the ship was back in port.

4.3 Survey Locations

4.3.1 Video Surveys of Dive Transects

4.3.1.1 Hornby Island

Twenty-five towed video transects were carried out along the west coast of Hornby Island following the transects as laid out for the dive survey. These transects had a total length of 9.4 km, and covered an approximately area of 2.48 km^2. These transects, and the dates upon which they were carried out, are given in the Table 1 below.

Table 1. Towed video surveys on the west coast of Hornby Island.

Transect	Date of Dive Survey	Date of Towed Video Survey
2315	13/03/2010	12/03/2010
2316	13/03/2010	12/03/2010
2317	12/03/2010	12/03/2010
2318	12/03/2010	12/03/2010
2319	12/03/2010	12/03/2010
2322	12/03/2010	10/03/2010
2323	12/03/2010	10/03/2010
2324	12/03/2010	10/03/2010
2325	15/03/2010	10/03/2010
2326	15/03/2010	10/03/2010
2327	15/03/2010	10/03/2010
2328	14/03/2010	10/03/2010
2329	14/03/2010	10/03/2010
2330	14/03/2010	10/03/2010
2331	14/03/2010	10/03/2010
2332	14/03/2010	14/03/2010
2333	14/03/2010	14/03/2010
2334	14/03/2010	14/03/2010
2335	14/03/2010	14/03/2010
2336	14/03/2010	14/03/2010
2337	14/03/2010	14/03/2010
2338	14/03/2010	14/03/2010
2339	14/03/2010	14/03/2010
2340	14/03/2010	14/03/2010
2341	14/03/2010	14/03/2010

Blue highlighting in the above table indicates transects where both the dive survey and the towed video survey occurred on the same day, often within hours of each other.

Figure1 and Figure 2 show the locations of both the dive transects and the towed video transects along the west coast of Hornby Island.

4.3.1.2 Swamp Island

Eight towed video transects were carried out in the region around Swamp Island following the transects as laid out for the dive survey. These transects had a total length of 7.0 km, and covered an approximately area of 1.73 km^2. These transects, and the dates upon which they were carried out, are given in the Table 2 below.

Table 2. Towed video surveys in the region around Swamp Island.

Transect	Date of Dive Survey	Date of Towed Video Survey
2015		04/04/2010
2016		04/04/2010
2017		04/04/2010
2018	04/04/2010	05/04/2010
2019	04/04/2010	05/04/2010
2020	04/04/2010	05/04/2010
2021	04/04/2010	05/04/2010
2022		05/04/2010

Red highlighting in the above table indicates transects where either no GPS data was recorded for the dive transect, or the data was not recorded properly, and thus no comparison will be possible between the dive and video transects. Note that a list of the transects to be surveyed by the towed video system was provided to the dive team prior to both teams departing from Prince Rupert.

Figure 3 shows the locations of both the dive transects and the towed video transects around Swamp Island.

4.3.1.3 Big Bay

Seven towed video transects were carried out in Big Bay following the transects as laid out for the dive survey. These transects had a total length of 5.6 km, and covered an approximately area of 0.78 km^2. These transects, and the dates upon which they were carried out, are given in the Table 3 below.

Table 3. Towed video surveys in Big Bay.

Transect	Date of Dive Survey	Date of Towed Video Survey
2052	13/04/2010	08/04/2010, 14/04/2010
2053	06/04/2010	08/04/2010, 14/04/2010
2060		14/04/2010
2061	13/04/2010	14/04/2010
2062		14/04/2010
2063	13/04/2010	14/04/2010
2064	13/04/2010	14/04/2010

Towed video transects were carried out on transects 2052 and 2053 on two separate days. On April 8th, herring were actively spawning on both transects, and the decision was made to re-video these transects after the spawning had ceased in order to make a more accurate estimate of the spawn deposition. Thus, the video work was repeated on April 14th.

Red highlighting in the above table indicates transects where no GPS data was recorded for the dive transect, and thus no comparison will be possible between the dive and video transects. Note that a list of the transects to be surveyed by the towed video system was provided to the dive team prior to both teams departing from Prince Rupert.

Figure 4 shows the locations of both the dive transects and the towed video transects in Big Bay.

4.3.2 Exploratory Video Surveys

4.3.2.1 Norris Rock

Four exploratory towed video transects were carried out around Norris Rock on March 12th, 2010. Figure 5 shows the locations of the towed video transects around Norris Rock.

4.3.2.2 Fillongley Park

Three exploratory towed video transects were carried out near Fillongley Park on March 14th, 2010. Figure 6 shows the locations of the towed video transects near Fillongley Park.

4.3.2.3 Hodgson Reef

One exploratory towed video transects was carried out around Hodgson Reef on April 5th, 2010. Figure 7 shows the location of the towed video transect around Hodgson Reef.

4.3.3 Drop Camera Survey

4.3.3.1 Hornby Island

Forty-three high definition camera drops were carried out along 6 transects on the west coast of Hornby Island. Information on these camera drops is given in Table 4 below.

Table 4. High definition drop camera survey on the west coast of Hornby Island.

Transect	Number of drops	Date of Drop Camera Survey	Date of Associated Towed Video Survey
2316	3	13/03/2010	12/03/2010
2317	3	13/03/2010	12/03/2010
2318	5	13/03/2010	12/03/2010
2319	10	13/03/2010	12/03/2010
2322	11	11/03/2010	10/03/2010
2323	11	11/03/2010	10/03/2010

Figure 8 shows the locations of the high definition camera drops on the west coast of Hornby Island.

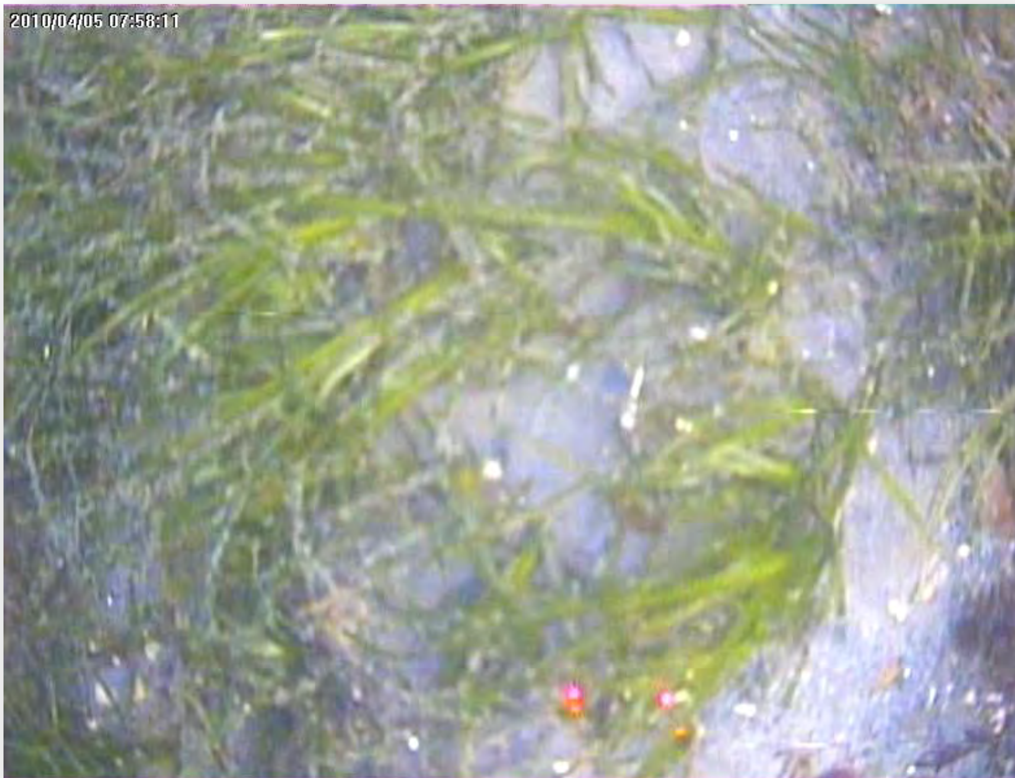
4.4 Habitats Surveyed

A variety of habitats were surveyed during the 2010 herring season using the towed video system. Surveyed substrates included mud, sand, cobble, boulder, and rock. Surveyed ecosystems included *Sargassum* beds, flat-kelp dominated rocky habitats, sea urchin barrens, eelgrass beds, and *Macrocystis* forests.

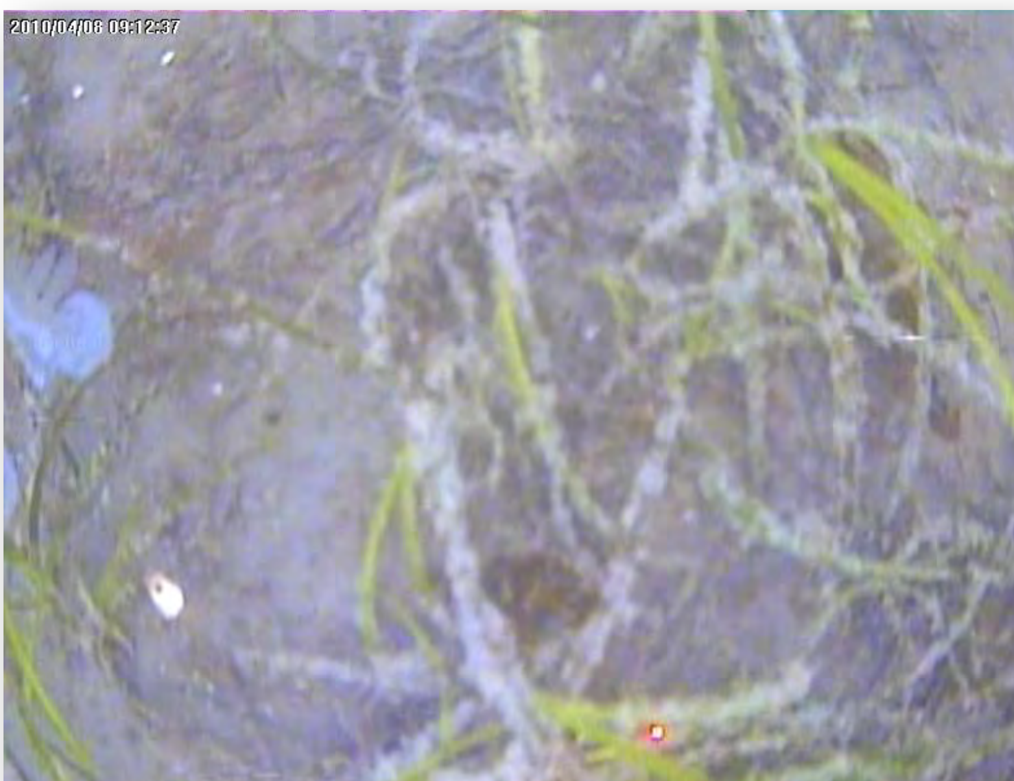
The towed video system operated with equal ease in both flat, obstacle-free habitats and steep, rocky habitats. Although the system was not towed through thick beds of surface *Macrocystis* (to prevent damage to the beds and gear entanglement), it was readily maneuvered through subsurface beds of *Macrocystis*, and entire *Macrocystis* plants could be surveyed by raising and lowering the camera as it was slowly towed through the bed.

Shown below are sample video images from some of the video footage showing herring spawn on different vegetation types.

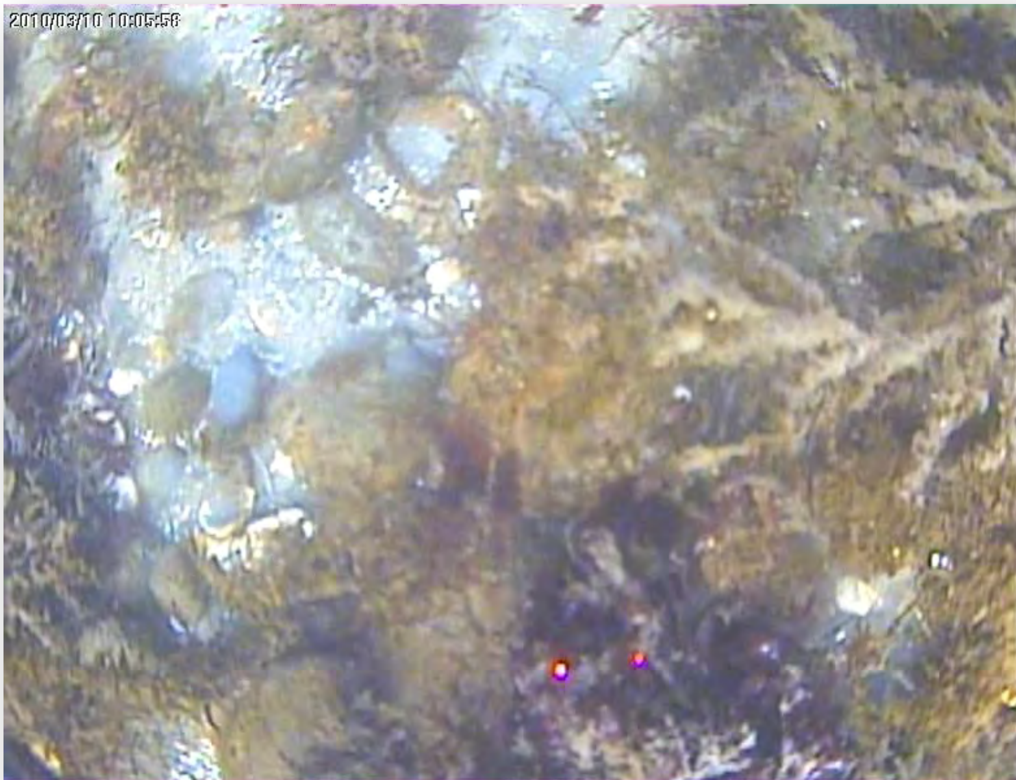
4.4.1 Eelgrass

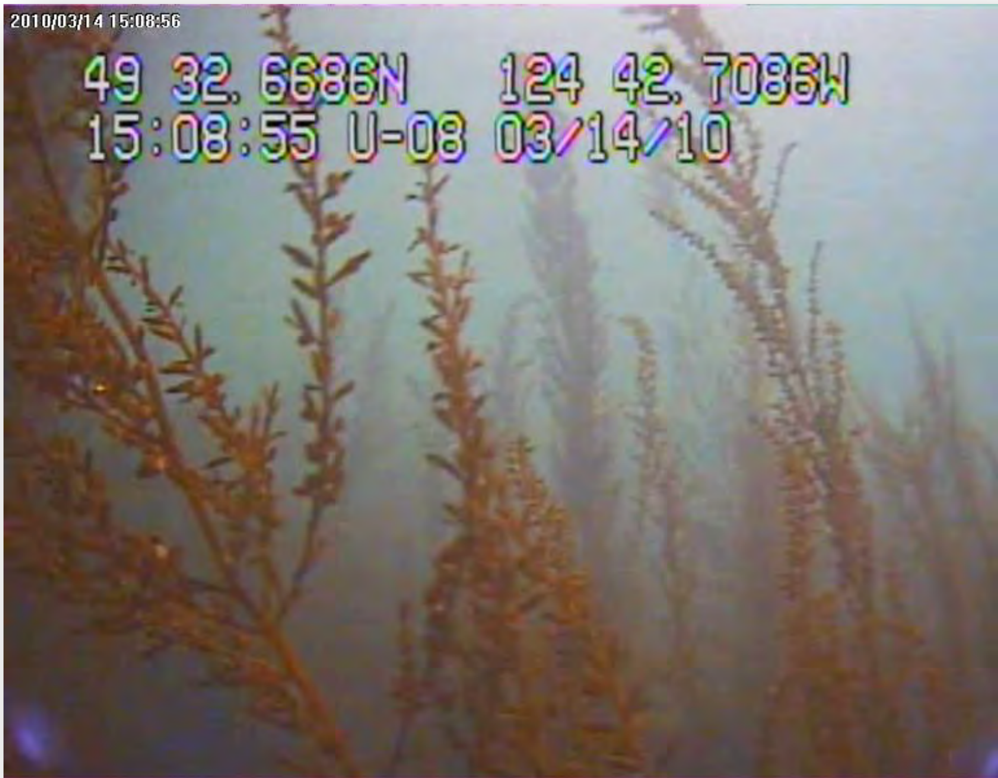


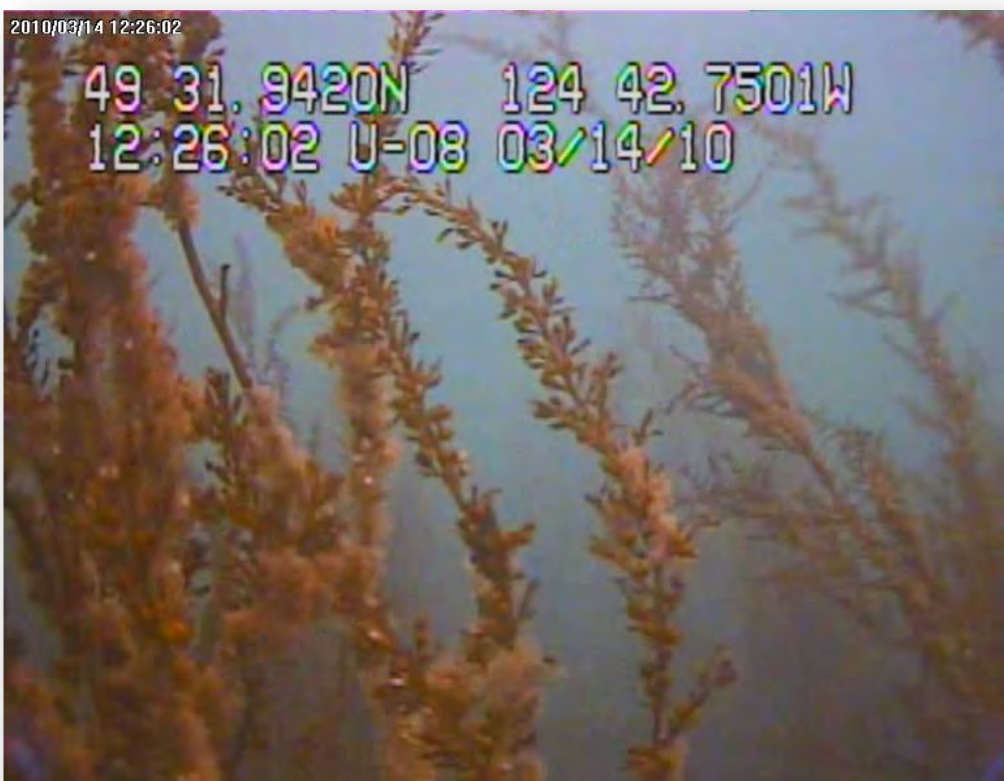

2010/04/05 13:32:40


2010/04/08 09:12:37

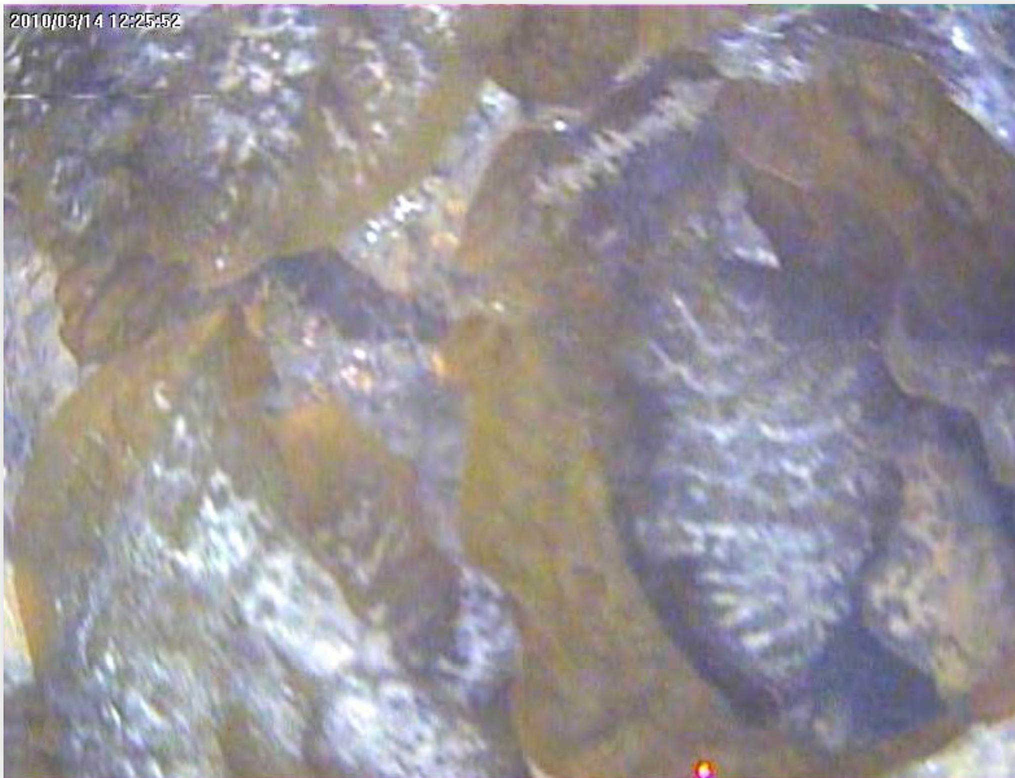
4.4.2 Sargassum



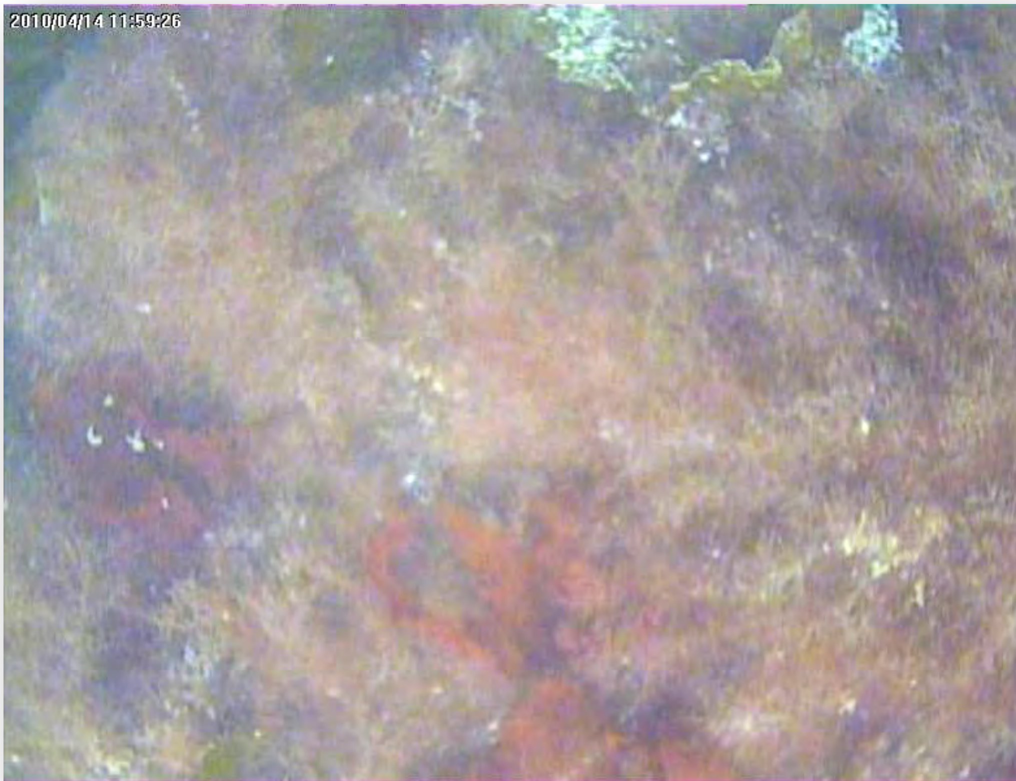

2010/03/14 15:08:56
49 32.6686N 124 42.7086W
15:08:55 U-08 03/14/10


2010/03/14 12:26:02
49 31.9420N 124 42.7501W
12:26:02 U-08 03/14/10

4.4.3 Flat Kelp



4.4.4 Stringy Seaweed



4.4.5 Macrocystis


2010/04/04 15:56:26
54 22.3150N 130 29.4519W
15:56:27 U-08 04/04/10


2010/04/04 15:58:15

4.5 General Observations of Spawn Distribution

During the 2010 herring spawn survey, ten DVDs of raw video data showing distribution of herring spawn were generated. From this data, the following generalizations can be made regarding spawn distribution.

4.5.1 Southern Herring Spawn Survey

The following general observations of spawn distribution were made during the video surveys of herring spawn in the Strait of Georgia:

1) On the west side of Hornby Island, herring spawn was observed from Norman Point to Collinshaw Point.
2) Spawn deposition appeared to be heaviest at the points, possibly due to the effects of winds and currents concentrating the herring on windward side of the points during southeast gale force winds. Lighter, narrower bands of spawn occurred between points.
3) Spawn deposition was heaviest and widest at Collinshaw Point.
4) There was little or no spawn observed around Norris Rock during the exploratory video survey of this area, even though milt was seen in the water around Norris Rock by local observers.
5) At Norris Rock, video surveys were carried out to a depth of 98 m; however no spawn was observed in the deep water.
6) There was little or no spawn observed in the region around Fillongley Park.
7) In the regions surveyed, there was a clear vegetation type preference shown for spawn deposition. The order of preference, from most preferred to least preferred, was:

Sargassum > *Laminaria* > foliose and filamentous reds > *Zostera* > *Agarum*

4.5.2 Northern Herring Spawn Survey

The following general observations of spawn distribution were made during the video surveys of herring spawn on the North Coast:

1) Herring spawn was observed throughout both the Swamp Island and Big Bay survey areas. In the Swamp Island region, herring spawn was found mainly on *Macrocystis*. In the Big Bay region, where there was no *Macrocystis*, herring spawn was largely deposited on flat kelps.
2) Although milt had been observed in the area, no spawn was found during the exploratory survey of Hodgson Reef.
3) Spawning occurred in small patches over a long period of time, rather than in a long continuous stretch over a short period of time as has been observed in the past.
4) In the regions surveyed, there was a clear vegetation type preference shown for spawn deposition. The order of preference, from most preferred to least preferred, was:

Macrocystis > *Laminaria* > foliose and filamentous reds > *Zostera* > *Agarum*

4.6 Hornby Island Survey

4.6.1 Benthic Video Survey

The transect lines for the survey as carried out are shown in Figure 1 and Figure 2. There were 25 transects in total, with a total length of 9.4 km. The field time taken for this survey was approximately 2.25 days (approximately 43 minutes per transect or 7 s per m). Depth coverage was from -0.6 m (lower intertidal zone) to 96.2 m.

Three DVDs 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.

4.6.2 Bathymetric Survey

The results of the bathymetric survey are shown in Figure 9 and Figure 10 (depth) and Figure 11 and Figure 12 (hardness).

Some observations regarding the bathymetry of the Hornby Island site are:

1) The depth of the region surveyed ranges from -0.6 m to 96.2 m. The NW side of Hornby Island has a relatively flat and shallow topography, whereas the SW side of Hornby Island has a narrow shelf which drops rapidly into deeper water. The deepest region of the area surveyed occurs around Norman Point, where the bottom drops off very steeply.
2) Bottom hardness values for the site ranged from 2.3 to 8.0. The maximum range for bottom hardness is 0 to 8.0. Overall, the Hornby Island region consists mainly of a shallow layer of sandy sediment over bedrock. In small, wave-sheltered areas, the sand accumulates to form thicker layers (observed around Manning Point and Norman Point). The sediment layer also increases with depth.

4.6.3 Substrate

Based on video observations, the site substrate consisted largely of sand, with areas of cobble in and around the rocky outcrops and points (see Figure 13 and Figure 14). Past Phipps Point, the substrate becomes more pebbly in nature.

4.6.4 Vegetation

Distributions of algae are shown in the following figures: (1) Figure 15 and Figure 16 – seagrasses and flat kelps; and (2) Figure 17 and Figure 18 – stringy algae, sargassum, and leafy algae. The dominant vegetation types throughout the site are shown in Figure 19 and Figure 20.

Table 5 lists the various types of vegetation identified at the site, their abundances in terms of number of observations, and their percentages in terms of total vegetation observations.

Table 5. Overall abundances of vegetation types.

Vegetation Identification	Number of Observations	Percentage of Total Vegetation Observations
Flat kelps	3636	34.96
Leafy algae	2549	24.51
Sargassum	2072	19.92
Seagrasses	1642	15.79
Stringy algae	500	4.81
Total	**10399**	**100.00**

Table 6 lists the various types of vegetation identified at the site with spawn present, their abundances in terms of number of observations, and their percentages in terms of total observations of vegetation with spawn present.

Table 6. Abundances of vegetation types with spawn present.

Vegetation Identification	Number of Observations	Percentage of Total Vegetation Observations
Flat kelps	2456	34.64
Leafy algae	1581	22.30
Sargassum	2123	29.94
Seagrasses	722	10.18
Stringy algae	208	2.93
Total	**7090**	**100.00**

Some observations regarding vegetation at the Hornby Island site are:

1) Flat kelps were the most abundant vegetation at the site, and were widely distributed throughout the site.
2) Sargassum occurred at Shingle Spit, and from Phipps Point to Collishaw Point.
3) Seagrasses were relatively sparse, and were found from Norman Point to Phipps Point.
4) The least abundant algae type was stringy algae.
5) Approximately 68% of the vegetation observed during the video survey had spawn on it.
6) The vegetation type which had the greatest occurrences of herring spawn was flat kelps; however, in the locations where it occurred, *Sargassum* appeared to be the preferred vegetation type. While only making up approximately 20% of the vegetation observations, *Sargassum* had 30% of the spawn observations, and thus had the second greatest occurrences of herring spawn.
7) The vegetation type which had the lowest occurrences of herring spawn was stringy algae, probably because it was the least abundant algae type at the site.
8) Seagrasses tended to be more dominant in the regions between points where sediment deposition occurred. *Sargassum* tended to be more dominant near the points where the wave energy was higher and the substrate was pebblier in nature. Flat kelps were the most dominant vegetation, and were found throughout the site on a variety of substrates.

4.6.5 Herring Spawn Density

Figure 21 and Figure 22 show the distribution of herring spawn as observed by the towed benthic video survey. The spawning bed boundary is delineated by the blue contour line in Figure 21 and Figure 22. Regions shoreward of this blue line have herring spawn densities greater than 0.01 layers ("sparse"), whereas regions seaward of this blue line have insignificant amounts of herring spawn. Areas of high spawn intensity are delineated by the yellow contour line in Figure 21 and Figure 22. Regions contained within this contour line have a spawn density of 2 or more layers ("moderate" to "dense").

Herring spawn occurred in the greatest density between Phipps Point and Collishaw Point. Other locations of significant spawn were (1) along the beach between Ford Cove and Shingle Spit and (2) just south of Ford Cove.

4.6.6 Comparison of Video and Dive Surveys for Hornby Island

4.6.6.1 General Observations

Using data provided by HCRS, the approximate locations of the dive surveys relative to the towed benthic video surveys were plotted. These positions are shown on Figure 23 and Figure 24. The following possible observations can be made:

1) Video transects went farther offshore than dive transects. This is not unexpected, as one of the objectives of the video survey was to search for herring spawn in deeper (and thus farther offshore) waters.
2) In the northern part of the survey area, the location of the dive transects correlated reasonably well with the location of the regions of high spawn density as observed by the video survey.
3) In some areas, significant amounts of herring spawn (e.g., densities of 1 to 2 egg layers) appeared to occur in regions outside of the dive survey transects.

4.6.6.2 Selection of Dive Survey Data for Comparison

Direct comparisons between the data from the dive survey and the data from the video survey were made somewhat difficult by the lack of consistency in the protocol used by the dive teams to record the GPS positions of the start and end of the spawn bed.

Table 7 below shows those transects on Hornby Island where both a dive survey and a video survey were carried out. The dive survey work around Hornby Island was done by two charter vessels, the *Viking Spirit* and the *Ocean Cloud*. The transects marked in green in Table 7 are the ones done by the *Ocean Cloud*. The transects marked in red in Table 7 are the ones done by the *Viking Spirit*. The second column in Table 7 is the measured distance, in meters, between the two GPS points provided for each dive transect. The third column in Table 7 is the spawn width, in meters, as recorded on the dive data sheets. Ideally, the distance between the GPS points and the spawn width should have been approximately the same. However, this was not the case in some instances. The fourth column in Table 7 is the difference between these two distances. The positional accuracy of an uncorrected GPS signal is approximately 10 m. Thus, if maximum positional error occurred at both GPS points on the transect, one might expect a maximum variance of ±20 m between the measured spawn width and the distance between the GPS points. Values in the fourth column of Table 7 which are highlighted in yellow represent transects where the distance between the GPS points is within ±20 m (the error limits of the GPS unit) of the spawn width. Only these transects were used for comparing the dive and video survey data. In those transects where the difference between the two distances exceeded ±20 m, it was not possible to accurately place the diver sampling quadrats along the transect line.

Table 7. Comparison of observed spawn width and distance between endpoint GPS positions for Hornby Island dive transects.

Transect Number	Distance between GPS Points	Spawn Width	Difference
2341	279.0	100.0	179.0
2340	453.9	252.0	201.9
2339	342.9	184.0	158.9
2338	349.0	269.0	80.0
2337	389.2	287.0	102.2
2336	234.3	48.0	186.3
2335	101.2	100.0	1.2
2334	48.9	47.0	1.9
2333	254.4		254.4
2332	103.0	100.0	3.0
2331	57.4	57.0	0.4
2330	69.2	68.0	1.2
2329	25.6	23.0	2.6
2328	29.0	28.0	1.0
2327*	13.9	10.0	3.9
2326	10.2	8.0	2.2
2325	27.5	25.0	2.5
2324	16.3	16.0	0.3
2323	38.0	36.0	2.0
2322	68.1	65.0	3.1
2319	42.1	40.0	2.1
2318	24.4	20.0	4.4
2317	17.5	11.0	6.5
2316	35.8	39.0	-3.2
2315	36.3	25.0	11.3

*Note: Transect 2327 had no quadrat data recorded on the dive data sheet.

Thus, after excluding transect 2327, which had no recorded quadrat observations, 17 transects were used for the comparison. These 17 transects had 76 individual quadrats. The data for these transects are given in Appendix 3, Table A6. Latitude and longitude data recorded by the dive teams was assumed to be in the WGS 1984 datum (the normal default setting for most GPS units). It is possible that the dive teams were using the NAD 1983 datum (the datum used on the newer CHS chart releases); however the difference between the two datums is minor (on the order of < 0.5 m). The positions of the quadrats were plotted in ArcGIS using the transect start GPS position and measuring the recorded distance for each quadrat along the transect from the start position. Depth from the raw dive data sheets was converted from feet into meters, and then corrected for the tidal height. The value "Average Spawn Layers" is a summed weighted average of the spawn layers observed on each of the vegetation types and on the substrate, and was calculated as follows:

$$\left[\left(\frac{Percent\ Cover\ Vegetation\ 1}{100}\right)(Spawn\ Layers\ Vegetation\ 1)\right] + \left[\left(\frac{Percent\ Cover\ Vegetation\ 2}{100}\right)(Spawn\ Layers\ Vegetation\ 2)\right] + \left[\left(\frac{Percent\ Cover\ Substrate}{100}\right)(Spawn\ Layers\ Substrate)\right]$$

The dive survey data was then converted into units which could be compared with the video survey data. The "Average Spawn Layers" from the dive survey data were converted into "Spawn Abundance" using Table 8 below.

Table 8. Table for conversion between "Average Spawn Layers" from the dive survey data and "Spawn Abundance" from the video survey data.

Average Spawn Layers	Spawn Abundance
0	0
> 0 to ≤ 0.49	0.01
≥ 0.50 to ≤ 1.49	1
≥ 1.5 to ≤ 2.49	2
≥ 2.5	2+

For comparison purposes, the dominant vegetation in the dive survey data was recorded as the vegetation type with the greatest percent cover. The converted data are given in Appendix 3, Table A7.

To determine which dive transect quadrats fell within the region covered by the video survey, a polygon was drawn in ArcGIS which encompassed the video survey transects (see Figure 25). The number of quadrats which fell within this polygon was determined. From this analysis, it was determined that 32 quadrats were within the region covered by the video survey and the remaining 44 quadrats were located landward of the video survey region in areas where the water depth was too shallow for the video survey to be safely carried out.

4.6.6.3 Direct Comparison of the Dive Survey Data with the Video Survey Data

Using the "Join" functionality of ArcMap, the dive survey data set was spatially joined with the video survey data such that each of the 32 quadrat points in the dive survey data set was given all of the "attributes" of the nearest point in the video survey data set. This process also calculated the distance between each dive survey data point and its nearest video survey data point.

The 32 dive quadrat points were then grouped into one of three categories based on the distance to the nearest video data point:

1) Distance to the nearest video data point was ≤ 10 m.
2) Distance to the nearest video data point was > 10 m and ≤ 20 m.
3) Distance to the nearest video data point was > 20 m.

Table 9 below shows the results of the comparisons between the dive and video survey data for cagtegories (1) and (2) above. Quadrats in categories (3) were discarded as a distance between data points of > 20 m is considered too great to make a valid comparison.

Table 9. Direct comparison of dive survey and video survey data points.

Dive Survey Data						Video Survey Data					
Transect	**Quadrat**	**Dominant Vegetation**	**Dominant Substrate**	**Spawn Abundance**	**Depth**	**Transect**	**Dominant Vegetation**	**Dominant Substrate**	**Spawn Abundance**	**Depth**	**Distance**
Distance Between Dive and Video Data ≤ 10 m											
2325	2	Sargassum	Cobbles	2+	-0.07	2325	Sargassum	Pebbles/ Sand	2+	-0.99	5.81
2325	3	Sargassum	Cobbles	2+	0.53	2325	Sargassum/ Leafy Algae	Pebbles/ Sand	2+	-1.29	0.07
Distance Between Dive and Video Data > 10 m and ≤ 20 m											
2325	1	Sargassum	Cobbles	1	-0.98	2325	Sargassum	Pebbles/ Sand	2+	-0.99	11.07

From this analysis, one can see that only two dive quadrats are within 10 m of a video data point, and only a single dive quadrat is located > 10 m but ≤ 20 m from a dive quadrat. Unfortunately, it is clear that very little information can be obtained from a direct comparison of the data sets, as the data sets to not have close overlaps.

On a positive note, the dominant vegetation and spawn abundances were the same for both surveys when the data points were located within 10 m of each other. There is some discrepancy in the dominant substrate coding, but this is most likely resulting from subjectivity in coding mixed substrate (e.g., sand/pebble/cobble mixtures).

4.6.6.4 Indirect Comparison of the Dive Survey Data with the Video Survey Data

Due to the problems associated with making a direct comparison between data points from the dive and video surveys, an indirect interpolation approach was employed.

A high accuracy herring spawn density grid was generated from the video survey data using Surfer (see Figure 26). This grid, which was used for the comparison of the dive and video survey data, was generated by a slightly different method than the herring spawn density grids shown in Figure 21 and Figure 22. The method used to generate this grid is described in Appendix 2. It is a more difficult procedure, and not generally used as it suffers from projection errors if the grid produced by Surfer does not have grid cells which are exactly square. However, it is not affected as much by format conversion errors, and thus more accurately reflects the original data.

Since the accuracy of an uncorrected GPS signal is approximately 10 m, the “Buffer” tool in ArcGIS was used to create a circular buffer polygon with a radius of 10 m around each of the 32 dive quadrat locations to be used in the comparison. Using the “Zonal Statistics” tool in ArcGIS, the average spawn density grid value was obtained for each of the 32 buffer polygons. The comparison between spawn abundance values for the two data sets is shown in Table 10 below. A “comparison rating” value was assigned to each pair of data values in Table 10. The rating system is given in Table 11.

From this table, it is clear that the correlation between the two data sets is only fair. A comparison rating of good is achieved 44% of the time, whereas a comparison rating of fair occurs 31% of the time, and a comparison rating of poor is found in 25% of the comparisons. The average comparison rating is 1.2, which is approximately the value for “fair”.

There are two likely explanations for quadrats which have fair to poor correlation:

1) Even though this method allows more comparisons to be made than a direct method, it is still strongly influenced by the issue that many of the dive survey quadrats are located significant distances from the video survey points. While this method allows interpolation between the video survey points, the accuracy of this interpolation decreases with distance from the video transect positions. Thus, while this method allows a greater comparison of the results than the direct comparison approach, accuracy is much lower for dive quadrats which are > 20 m from the video transect lines.
2) There are significant variabilities in both the environment and the observers. Large changes in the environment (e.g., substrate type, vegetation type, amount of spawn deposited) can occur over small horizontal distances (< 10 m). This can reduce the precision of interpolative methods. Likewise, spawn abundance observations are subjective in nature and can vary significantly from observer to observer.

Table 10. Comparison of the spawn abundance as observed in the dive survey quadrats to the spawn abundance as estimated from the spawn density grid generated from the video survey data.

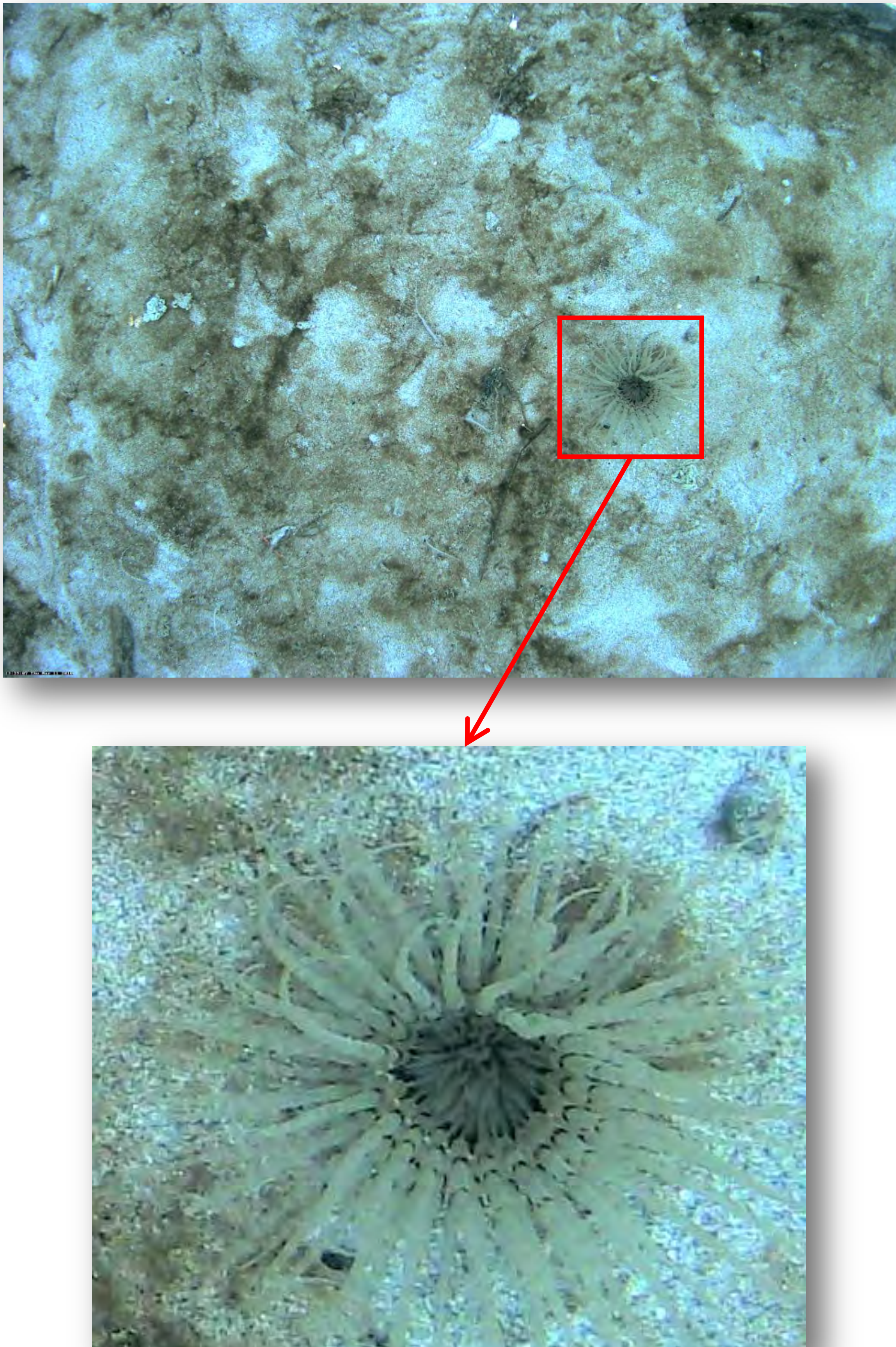
Transect	Quadrat	Spawn Abundance from Dive Data Qudatat	Average Spawn Abundance Estimated from Video Data in 10 m Radius around the Dive Data Quadra	Comparison Rating
2316	1	0.01	0.01	2
2316	3	0.01	0.01	2
2316	4	0.01	0.01	2
2316	5	0.01	0.01	2
2316	6	0.01	0.01	2
2316	7	0.01	0.01	2
2316	8	0.01	0.01	2
2329	1	0.01	0.01	2
2329	2	0.01	0.01	2
2329	3	0.01	0.01	2
2330	1	2	2	2
2331	1	2	2	2
2332	1	0.01	0.01	2
2335	1	1	1	2
2316	2	0	0.01	1
2317	4	1	0.01	1
2317	5	1	0.01	1
2319	1	2+	2	1
2319	2	1	2	1
2319	3	2+	2	1
2325	1	1	2	1
2325	2	2+	2	1
2325	3	2+	2	1
2335	3	1	2	1
2317	1	2+	0.01	0
2317	2	2+	0.01	0
2317	3	2+	0.01	0
2319	4	0.01	2+	0
2319	5	0.01	2+	0
2323	1	0.01	2+	0
2335	2	0.01	2	0
2335	4	1	2+	0

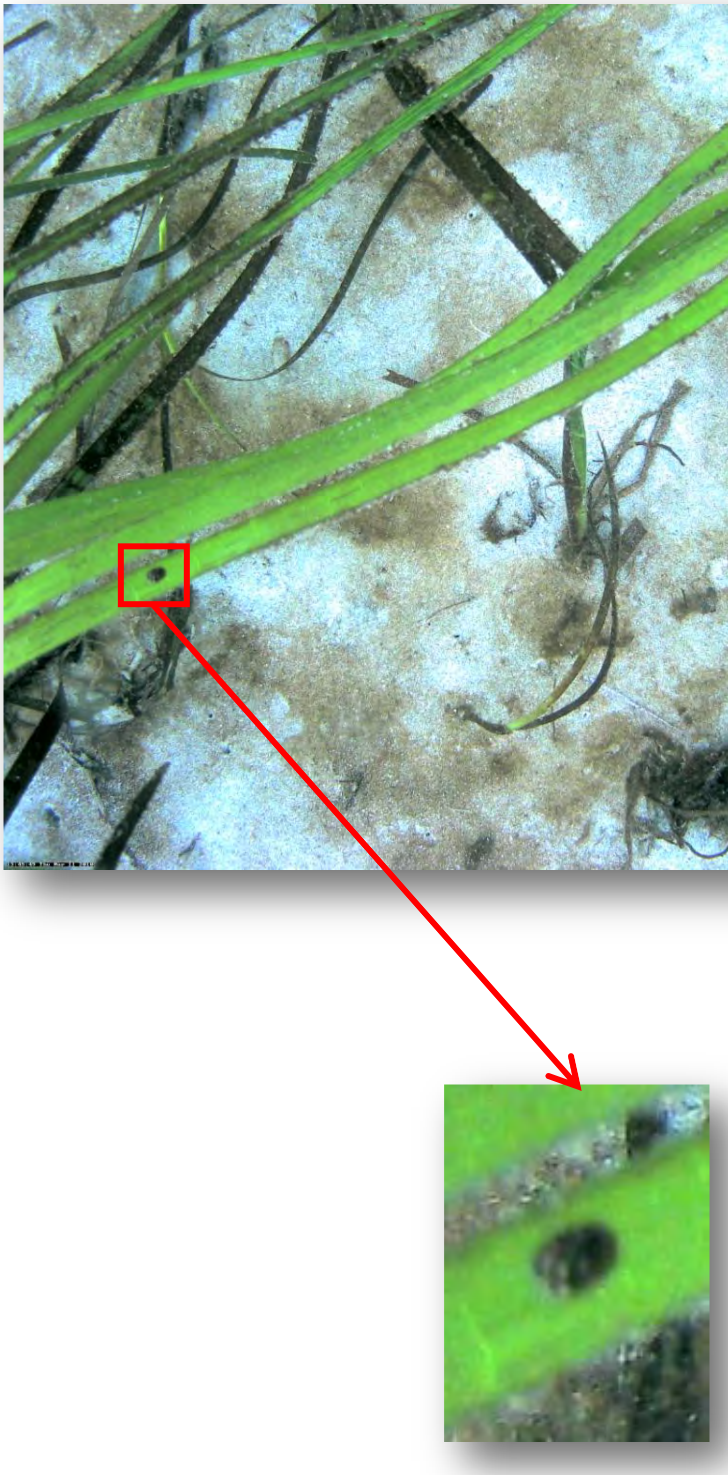
Table 11. Rating system used to compare the dive and video survey data.

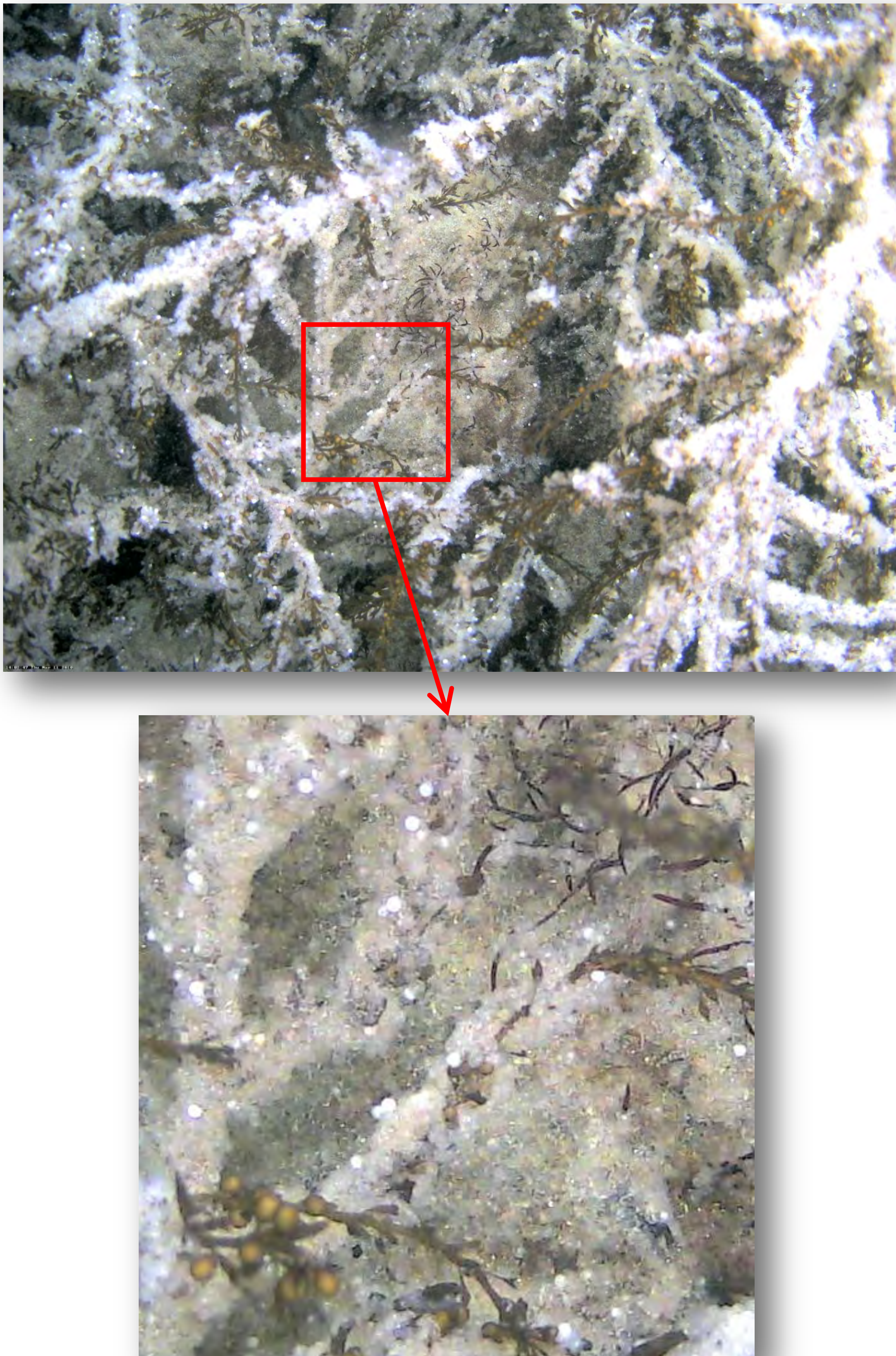
Rating	Rating Value	Description	Example
Good	2	Both data sets have the same spawn abundance category.	0 and 0; 0.01 and 0.01; 1 and 1; 2 and 2; 2+ and 2+
Fair	1	Spawn abundance categories varied between the two data sets by one category.	0 and 0.01; 0.01 and 1; 1 and 2; 2 and 2+
Poor	0	Spawn abundance categories varied by more than one category between the two data sets.	0.01 and 2+; 0.01 and 2; 1 and 2+

4.6.7 High Definition Drop Camera Survey

Shown below are three examples of images taken from the high definition drop camera survey at Hornby Island. This survey was largely investigative in nature, and its primary objective was to see if the quality of the images produced merited further study into the use of the high definition drop camera as a new methodology for assessing herring spawn abundance.







From the above images, the following observations can be made:

1) The images are crisp and clear, and can be enlarged sufficiently to see small organisms (the limpet shown on the eelgrass is less than 5 mm long).
2) Individual eggs can be seen clearly, and their shape, texture, and distribution patterns can be easily seen. This should make the identification of the eggs to species a possibility.
3) The amount of vegetation covered by eggs can be estimated, and in many cases, the number of egg layers can also be seen.

5. Survey Costs

5.1.1 High Definition Drop Camera Design and Testing Costs

High definition drop camera design work was charged at a rate of $350/day (technologist"s daily rate excluding HST). Camera testing was charged at a rate of $850/day (technologist"s and oceanographer"s daily rates excluding HST).

The total cost for camera design work was $1,750.00. The total cost for camera testing was $850.00.

5.1.2 Field Work Costs

Field work carried out by Ocean Ecology was charged at a rate of $1845/day (excluding HST). The breakdown of this field work rate is shown in Table 12. The number of days spent surveying a particular site depended on the size of the site and the number of transects to be surveyed at that site. The field work costs for the different components of the survey were as follows:

1) Hornby Island towed video survey - $4,151.25
2) Swamp Island towed video survey - $2,583.00
3) Big Bay towed video survey - $2,767.50
4) Norris Rock exploratory video survey - $922.50
5) Fillongley Park exploratory video survey - $461.25
6) Hodgson Reef exploratory video survey - $184.50
7) Hornby Island drop camera survey - $3,690.00

Table 12. Ocean Ecology"s rate breakdown for field work.

Item	Daily rate
Ship expenses	$395
Fuel expenses	$100
Camera system expenses (includes winch and all necessary electronics)	$500
Ship"s Master rate	$350
Professional Biologist/Oceanographer rate	$500
Total	**$1845**

The total cost for all field work during the field season of 2010 was $14,760.00.

5.1.3 Travel Costs

Travel costs were charged based on distance traveled from Prince Rupert to a particular site. Thus, the travel cost varied significantly from site to site, with the Hornby Island survey work having the greatest associated travel costs. The rate for travel was $595/day (excluding HST). The breakdown of this travel rate is shown in Table 13.

Table 13. Ocean Ecology"s rate breakdown for travel.

Item	Daily rate
Ship expenses	$145
Fuel expenses	$100
Ship"s Master rate	$350
Total	**$595**

The total cost for all travel during the field season of 2010 was $7,586.25.

5.1.4 Data Processing and Reporting Costs

Data processing and reporting costs were charged at $62.50/h (oceanographer"s hourly rate excluding HST). This includes activities such as video conversion, geological and biological interpretation of video frames, relational and random access database creation, geological and biological GIS mapping, and report preparation. The costs for data processing varied significantly from site to site depending on the requirements of the study. The requirement for most sites (e.g., Swamp Island, Big Bay, Norris Rock, Fillongley Park, and Hodgson Reef) was simply to archive the data in a searchable manner. However, a full data work-up and comparison of video survey with dive survey data was carried out at Hormby Island.

The total cost for data processing and reporting was $6,796.88. A breakdown of this cost is given in Table 14.

Table 14. Breakdown of Data Processing and Reporting Costs.

Item	Cost
Video data backup	$156.25
Video format conversion	$250.00
Video analysis	$1,671.88
Data processing and mapping using ArcGIS	$2,531.25
Report writing	$2,187.50
Total	**$6,796.88**

6. Discussion and Recommendations

6.1 Benefits and Limitations of the Video Survey Systems

6.1.1 Towed Video System

The main limitations of using the towed video system to assess herring spawn were:

1) ***Weather***. There were almost constant gale force winds during the survey season this year. While this did not prevent filming, there were times during each day when the winds were strong enough to force a temporary halt to the work. However, the dive survey was also adversely affected by the weather.
2) ***Shallow or rocky regions***. Particularly rocky or shallow regions cannot be safely surveyed using the towed video system.
3) ***Operator expertise***. Operating the towed video system requires skill in ship handling and navigation, scientific experimental design, computer systems, and electronics. This system is not designed for inexperienced users.
4) ***Quantitative ability***. The capacity of the system to quantify spawn has yet to be fully assessed.

The main benefits of using the towed video system to assess herring spawn were:

1) ***Speed and efficiency***. A single 2-person team in a 40" ship can survey spawn at nearly the same speed as 2 dive teams with a seine boat.
2) ***Operating depths***. The system can operate in water depths up to 100 m.
3) ***Weather limitations***. The system can operate in rougher water than dive teams. Filming is regularly carried out in waves up to 1-2 meters height. Filming in rough weather is usually halted as a result of film quality (too much motion in the video for good organism identification) rather than safety issues.
4) ***Toothy megafauna***. The system can be operated in the presence of sea lions. The sea lions are curious and playful, but do not otherwise pose a problem for filming.


2010/03/12 09:46:55
49 29.0942N 124 38.7421W
09:46:57 U-08 03/12/10


2010/03/12 09:57:29
49 29.1588N 124 38.8927W
09:57:33 U-08 03/12/10

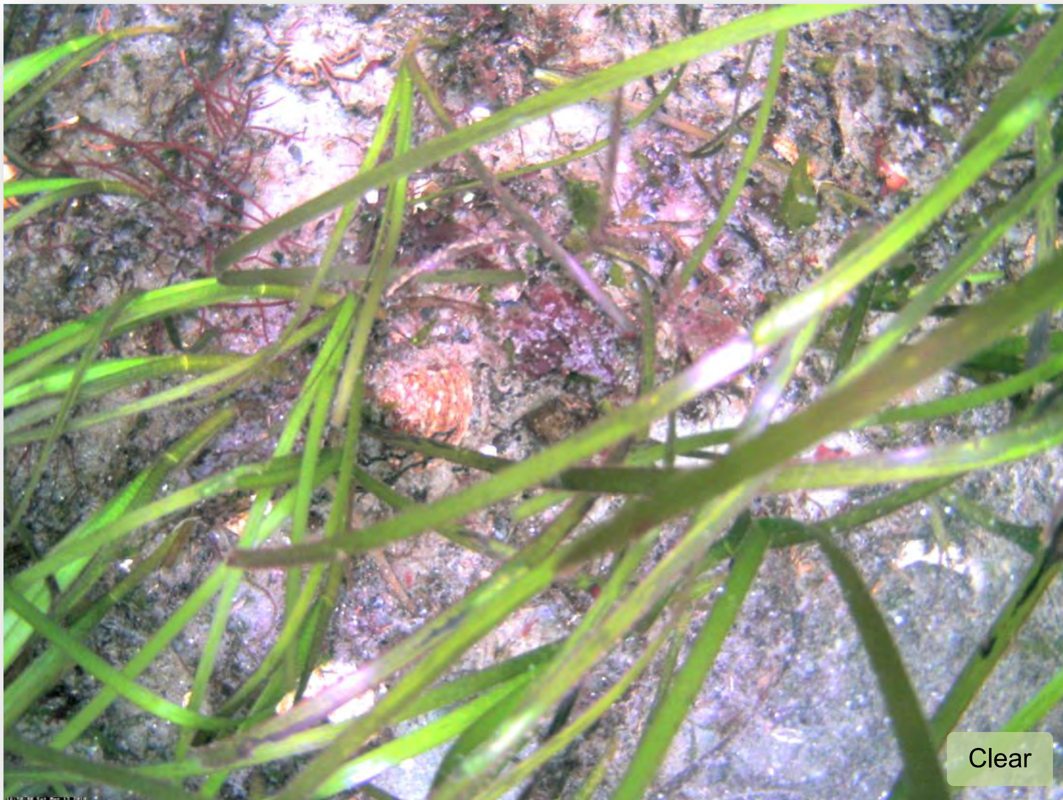

2010/03/12 09:57:48
49 29.1530N 124 38.8972W
09:57:51 U-08 03/12/10

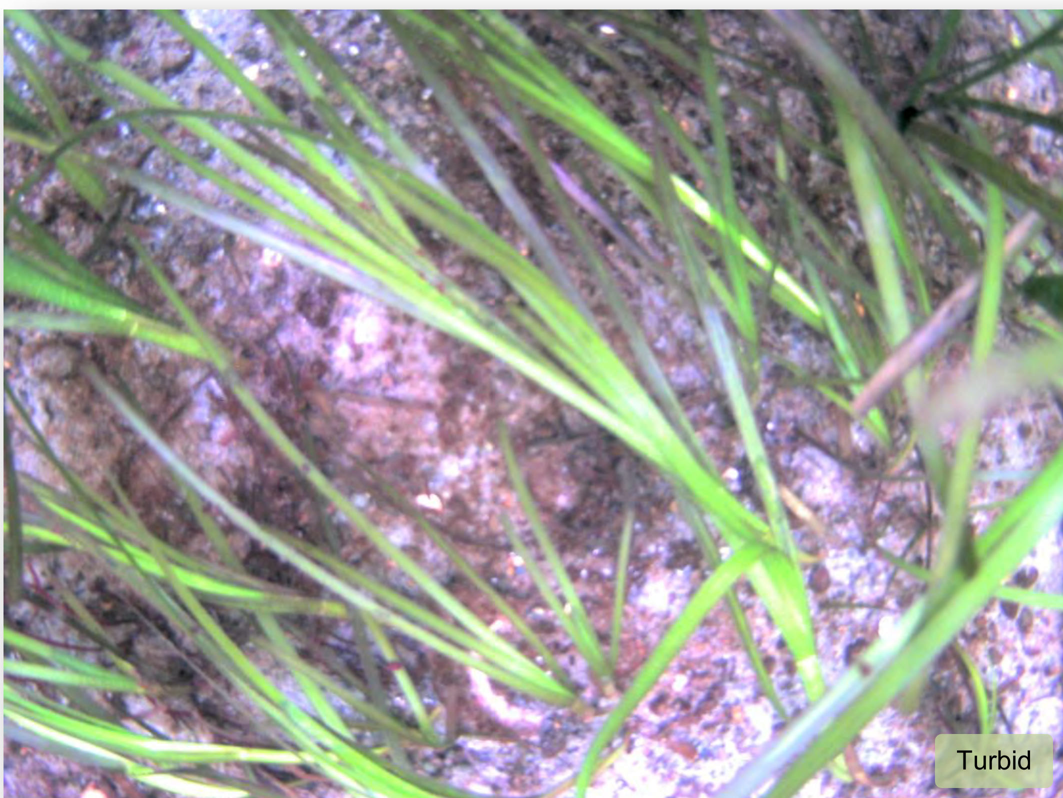

2010/03/12 10:01:08
49 29.0989N 124 38.9713W
10:01:08 U-08 03/12/10

6.1.2 High Definition Drop Camera System

The main limitations of using the high definition drop camera system to assess herring spawn were:

1) ***Speed***. The high definition drop camera system is slower to deploy than the towed video system, and thus the area covered per day is much smaller.
2) ***Ethernet connection***. The lack of an armored Ethernet cable to the camera meant that the camera deployment time was limited by the size of the on board CF card used to store images. It also meant that real time adjustments could not be made to the camera"s settings.
3) ***Depth of field***. Since the camera was operating in relatively "low light" conditions, its depth of field was quite small. As a result, not all the features of the irregular sea floor were in focus at the same time.
4) ***Turbidity***. Water turbidity had a significant impact on the drop camera"s resolution. Images in highly turbid water had poor resolution regardless of the camera"s 5 MP capacity. The following pair of images was taken on the same day within approximately 10 minutes of each other. No adjustments to any of the camera"s settings have taken place. The first image shows the resolution under relatively clear water conditions, whereas the second image shows the resolution under much more turbid water conditions.


Clear


Turbid

The main benefits of using the high definition drop camera system to assess herring spawn were:

1) ***Higher resolution***. The high definition drop camera system had a significantly higher resolution than the towed analog video system.
2) ***Constant field of view***. The lander frame held the camera in a constant position relative to the sea floor, thus the field of view was always the same and could be adjusted to a specific value (in this case 0.25 m^2).
3) ***Motion blur***. Use of the lander frame prevented the blur which results from camera motion during towing.

6.2 Potential Methodology for Quantitative Measurements of Herring Spawn using High Definition Imagery

Ocean Ecology feels that the high definition drop camera system provides an opportunity for a new approach to quantitative herring spawn measurements. Thus, the following recommendations do not attempt to duplicate the existing herring spawn dive survey, but rather take advantage of the unique capabilities of the high definition drop camera system.

6.2.1 Sampling Design

Stratified random sampling is the approach which Ocean Ecology recommends for use with the high definition drop camera system. This sampling design has a number of advantages:

1) It is an accepted and approved methodology used by DFO. As an example, it is the methodology which is used by DFO for intertidal clam surveys[2].
2) Random sampling avoids bias. “Randomization provides a fair and repeatable means of avoiding bias in the selection of sampling locations, whether accidental or intentional. This advantage is particularly desirable where the data is likely to be used by parties with conflicting interests: fishery managers, commercial fishers, and First Nations biologists may use the data or estimates for disparate purposes.” (Gillespie and Kronlund, 1999).
3) Since we know that the distribution of herring spawn is not homogenous (e.g., herring spawn preferentially on certain types of vegetation, in certain types of habitats, or in association with particular physical features, such as points), we can use prior knowledge to break a large site down into units, called stratum, which are as similar as possible. This process is called stratification. Stratification improves the precision of estimates from a survey where distribution is not homogenous.
4) When using a stratified random survey design, the data collected from one year can be used to improve the experimental design for the next year, and thus increase the precision of the estimate.

[2] Gillespie, G.E., Kronlund, A.R. 1999. A Manual for Intertidal Clam Surveys. Canadian Technical Report of Fisheries and Aquatic Sciences 2270.

6.2.2 Image Analysis

Calculation of spawn density by areal coverage of a photographed quadrat would be Ocean Ecology"s recommended approach for image analysis. Each high resolution image generated during the survey covers a known area (0.25 m^2). The amount of spawn seen in the photograph can be calculated using a program such as ArcGIS. The photograph is imported into ArcGIS, and a polygon tool is used to draw outlines around all of the spawn seen in the photograph. The total area of the photograph is determined by using the polygon tool to outline the entire photograph. The area occupied by spawn, in m^2, can then be calculated:

$$Area\ (in\ m^2) = \frac{Total\ area\ of\ all\ spawn\ polygons\ (unitless)}{Total\ area\ of\ photograph\ (unitless)}\ x\ 0.25\ m^2$$

Areal coverage incorporates aspects of both “spawn percent cover” and “spawn egg layers”. For example, consider a single filament of algae with 100% spawn cover. If the filament is covered with a single layer of eggs, then it will have a width of “2 units” when viewed from the side (e.g., one layer of eggs on each side). If the filament is covered with two layers of eggs, then it will have a width of “4 units” (e.g., two layers of eggs on each side). In the first case, the area covered by spawn would be:

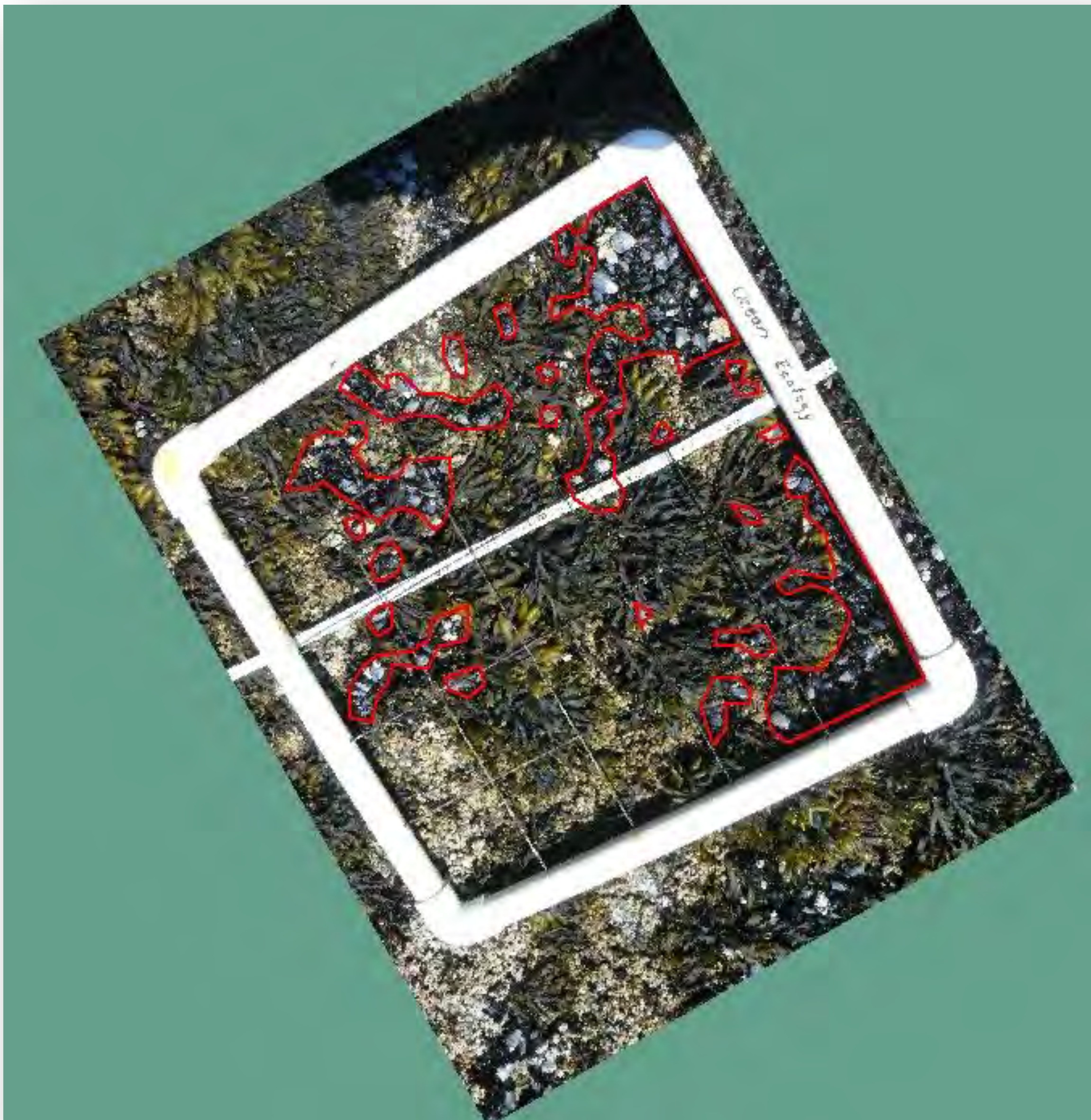
“2 units” x “filament length”

In the second case, the area covered by spawn would be:

“4 units” x “filament length”

Although this is a very simplistic example, it shows how the calculation of area covered by spawn would include some component of both “spawn percent cover” and “spawn egg layers”. The relationship between areal coverage and total number of eggs would not be a linear one, and would need to be calibrated.

Shown below is an example of a photographed quadrat where the area of coverage by mussels has been determined using the methodology described above.



6.3 Future Directions and Further Research

Based on the results and discussion above, the following are some possible future directions that HCRS might wish to consider:

1) ***Towed Video System***. Unfortunately, while we were unable to make a quantitative comparison between the video survey and the dive survey, the capacity of the towed video system to locate, delineate, and to a certain extent, quantify, herring spawn has been well proven over the last two years. It may be possible that the video survey will never be an acceptable substitute for the dive survey; however, one possibility would be to use the video survey as a pre-assessment tool. The video system could be sent ahead of the divers to areas where the presence of spawn in uncertain. The presence/absence of spawn in that area could be quickly assessed, the location and extent determined, and divers could be sent in at a later time to carry out the quantitative survey.
2) ***High Definition Drop Camera System***. The high definition drop camera system clearly has the capacity to be a quantitative tool for herring spawn assessment. However, further calibration of the system would be required. A series of controlled experiments using a tank and a variety of different vegetation types with different amounts of spawn could be set up to achieve this calibration.
3) ***Dive Survey GPS Protocol***. After the failure this year to collect consistent GPS data from the dive survey teams, it appears that some protocol for this type of data collection needs to be developed, and the dive teams need to be trained in the use of this protocol. The collection of GPS coordinates when studying a phenomenon which is distributed geographically is essential. Land-marking by eyeball is no longer an acceptable means of georeferencing data.

During the process of carrying out this research, a number of intriguing questions have surfaced which may bear further study. Many of these questions arise out of the poor correlation between measured herring biomass in the water and observed spawn deposition which has occurred during the last two years. Where are the herring spawning?

1) Do herring require contact with the substrate in order to deposit their eggs, or do they release them just above the substrate? There are conflicting reports regarding this behavior. According to Schaefer (1937)[3], extrusion of eggs appears to be impeded unless the vent is in contact with the substrate. However, Griffin *et al*.(2009)[4] report that the eggs are released by females and settle on and attach to biotic and abiotic substrata. If eggs are not laid directly on the substrate, but rather are allowed to settle to the substrate, are they more susceptible to being "washed" out during rough weather? During the 2010 herring season, gale force winds were common. Ocean Ecology observed quantities of loose "free" eggs on the beaches where herring were spawning (see image below, taken from Ford Cove). Could these eggs have been carried to shore by strong currents before they had a chance to settle and attach to a substrate? Would it be possibly to carry out plankton tows to determine how many herring eggs are present in the water column during spawning? What is the rate of survival of loose herring eggs?

[3] Schaefer. M.B. 1937. Notes on the spawning o f Pacific herring *Clupea pallasi*. Copeia 1937(1):57.
[4] Griffin, F.J., Smith, E.H., Vines, C.A., Cherr, G.N. 2009. Impacts of suspended sediments on fertilization, embryonic development, and early larval life stages of the Pacific herring, *Clupea pallasi*. Biol. Bull. 216:175–187.

2) Does the presence of sediment cause the herring to release their eggs in the water? Stacey and Hourston (1982)[5] report that the texture and rigidity of the substrate are tested by the fish using the tips of the pelvic and pectoral fins before they spawn, and that sediment on the substrate may inhibit spawning. Could changes in upland uses near herring spawning regions have increased sedimentation rates and possibly changed spawning patterns?
3) Is it possible that the herring "broadcast" spawn in the absence of suitable substrate? How long can female herring retain their eggs before they must spawn or the retained eggs loose viability? Hay (1986)[6] reports that delayed spawning of greater than 2-3 weeks resulted in progressive loss of egg and larva viability.
4) Do urchin barrens, which result in loss of suitable spawning substrate, have an effect on where and how the herring spawn? Ocean Ecology observed large expanses of sea urchin barrens around Norris Rock (see image below) where milt had been seen in the water, but no spawn was observed. Although milt released by the male herring may initiate the spawning act and egg deposition by the female (Hay, 1985)[7], will the female release eggs in the absence of suitable substrate?

[5] Stacey, N., Hourston A.S. 1982. Spawning and feeding behavior of captive Pacific herring. Can. J. Fish. Aquat. Sci. 39:489-498.
[6] Hay, D.E. 1986. Effects of delayed spawning on viability of eggs and larvae of Pacific herring. Transactions of the American Fisheries Society 1986; 115: 155-161.
[7] Hay, D.E. 1985. Reproductive biology o f Pacific herring (Clupea harengus pallasi). Can. J. Fish. Aquat. Sci. 42 (Suppl. 1):111-126.

5) Can we improve our ability to track herring schools? During the 2010 herring season, spawning was patchy in both space and time. This pattern was observed both in the Strait of Georgia and on the North Coast. Aerial surveys were frequently missing the actual spawn locations. In some cases, for example around Hodgson Reef, milt was observed, but no spawn was present. In these cases, it is most likely that the milt has been transported away from its site of release ("washed out") by currents and tides. In other cases, the aerial survey completely missed spawn events. For example, Ocean Ecology observed the presence of spawn during anchoring (see image below) in Pearl Harbour and reported the location to the dive team. No milt had been observed by the aerial survey in this area, and the region would not have been surveyed by the divers if Ocean Ecology had not come across the spawn happenchance. Acoustical surveys are used to track the movement of herring schools, but on the North Coast in 2010 the single available survey ship (normally there are two) was not sufficient (personal communication with Corey Martens, Resource Manager Areas 3-5, DFO, on April 12th, 2010). Do we need more ships equipped with scientific split beam sounders to provide better tracking of the herring schools? Observations with scientific sounders can also help determine when a particular school of herring is about to start spawning, as the school may segregate vertically into a pelagic component (immature individuals) that contracted to a tight ball and a demersal component (ripe individuals) that spread out in a flat layer on the bottom (Axelsen *et al.*, 2000)[8].

[8] Axelsen, B.E., Nottestad, L., Ferno, A., Johannesen, A., Misund, O.A. 2000. „Await" in the pelagic: dynamic trade-off between reproduction and survival within a herring school splitting vertically during spawning. Mar Ecol Prog Ser 205: 259–269.

6) What are the effects of oceanographic conditions (e.g., currents, tides, wind) on the spawning locations? In both 2009 and 2010, Ocean Ecology observed concentrations of spawn on the windward sides of points. Will a better understanding of how oceanographic factors affect the spawning behavior of herring allow us to better locate the areas where spawn deposition occurs? Should the fisheries modeling for herring be combined with oceanographic modeling (as is done with Ecopath with Ecosim and ROMS)?

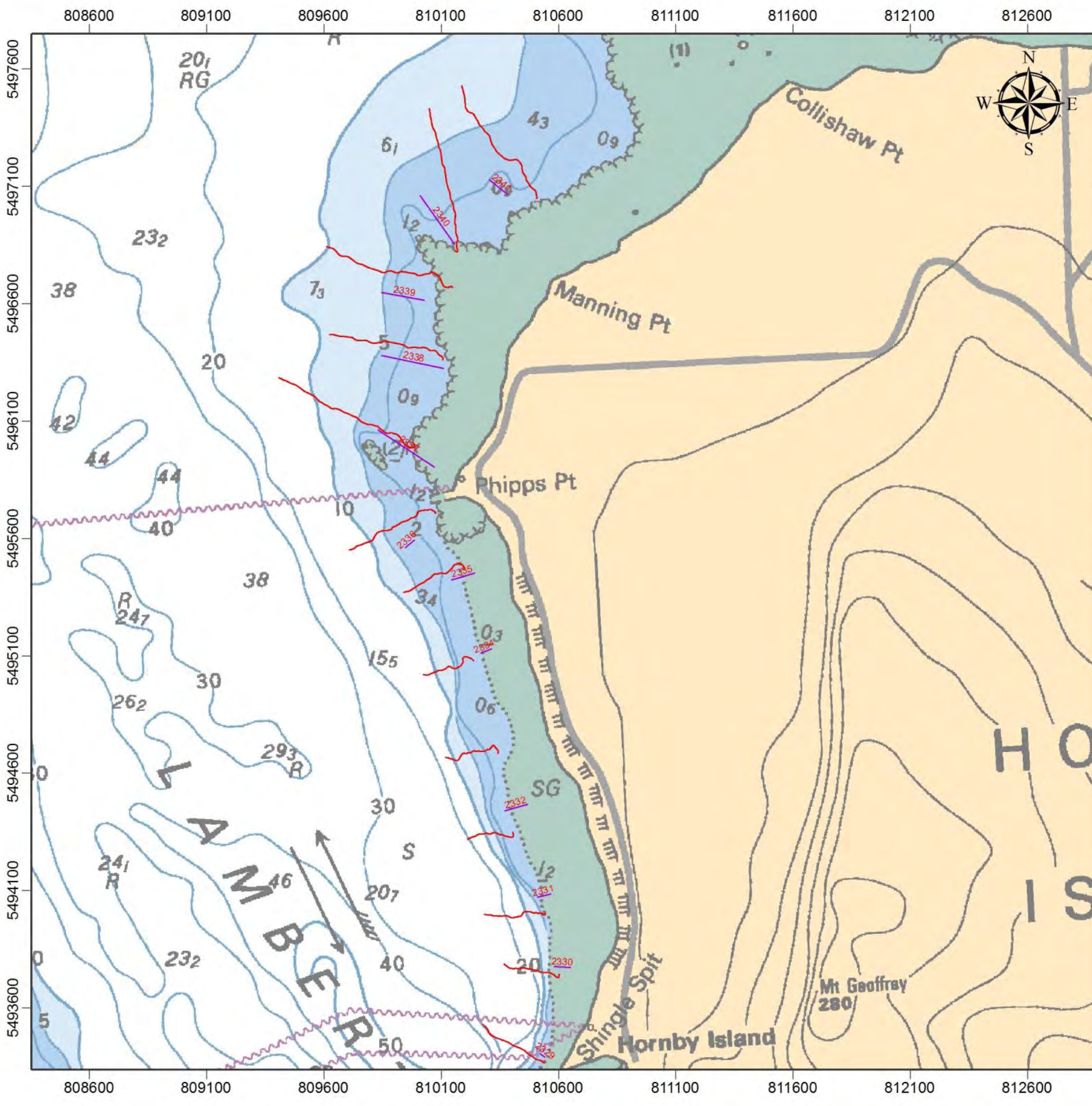
Herring spawning in Big Bay

7) Do herring have a vegetation type preference when spawning? Again, there are conflicting reports regarding this behavior. Hardwick (1973)[9] states that once the herring have moved into shallow waters, they will spawn on any available substrate. Haegele and Schweigert (1985)[10], on the other hand, observed that eggs were laid almost exclusively on marine vegetation. However, within vegetation as a substrate category, they found that there was no preference of one type over another. Other researchers have reported substrate preferences. In San Francisco Bay, herring choose algae and grass first, then prominent rocks, and lastly flat surfaces (Eldridge and Kaill, 1973)[11]. The principal substrate used in Tomales Bay and Humboldt Bay was common eelgrass (*Zostera marina*) (Miller and Schmidkte, 1956; Rabin and Barnhart, 1986)[12,13]. During the 2010 herring survey, Ocean Ecology observed a distinct substrate preference, with tall, upright forms (*Sargassum*, *Macrocystis*) being strongly preferred. Does the lack of availability of preferred substrates (e.g., the past reductions of *Macrocystis*) result in a change in herring spawning behavior? For example, *Macrocystis* was much thicker on the North Coast in 2010 than it has been in past years, and this was where the heaviest concentrations of herring spawn occurred.
8) What effect does selective fishing pressure have on herring spawning behavior? By fishing most heavily on populations which spawn in continuous bands over short periods of time, are we selecting for populations which spawn in a less dense, patchier pattern?
9) Are global climate changes affecting the locations and patterns of herring spawning? Do we need to be taking large scale climate changes into account when modeling herring?

[9] Hardwick, J.E. 1973. Biomass estimates of spawning herring, *Clupea harengus pallasi*, herring eggs, and associated vegetation in Tomales Bay. Calif. Fish Game 59:36-61.
[10] Haegele, C.W., Schweigert, J.F. 1985. Distribution and characteristics of herring spawning grounds and description of spawning behavior. Can. J. Fish. Aquat. Sci. 42 (Suppl. 1):39-55.
[11] Eldridge, M.B., and W.M. Kaill . 1973. San Francisco Bay Area's herring resource - a colorful past and a controversial future. Mar. Fish. Rev. 35(11): 25-31.
[12] Miller , D.J., and J. Schmidtke. 1956. Report on the distribution and abundance of Pacific herring (Clupea pallasi) along the coast o f central and southern California. Calif. Fish Game 42: 163-187.
[13] Rabin D. J., and R. A. Barnhart. 1986. Population characteristics of Pacific herring, Clupea harengus pallasi , in Humboldt Bay, California. Calif. Fish Game 72(1):4-16.

Hooded nudibranchs feeding on loose herring eggs

7. Figures



2010 Experimental Herring Video Survey

Figure 1. Towed video and dive transects on NW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

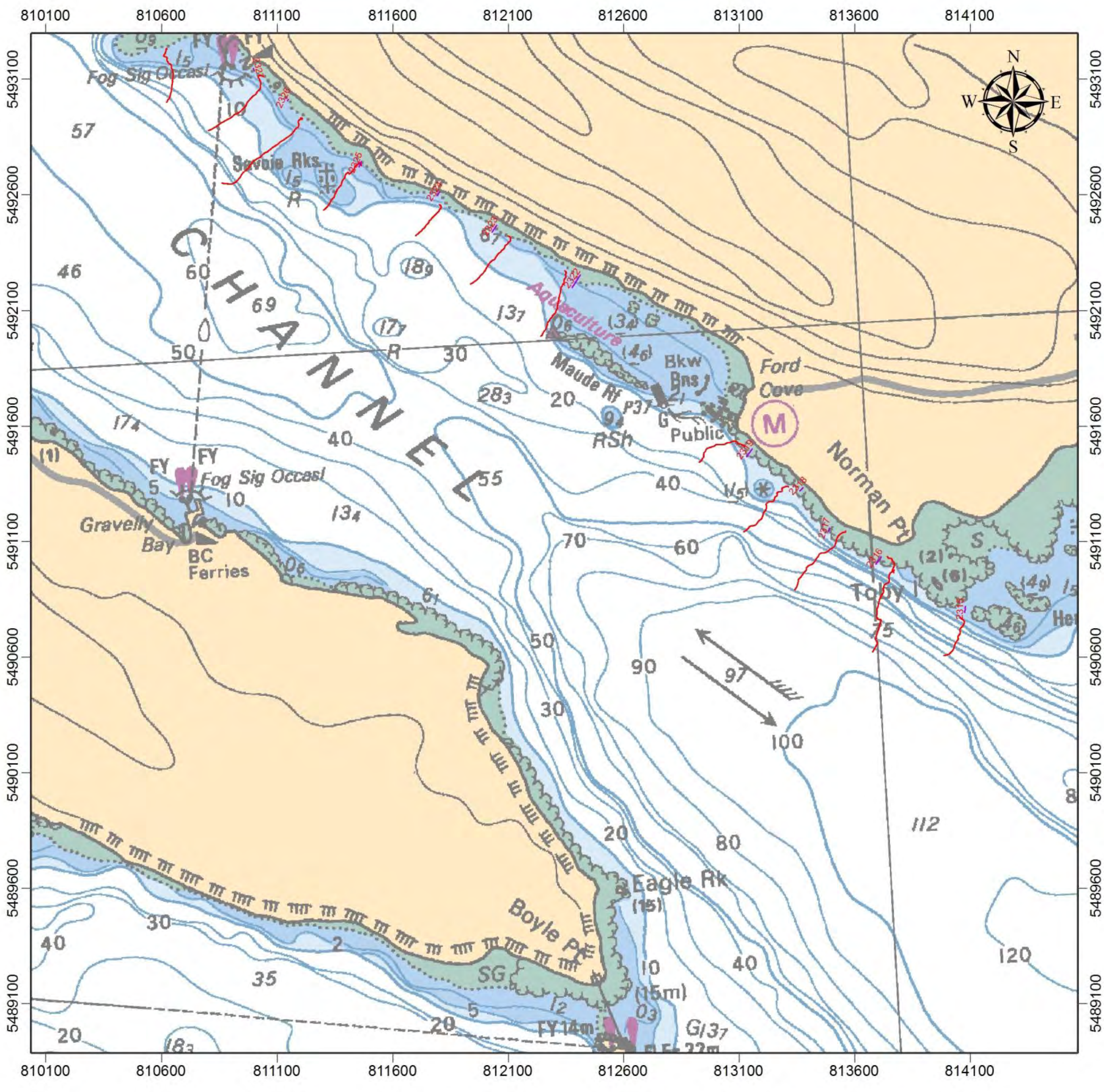
Scale: 1:23,000

Legend

- Dive transect width
- Video transect lines

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 2. Towed video and dive transects on SW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

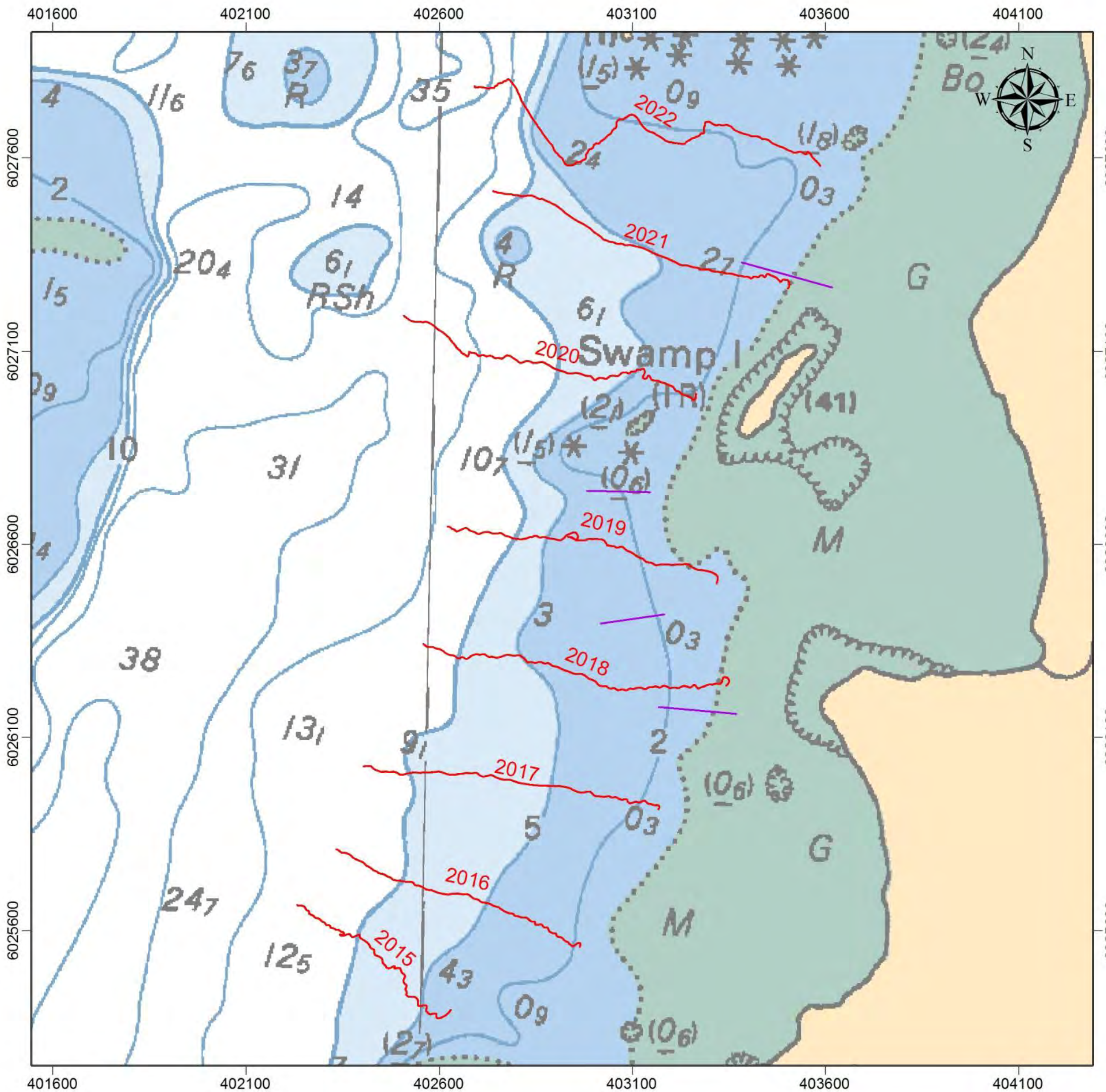
Legend

Dive transect width

Video transect lines

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 3. Towed video and dive transects around Swamp Island.

Chart used for navigation: CHS 395901 (Hudson Bay Passage)

Station for tide height corrections: Port Simpson, CHS reference station 10939

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:13,950

Legend

- Dive transect width
- Video transect lines

0 125 250 500 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

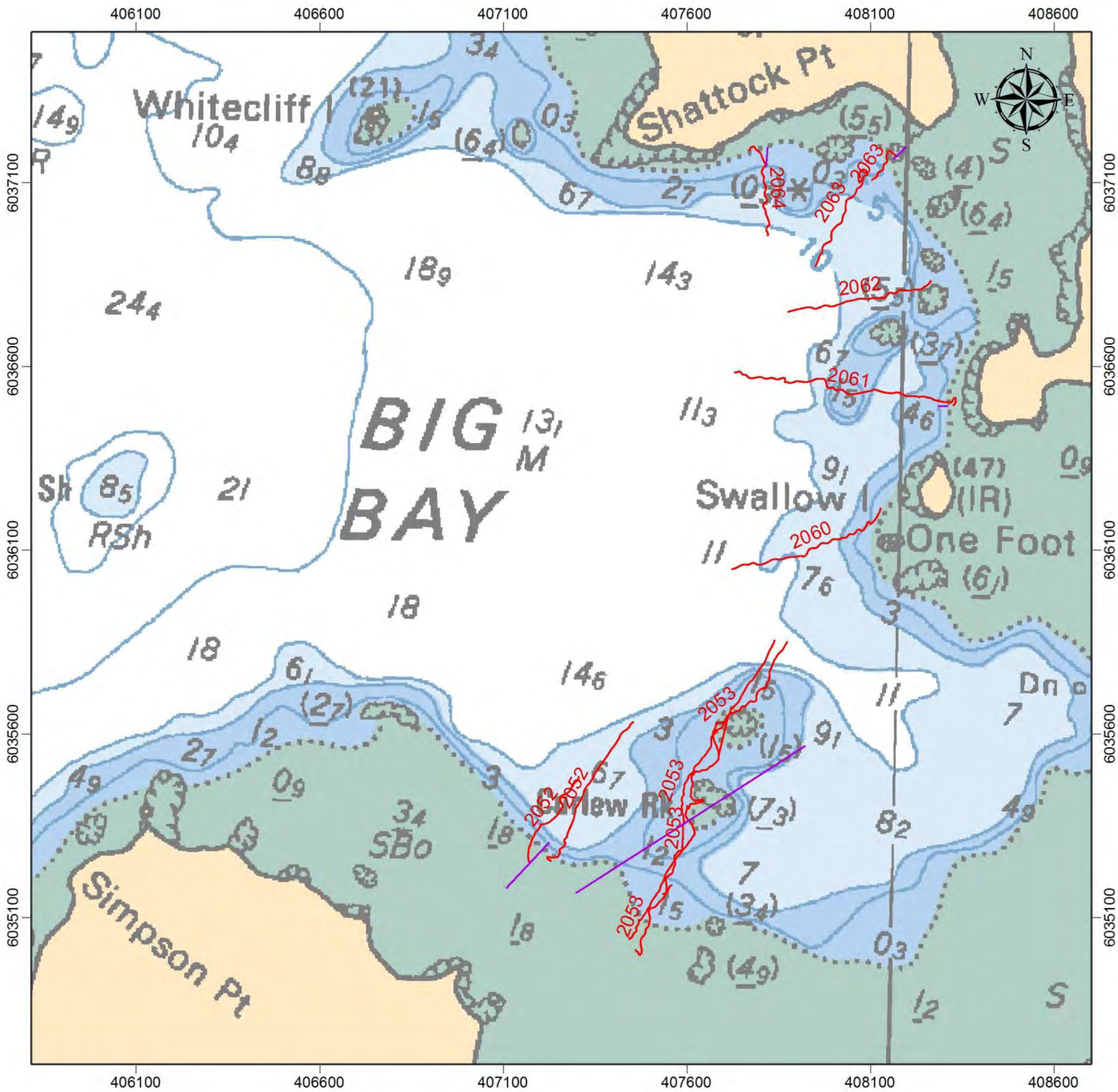


Figure 4. Towed video and dive transects in Big Bay.

Chart used for navigation: CHS 396301 (Work Channel)

Station for tide height corrections: Port Simpson, CHS reference station 10939

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:14,660

Legend

- Dive transect width
- Video transect lines

0 125 250 500 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

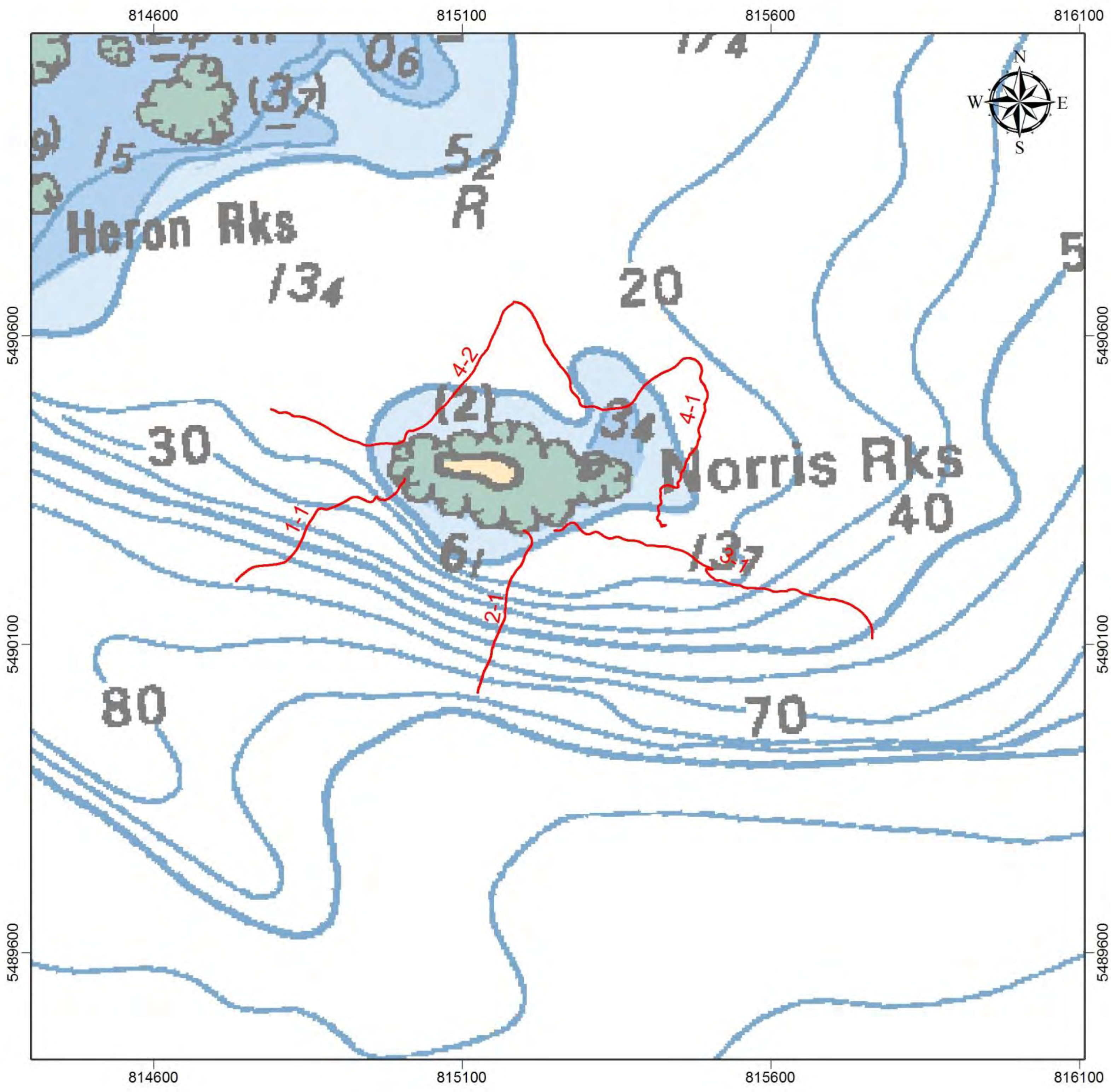


Figure 5. Towed video transects around Norris Rock.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:8,660

Legend

Towed video survey

0 100 200 400 Meters

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2010 Experimental Herring Video Survey

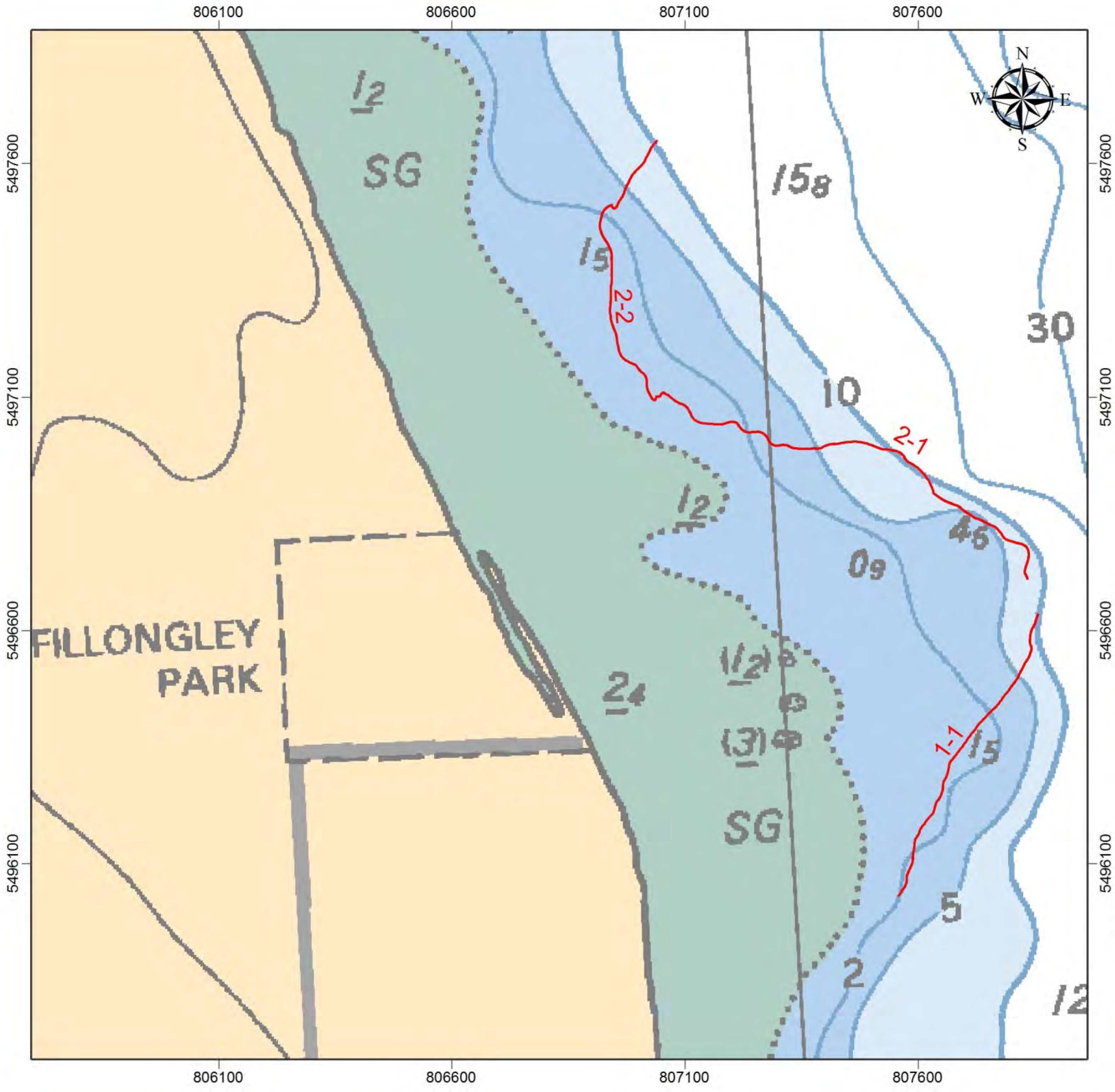


Figure 6. Towed video transects near Fillongley Park.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

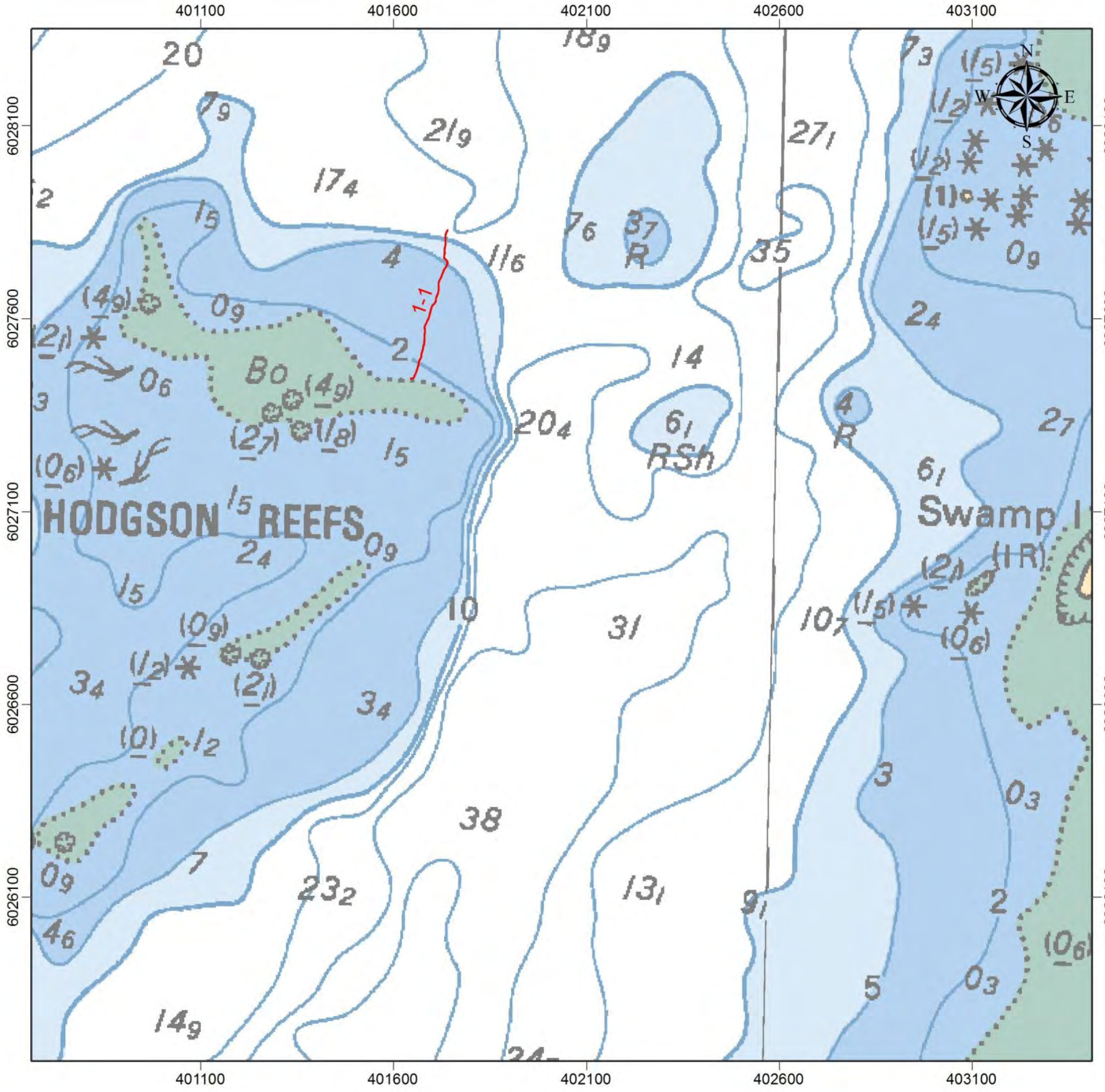
Scale: 1:11,500

0 125 250 500 Meters

Legend

Towed video survey

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 7. Towed video transects around Hodgson Reef.

Chart used for navigation: CHS 395901 (Hudson Bay Passage)

Station for tide height corrections: Port Simpson, CHS reference station 10939

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:13,950

Legend

Towed video survey

0 125 250 500 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

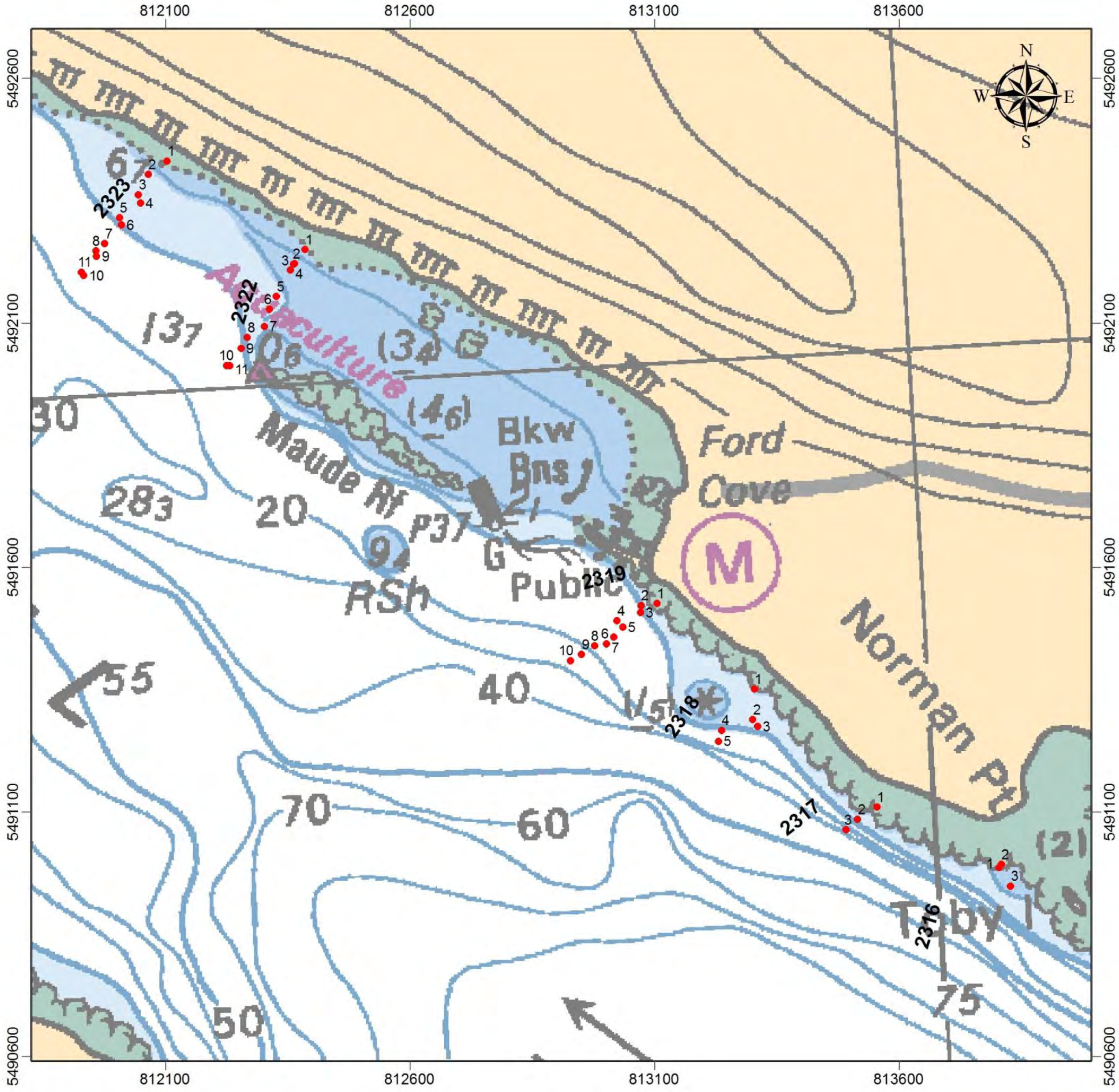


Figure 8. High definition drop camera survey on the west coast of Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:11,000

Legend

Drop locations

0 125 250 500 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

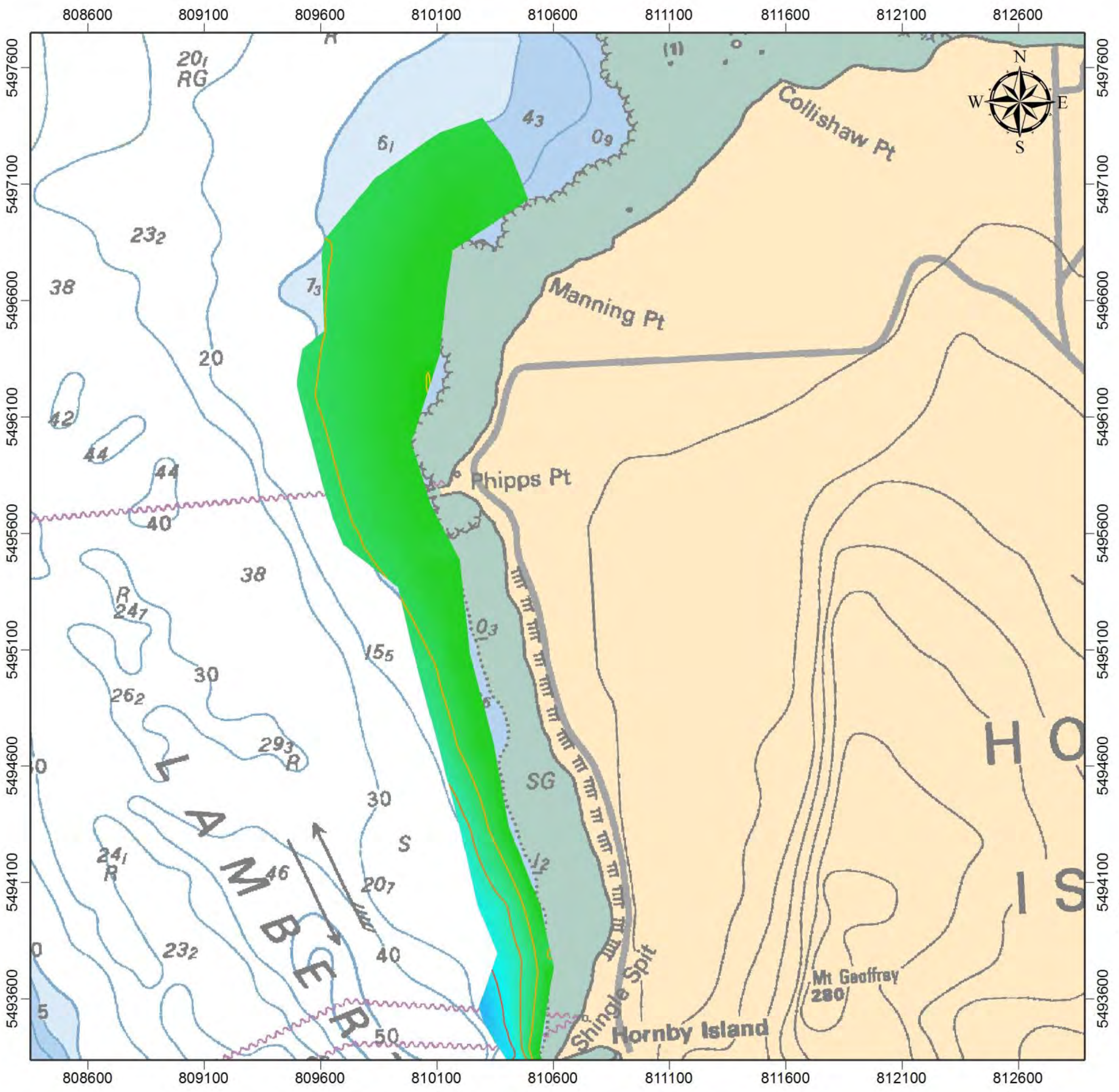


Figure 9. Map of bathymetry on NW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

Depth

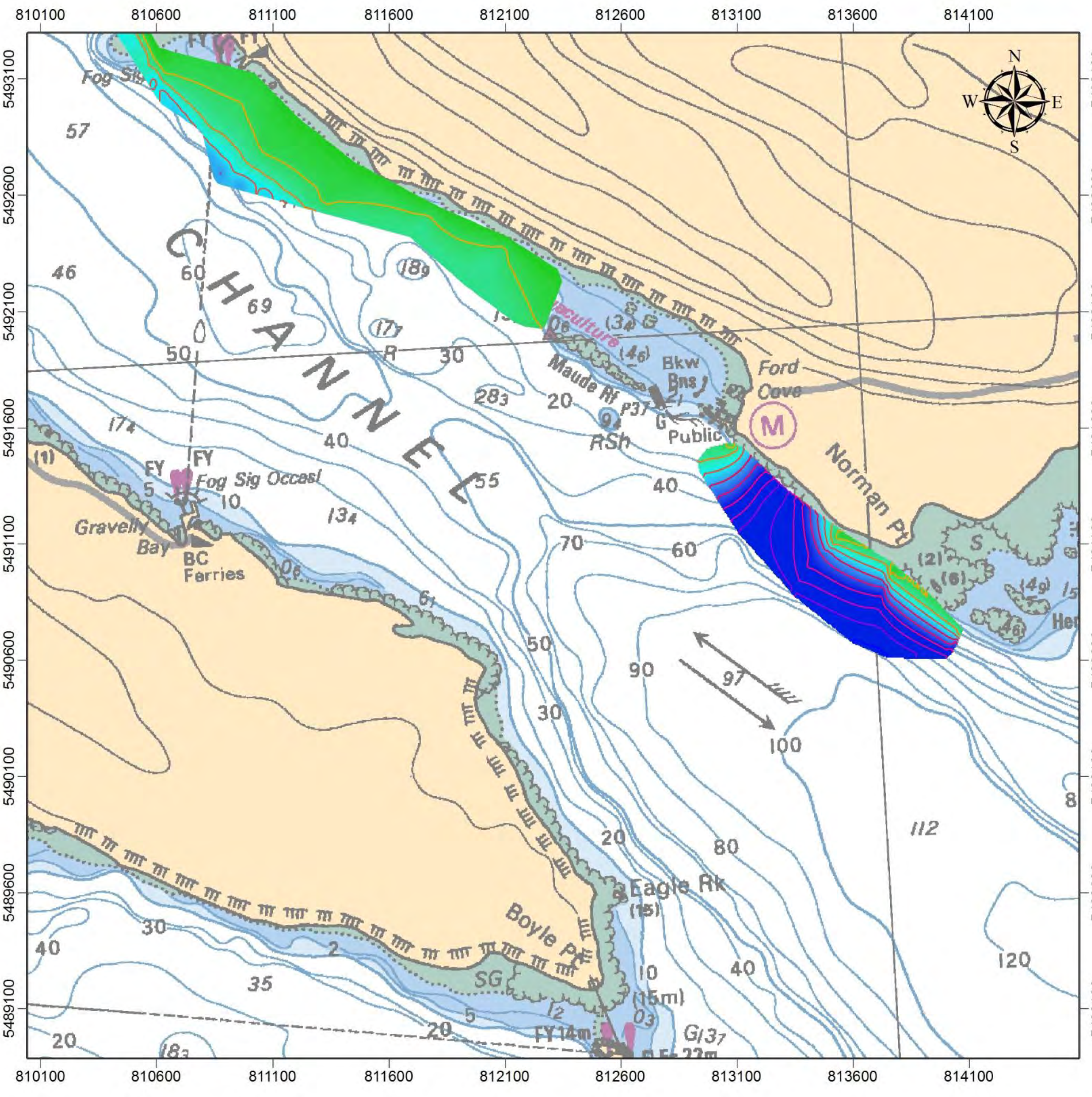
High : 0

Low : -90

-90, -80, -70, -60, -50, -40, -30, -20, -10, 0

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 10. Map of bathymetry on SW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

Depth

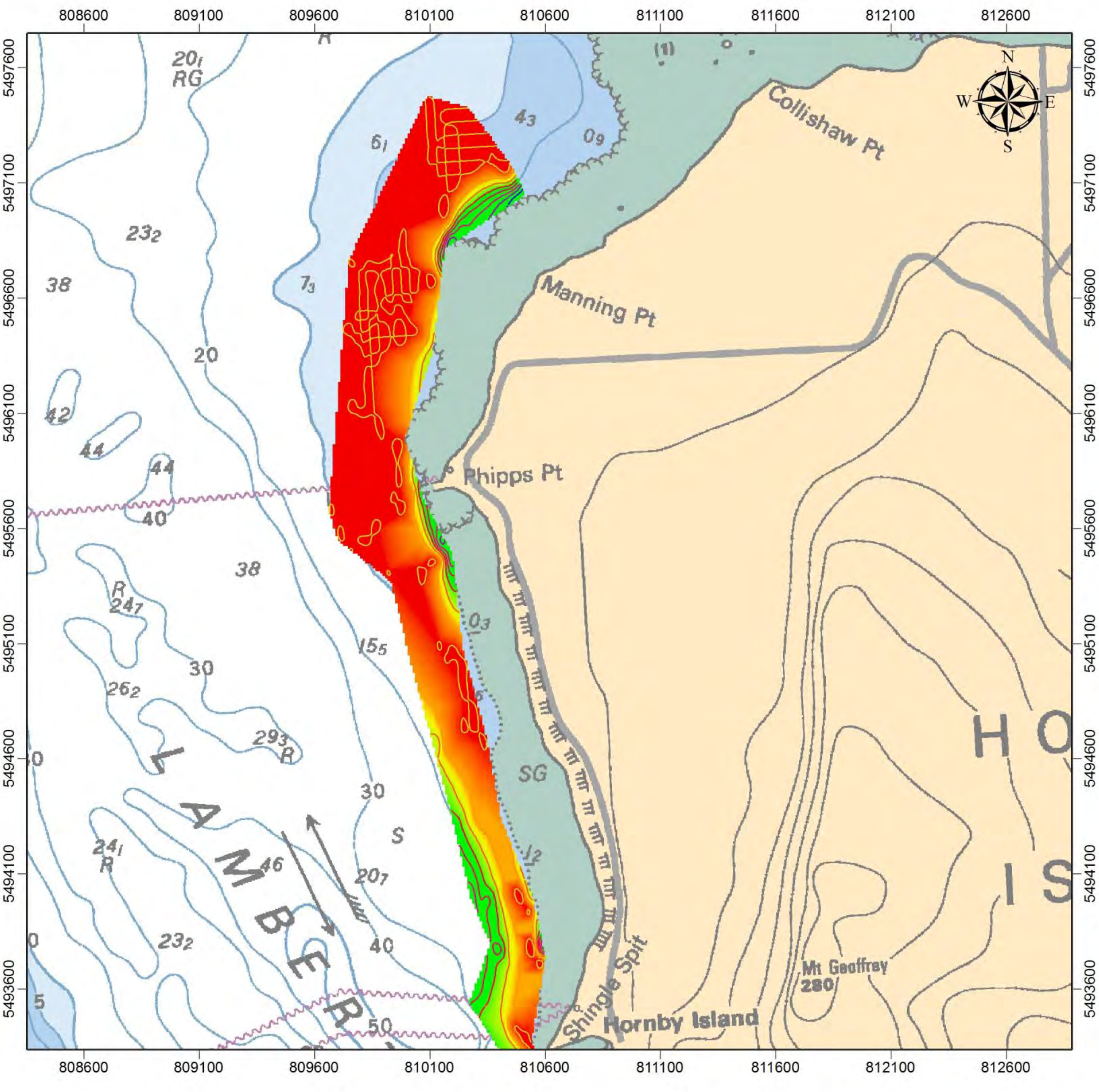
High : 0

Low : -90

-90, -80, -70, -60, -50, -40, -30, -20, -10, 0

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 11. Map of bottom hardness on NW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

Hardness

High : 8

Low : 4.5

4.5, 5, 5.5, 6, 6.5, 7, 7.5, 8

0 250 500 1,000 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

Figure 12. Map of bottom hardness on SW Hornby Island.

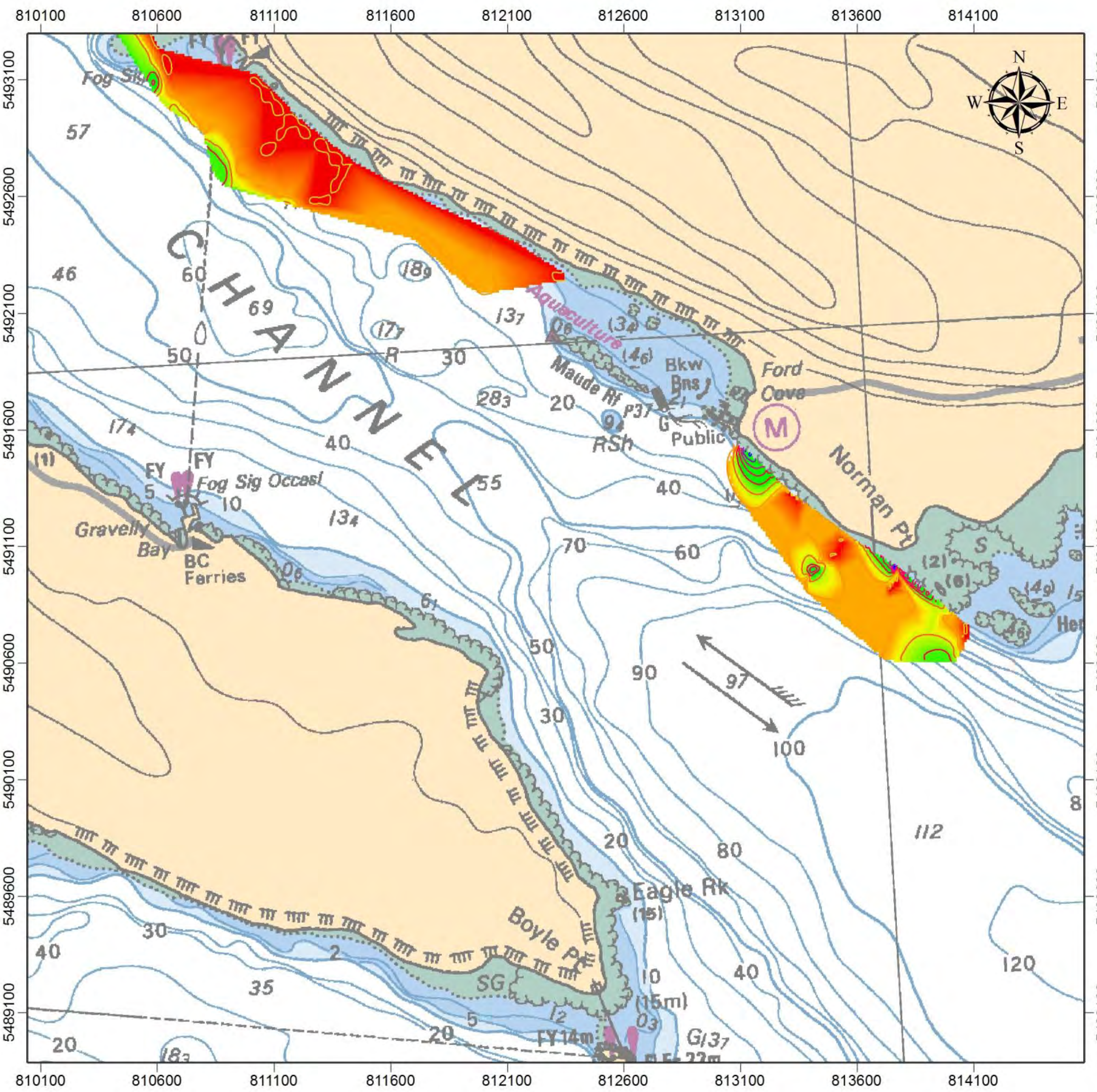


Chart used for navigation:
CHS 352701
(Baynes Sound)

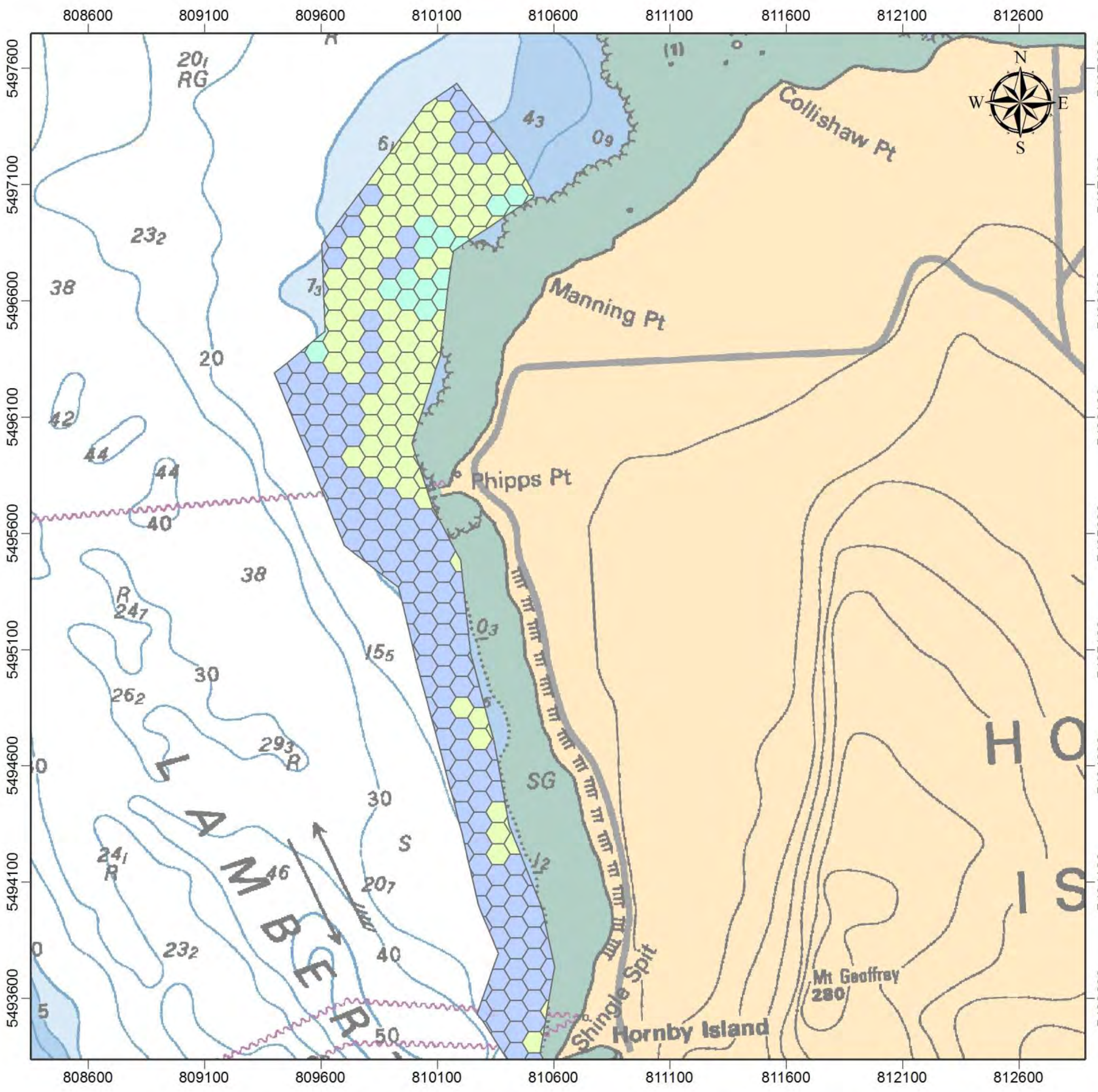
Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 13. Map of dominant substrate on NW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

- Cobbles
- Pebbles
- Rock
- Sand

0 250 500 1,000 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

Figure 14. Map of dominant substrate on SW Hornby Island.

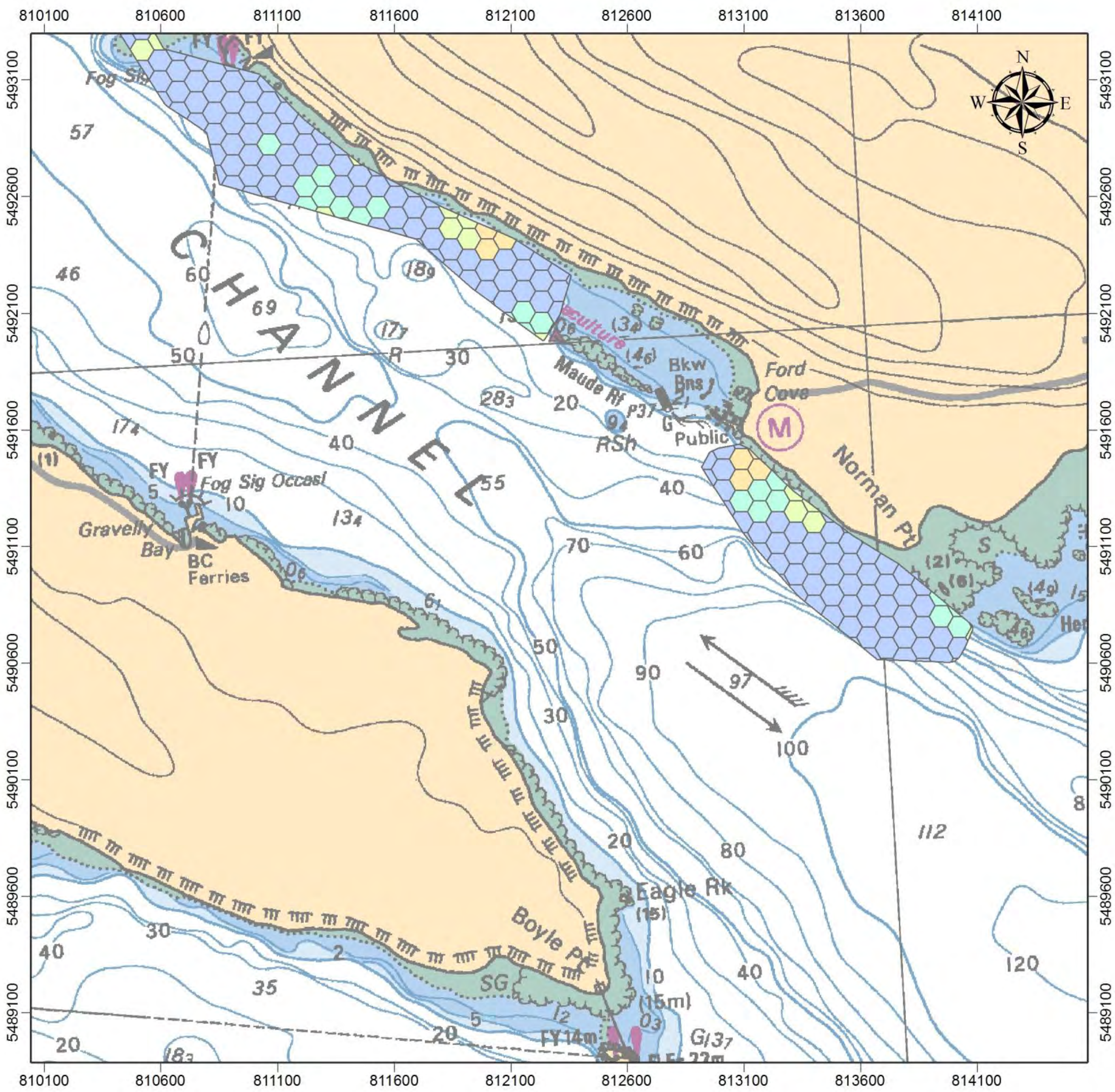


Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

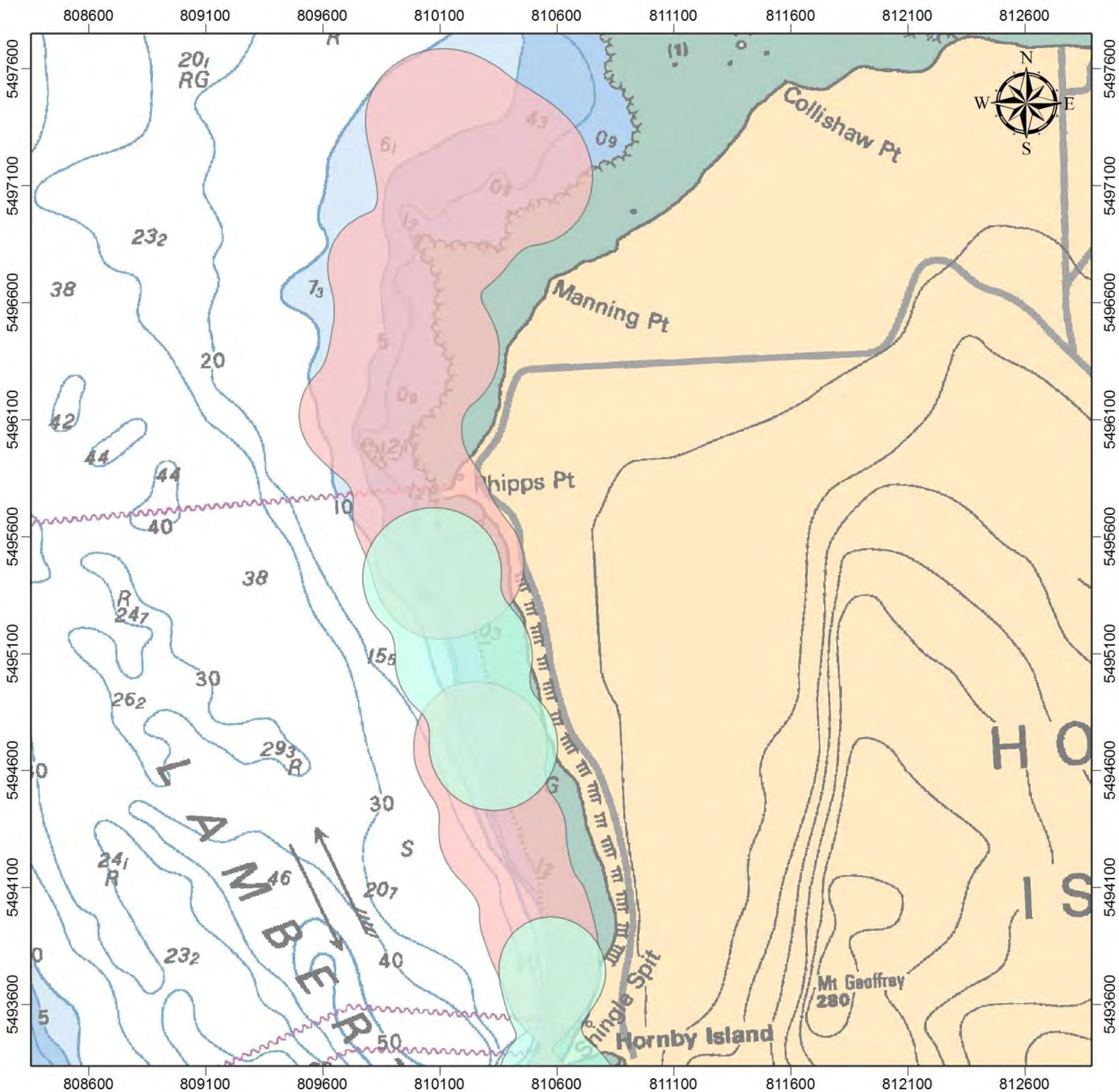
Scale: 1:23,000

Legend

- Cobbles
- Pebbles
- Rock
- Sand

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 15. Range map of seagrasses and flat kelps on NW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

- Flat kelps
- Seagrasses

0 250 500 1,000 Meters

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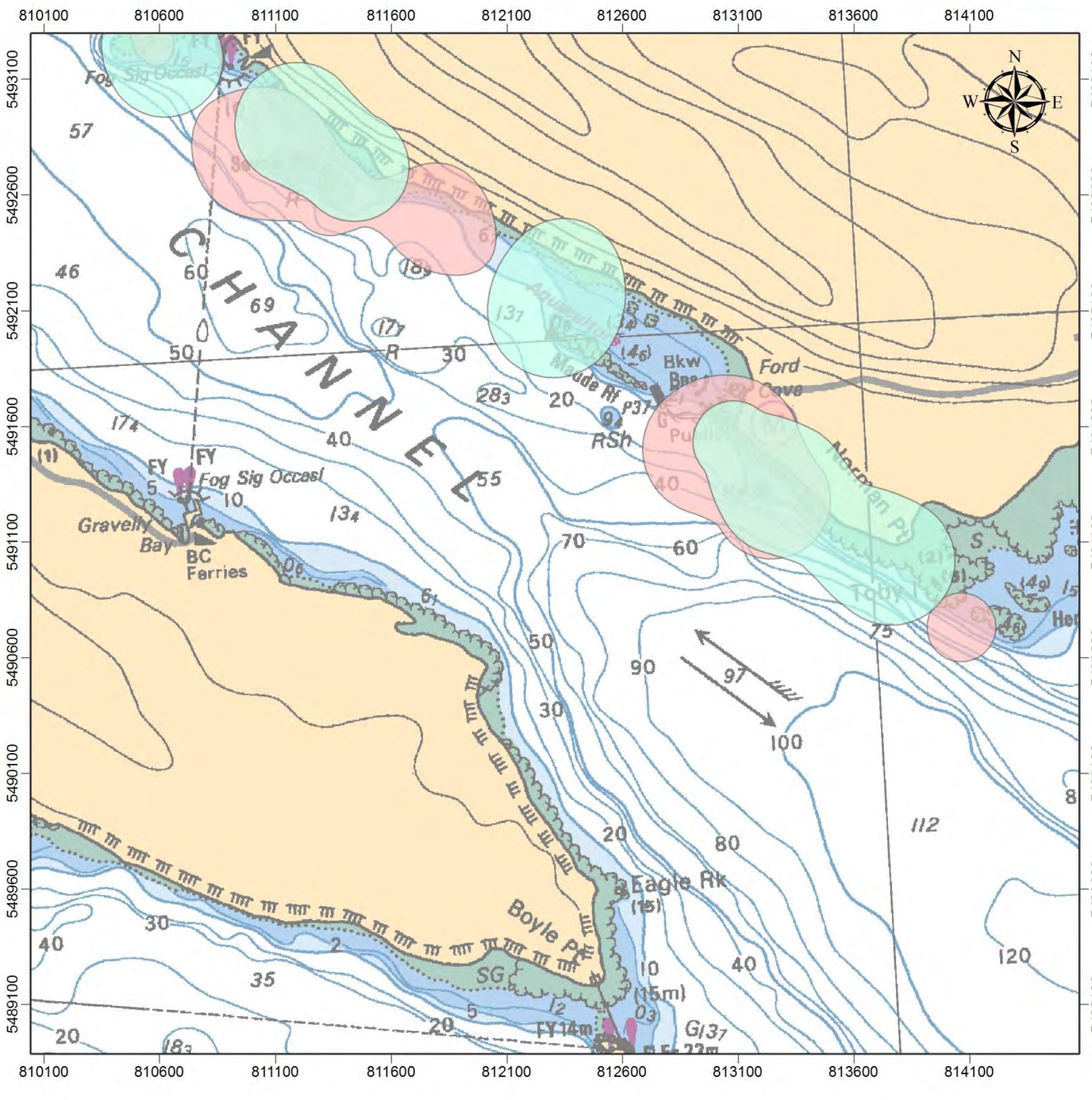


2010 Experimental Herring Video Survey

Figure 16. Range map of seagrasses and flat kelps on SW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

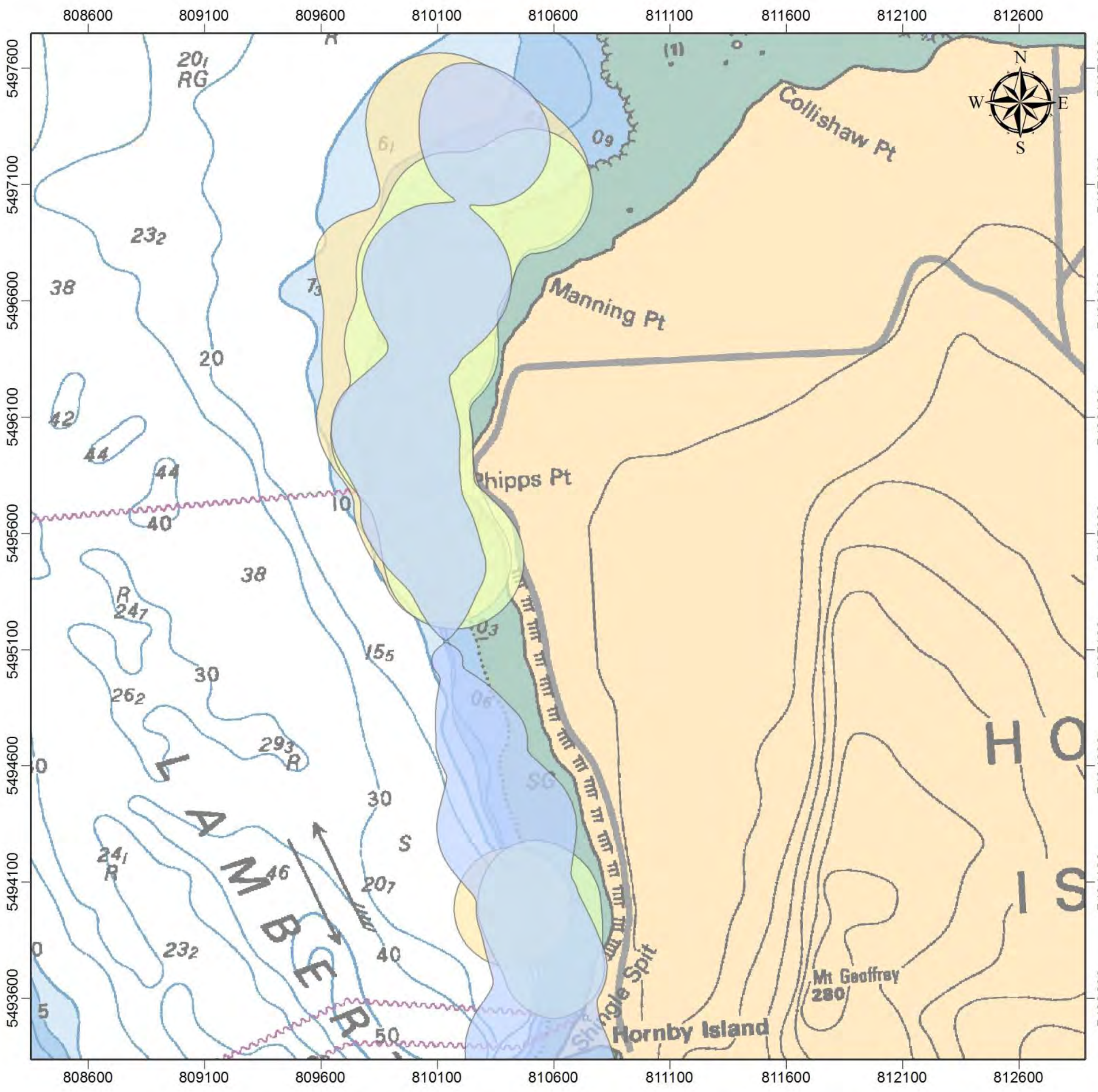
Legend

Flat kelps

Seagrasses

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 17. Range map of stringy algae, sargassum, and leafy algae on NW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

- Leafy algae
- Sargassum
- Stringy algae

0 250 500 1,000 Meters

OCEAN ECOLOGY

2010 Experimental Herring Video Survey

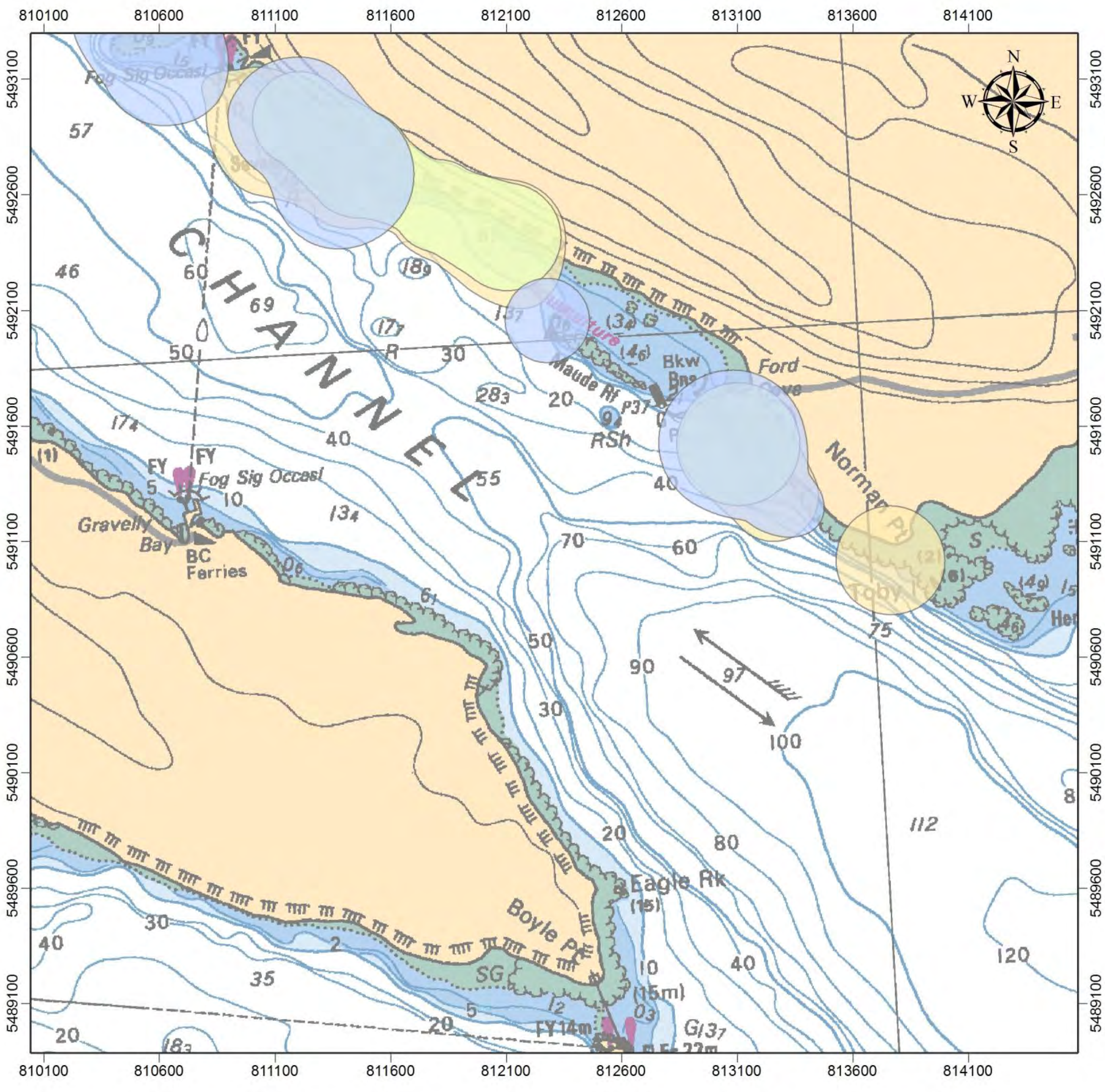


Figure 18. Range map of stringy algae, sargassum, and leafy algae on SW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

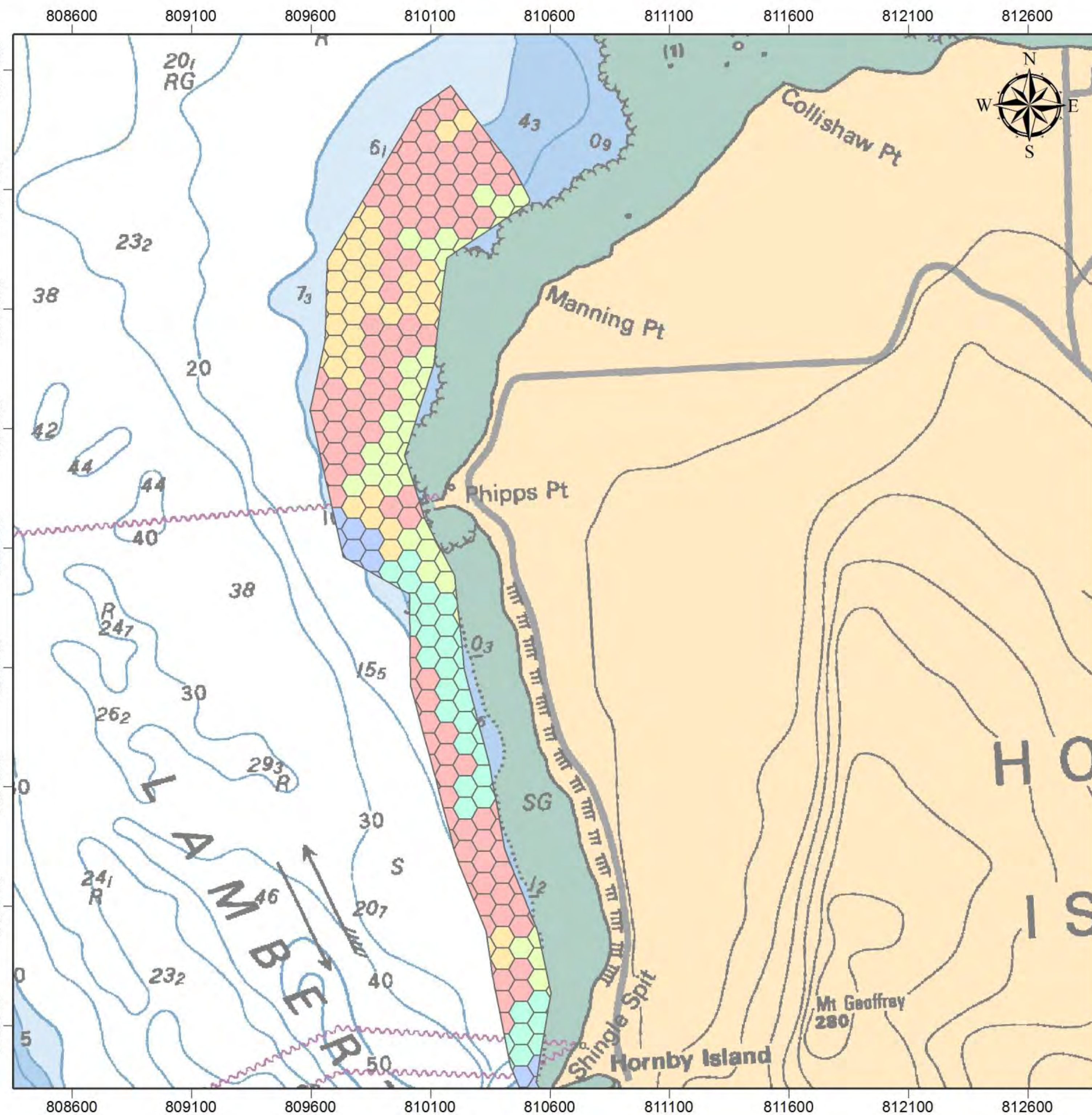
Scale: 1:23,000

Legend

- Leafy algae
- Sargassum
- Stringy algae

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 19. Map of dominant vegetation on NW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

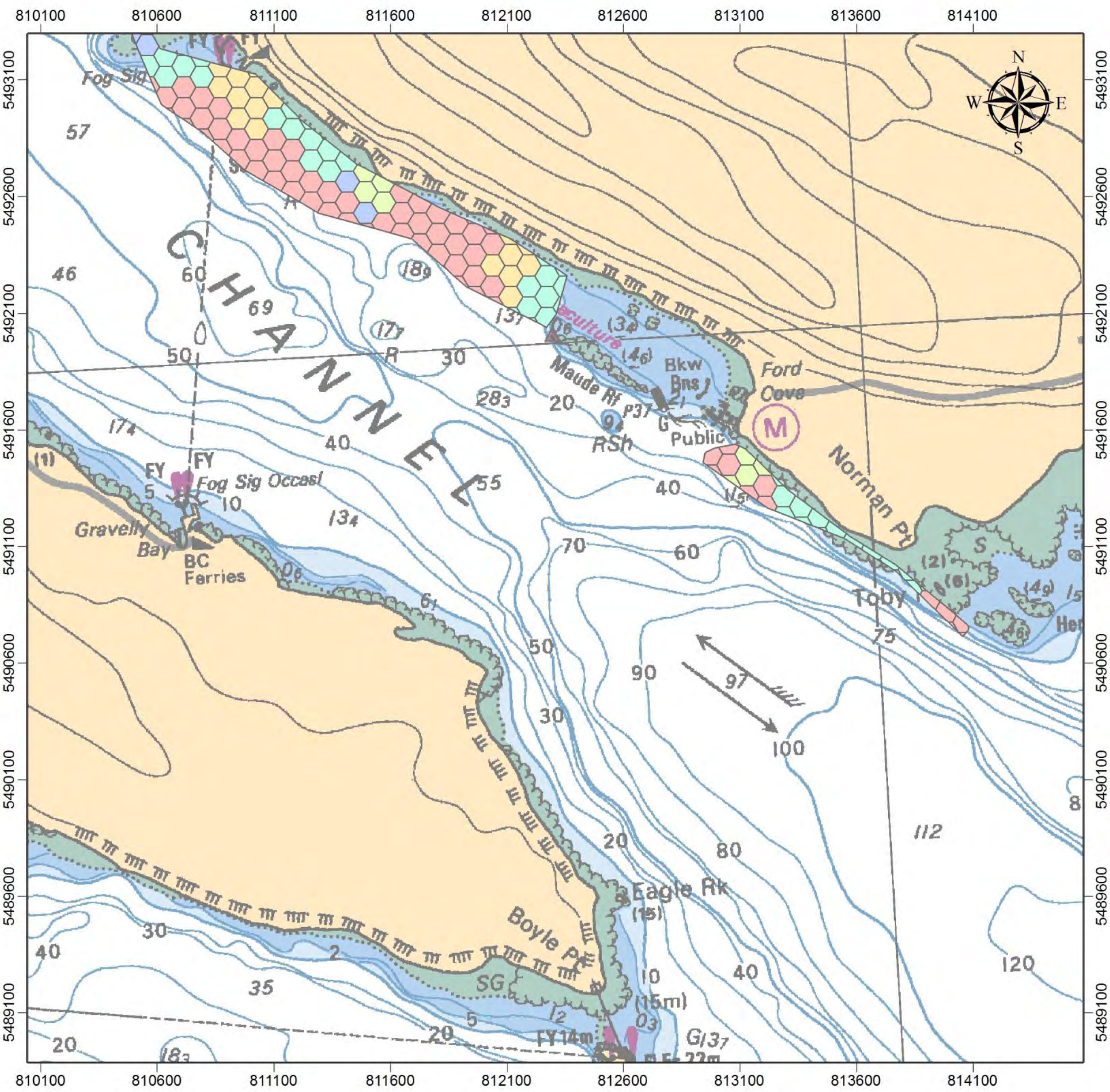
Scale: 1:23,000

Legend

- Flat kelps
- Leafy algae
- Sargassum
- Seagrasses
- Stringy algae

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 20. Map of dominant vegetation on SW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

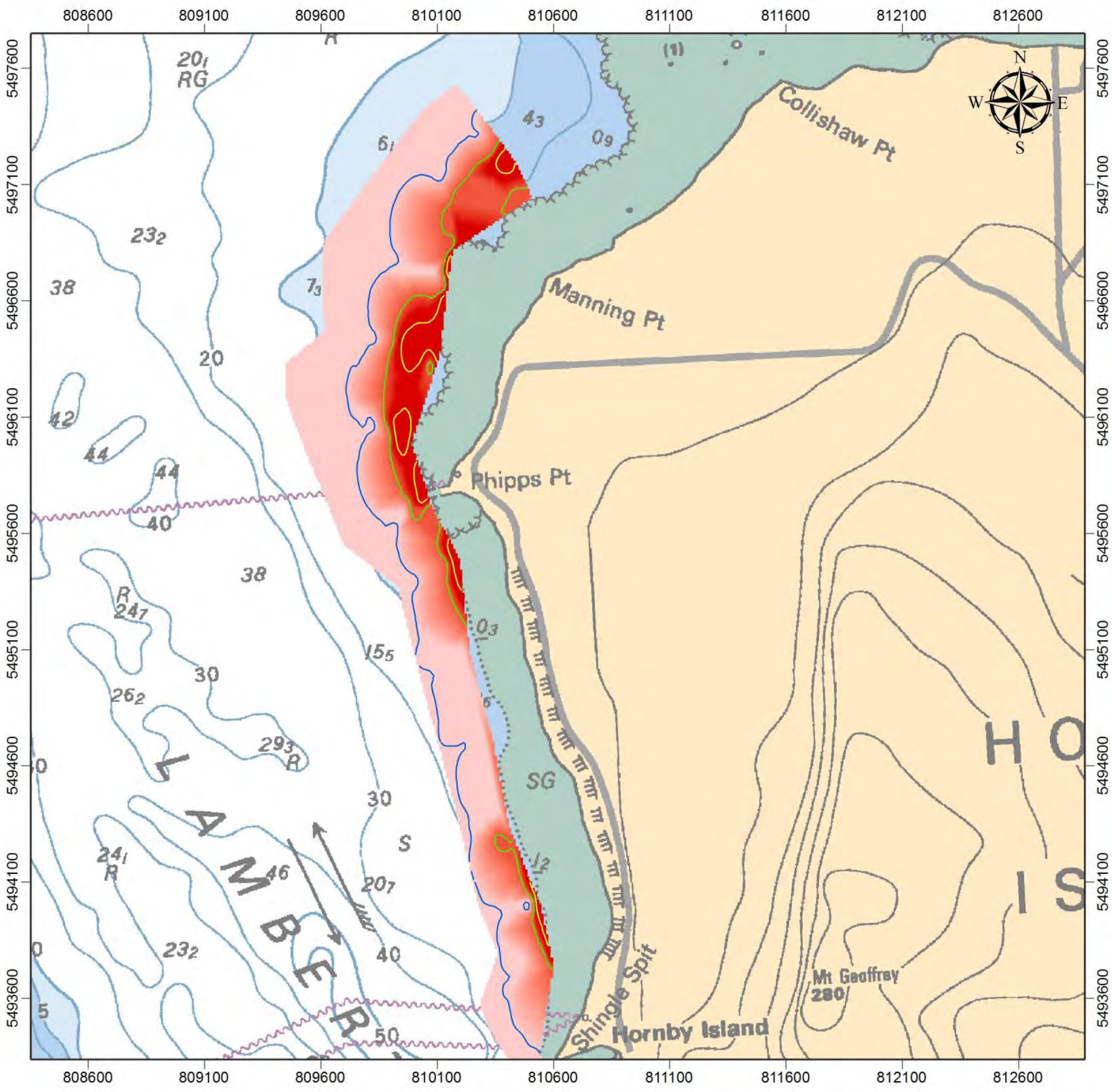
Scale: 1:23,000

Legend

- Flat kelps
- Leafy algae
- Sargassum
- Seagrasses
- Stringy algae

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 21. Map of spawn density on NW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

Spawn

High : 2+

Low : 0

< 0.01

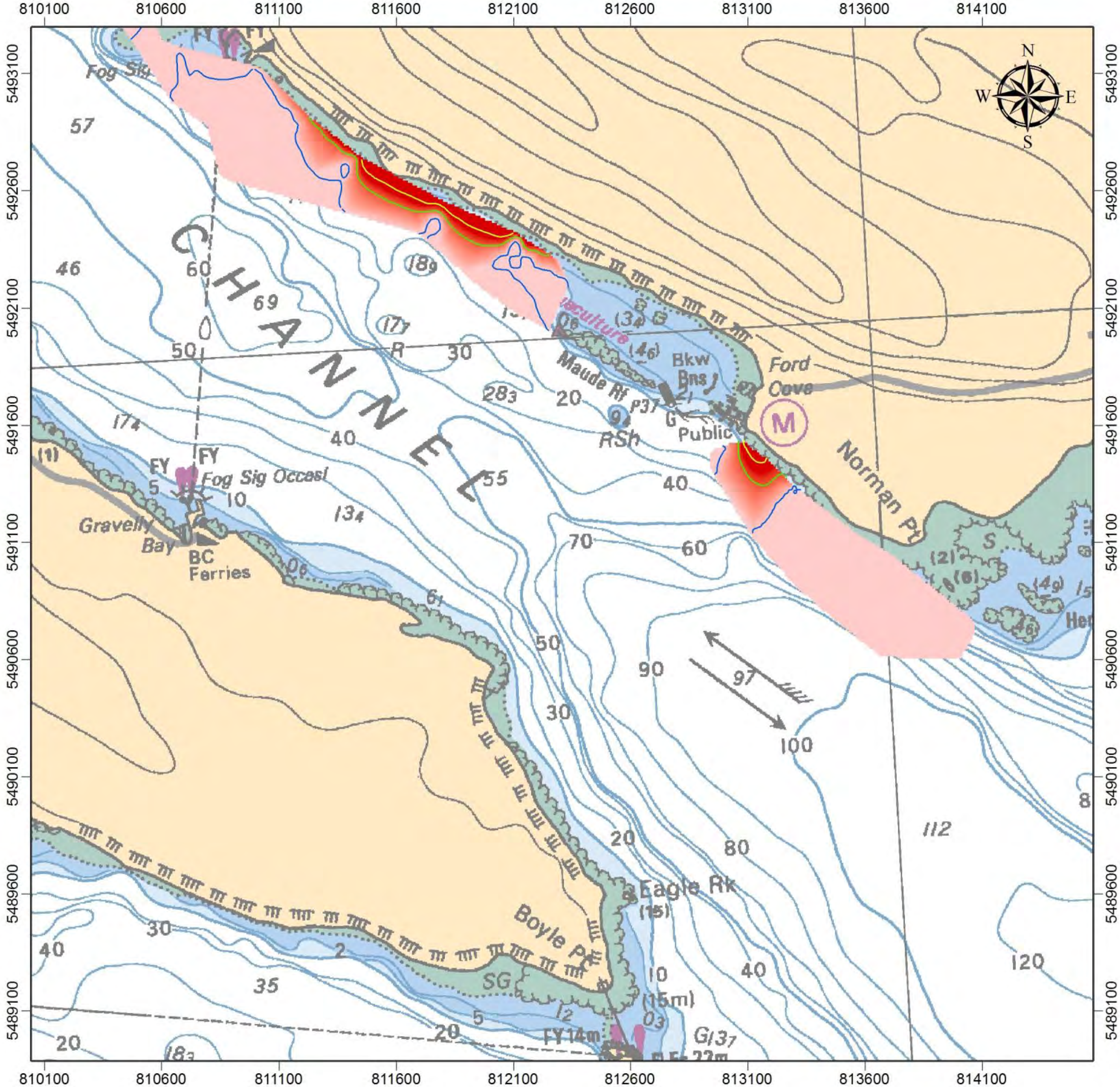
1

2

2+

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 22. Map of spawn density on SW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

Spawn

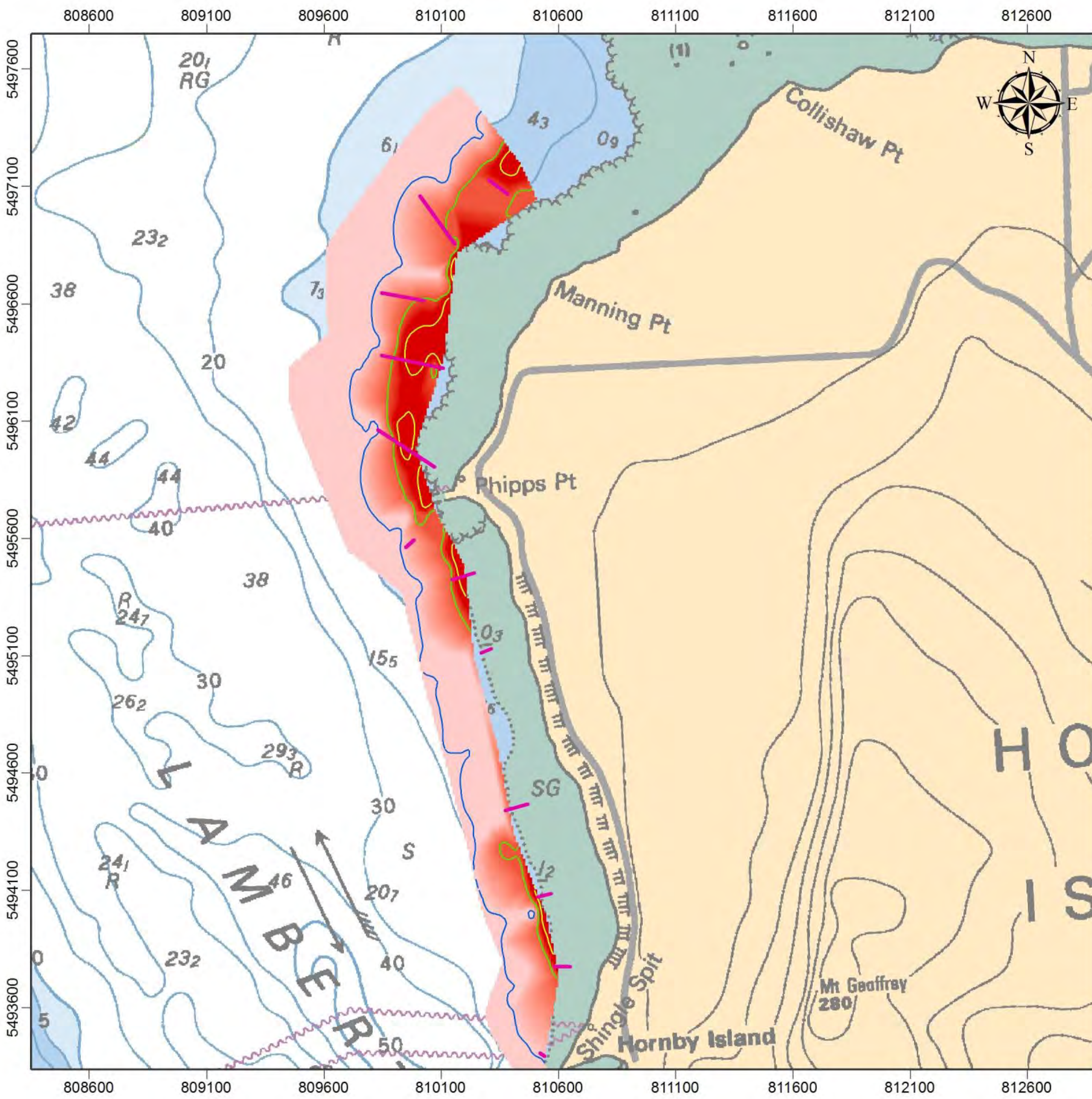
High : 2+

Low : 0

< 0.01
1
2
2+

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 23. Map of spawn density and dive transects on NW Hornby Island.

Chart used for navigation: CHS 352701 (Baynes Sound)

Station for tide height corrections: Hornby Island, CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,009

Legend

Dive transect width

Spawn

High : 2+

Low : 0

< 0.01

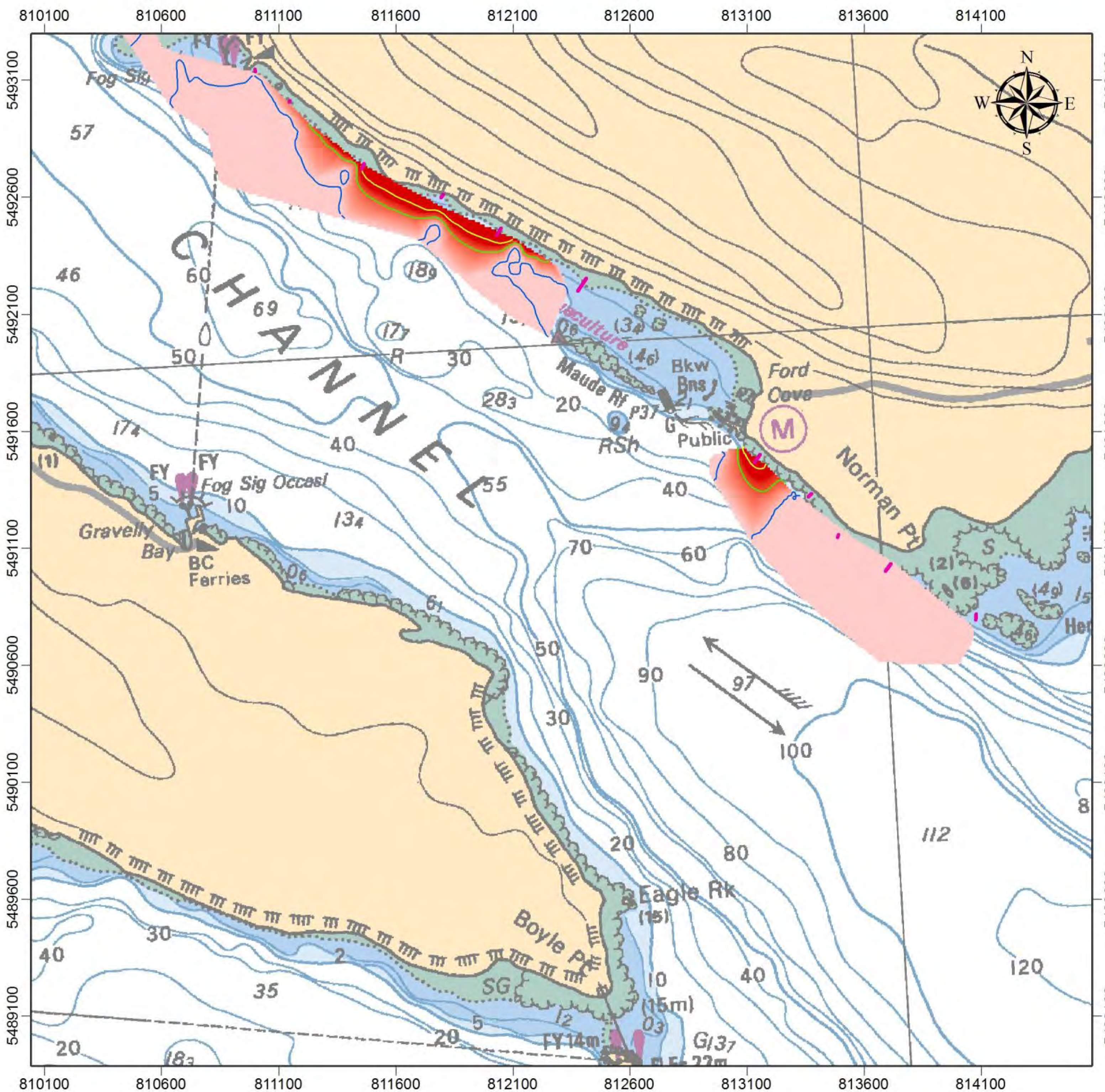
1

2

2+

0 250 500 1,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 24. Map of spawn density and dive transects on SW Hornby Island.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:23,000

Legend

Dive transect width

Spawn

High : 2+

Low : 0

< 0.01

1

2

2+

0 250 500 1,000 Meters

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2010 Experimental Herring Video Survey

Figure 25. Boundary of the video survey and the dive quadrats within this boundary used in a comparison of the dive and video survey.

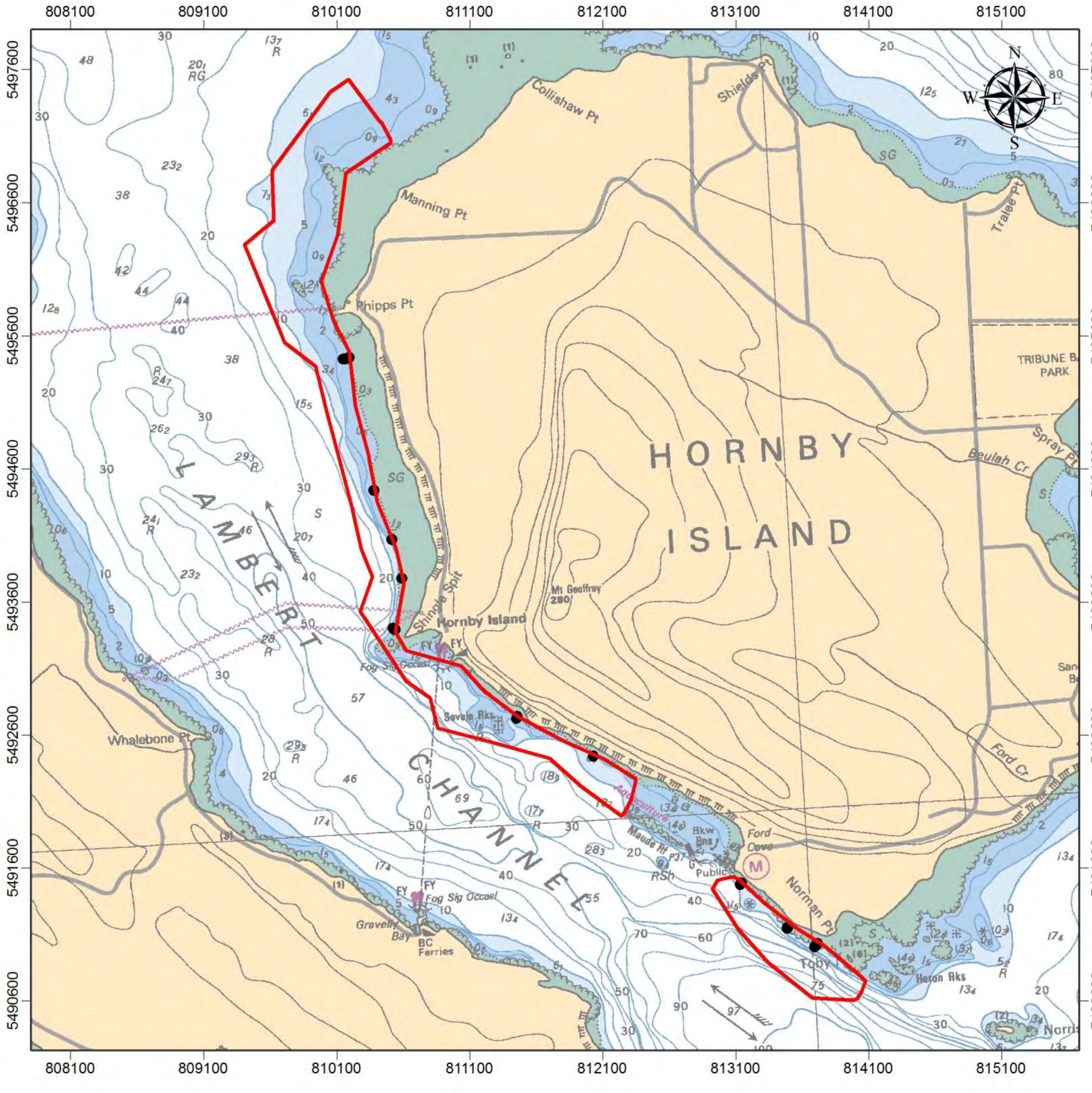


Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:40,000

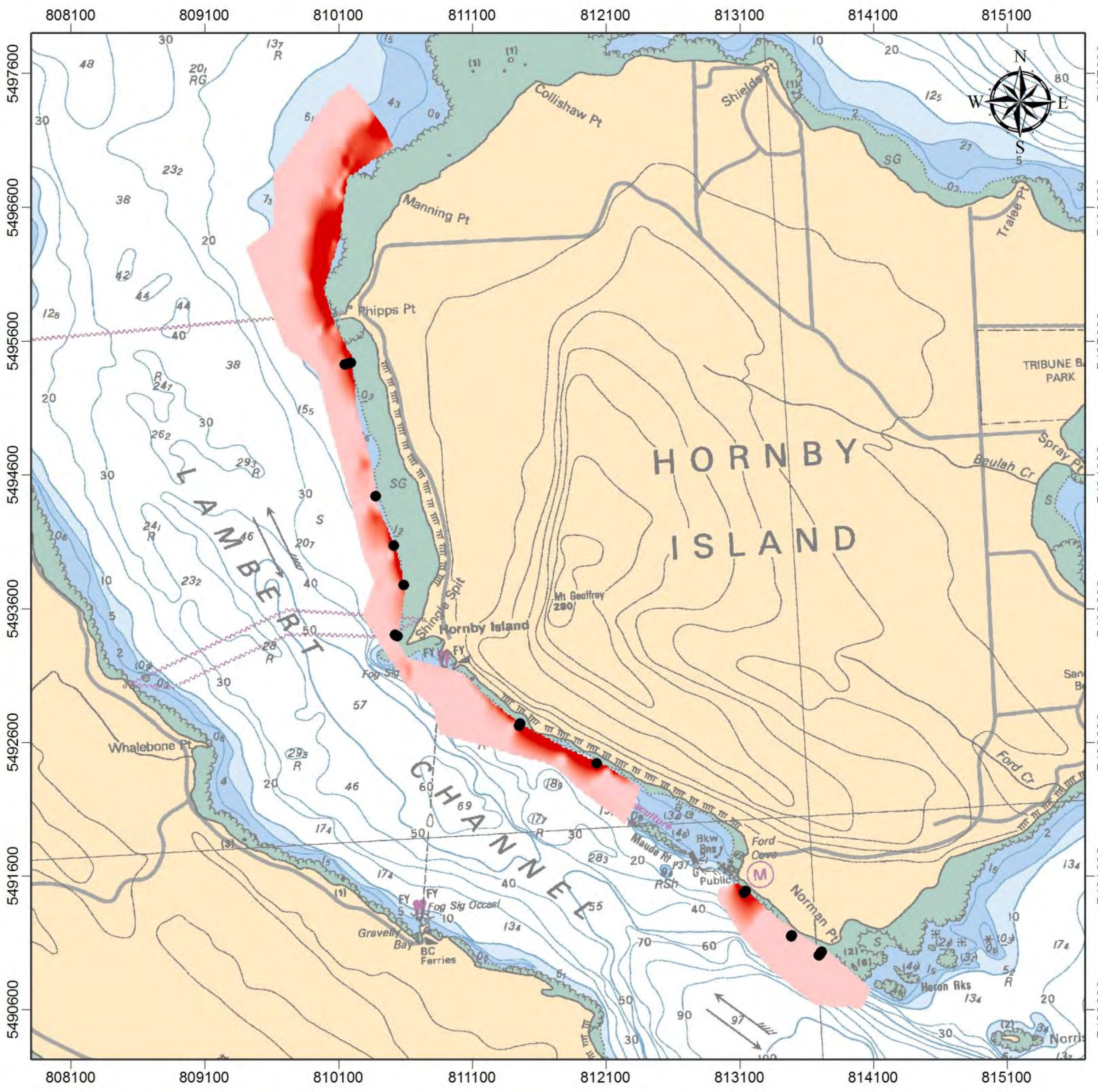
Legend

Survey boundaries

• Dive quadrats

0 500 1,000 2,000 Meters

OCEAN ECOLOGY



2010 Experimental Herring Video Survey

Figure 26. Spawn density grid and the dive quadrats used in a comparison of the dive and video survey.

Chart used for navigation:
CHS 352701
(Baynes Sound)

Station for tide height corrections:
Hornby Island,
CHS reference station 10772

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:40,000

Legend

Spawn density grid

2+

0

• Dive quadrats

0 500 1,000 2,000 Meters

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8. Disclaimer

The findings presented in this report are based upon data collected during the period March 10^{th} to April 14^{th}, 2010 using the methodology described in the Survey Design 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.

This report has been prepared solely for the use of the Herring Conservation and Research Society, pursuant to the agreement between Ocean Ecology and Herring Conservation and Research Society. Any use which other parties make of this report, or any reliance on or decisions made based on it, are the responsibility of such parties. Ocean Ecology accepts no responsibility for damages, if any, suffered by other parties as a result of decisions made or actions based on this report.

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

Prepared By:

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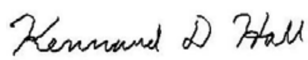
Oceanographer, R.P.Biol.

Reviewed By:



Kennard Hall, Captain
Partner, Ocean Ecology

Appendix 1 - Video Data Coding

Table A1. Substrate type codes.

Type Code	Class
SH	Shell
M	Mud
S	Sand
P	Pebble
CO	Cobble
B	Boulder
R	Rock

Table A2. Percentage substrate cover codes.

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

Table A3. Vegetation type codes.

Type Code	Class
FKP	Flat kelps
LFA	Leafy algae
STA	Stringy algae
SAR	Sargassum
STK	Stalked kelps
SEA	Seagrasses
RCK	Rockweed
GRU	Grunge

Table A4. Vegetation coverage codes.

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

Table A5. Spawn density codes.

Density Code	Description	Average Egg Layers in Video Field of View
1	Trace	0.01
2	Low	1
3	Moderate	2
4	Dense	>2

Appendix 2 - Software Used for Generation of Herring Spawn Maps

Small data files were processed using Microsoft Office Excel 2007. While not essential, two Excel add-ins, ASAP Utilities and DigDB, were very useful for data management and transformations.

Contours of herring spawn density were generated using Surfer 9. The production of the contours involved four steps:

1) Files containing latitude, longitude, and herring spawn density data were gridded using the natural neighbour method. All other settings were left at the Surfer default values.
2) The grid file was then filtered using a nonlinear threshold averaging filter to remove any potentially erroneous data points. The filter size was set to 3 rows by 3 columns. The threshold value was set to 10. All other settings were left at the Surfer default values.
3) Spline smoothing was applied to remove any small scale jaggedness from the contour lines. The "Insert Node" method was used, and the number of nodes inserted was set to 10 for both rows and columns. All other settings were left at the Surfer default values.
4) Contours generated outside the actual data range were removed by "blanking" the grid file with a data boundary mask set such that any contour values generated outside the data range were clipped.

Contours generated by Surfer were exported as AutoCAD (*.dxf) files which could then be imported into ArcGIS. The projection of the exported files was WGS 1984.

Map and raster generation were carried out using ArcMap 9.2 and ArcCatalog 9.2 with an ArcInfo license. Three extensions were required - 3D Analyst, Hawth"s Analysis Tools, and Spatial Analyst.

ArcCatalog was used to convert the contours created by Surfer from AutoCAD format to ESRI shapefile format (*.shp). These new shapefiles were opened in ArcMap and reprojected to WGS 1984 UTM Zone 9N.

A herring spawn density distribution raster file was created from the herring spawn density contours as follows:

1) Using the 3D Analyst extension, the herring spawn density contours shapefile was used to create a TIN file. The "Elevation" value from the contours was used as the height source for the TIN, and the triangulation method was set to "soft line".
2) Again using the 3D Analyst extension, the new TIN file was converted to a raster file. The "Elevation" value of the TIN file was used as the raster"s "Attribute" value, and the cell size was set to 10.
3) If the raster file extended beyond the actual data range, data outside the data range was clipped using a data boundary mask. This was done using the Spatial Analyst extension. The analysis mask was set to the data boundary, and the Raster Calculator function was used to create a new raster based on this analysis mask.

A high accuracy herring spawn density distribution raster file was created from the herring spawn grid file generated by Surfer as follows:

1) Using Surfer, the Surfer grid was checked to ensure that the X and Y grid spacing was exactly the same (e.g., the grid cells were square). If this was not the case, the grid was reformatted in Surfer to create square cells.
2) Again using Surfer, the Surfer grid was converted to an Arc/Info ASCII grid.
3) Using ArcCatalog, the ASCII grid was converted to an ArcGIS raster. The spatial reference of the raster was set to WGS 1984, and the raster was added to ArcMap.
4) Using ArcMap, the raster file was reprojected to WGS 1984 UTM Zone 9N.

Appendix 3 - Dive Survey Data Used for Comparisons

Table A6. Dive Survey Data.

Transect	Quadrat	Spawn Width	Vegetation 1	Percent Cover 1	Spawn Layers 1	Vegetation 2	Percent Cover 2	Spawn Layers 2	Distance	Depth	Substrate	Percent Cover	Spawn Layers	Longitude	Latitude	Average Spawn Layers
2315	1	25.0	Stringy Algae	20	1.25	Sargassum	60	2.00	1	-0.19	Rock	0	0.00	-124.66273385	49.48837895	1.45
2315	2	25.0	Sargassum	70	1.75				6	0.425	Rock	0	0.00	-124.66272811	49.48842372	1.23
2315	3	25.0	Stringy Algae	20	0.50	Sargassum	65	0.75	11	0.43	Rock	0	0.00	-124.66272237	49.48846848	0.59
2315	4	25.0	Stringy Algae	50	0.75	Sargassum	30	0.50	16	0.436	Rock	0	0.00	-124.66271664	49.48851324	0.53
2315	5	25.0	Sargassum	75	0.50				21	0.762	Rock	0	0.00	-124.66271090	49.48855801	0.38
2316	1	39.0	Stringy Algae	30	0.75				4	-0.47	Sand	0	0.00	-124.66784578	49.49045819	0.23
2316	2	39.0							9	-0.46	Sand	0	0.00	-124.66780300	49.49049342	0.00
2316	3	39.0	Sargassum	5	0.01				14	0.149	Cobbles	70	0.01	-124.66776023	49.49052865	0.01
2316	4	39.0	Rockweed	25	0.50				19	0.765	Boulders	50	0.01	-124.66771745	49.49056388	0.13
2316	5	39.0	Stringy Algae	10	0.25	Rockweed	30	0.01	24	1.683	Rock	100	0.01	-124.66767468	49.49059912	0.04
2316	6	39.0	Rockweed	60	0.01				29	2.915	Rock	0	0.00	-124.66763190	49.49063435	0.01
2316	7	39.0	Rockweed	100	0.01				34	3.234	Rock	0	0.00	-124.66758912	49.49066958	0.01
2316	8	39.0	Rockweed	90	0.01				39	3.542	Rock	0	0.00	-124.66754635	49.49070481	0.01
2317	1	11.0	Stringy Algae	65	3.75	Sargassum	25	2.50	1	-0.09	Cobbles	40	1.25	-124.67058171	49.49185005	3.56
2317	2	11.0	Stringy Algae	70	3.50	Sargassum	20	2.25	3	-0.08	Boulders	90	1.50	-124.67057180	49.49186682	4.25
2317	3	11.0	Rockweed	80	1.25				5	0.838	Rock	100	2.00	-124.67056190	49.49188359	3.00
2317	4	11.0	Rockweed	75	0.50				7	1.454	Rock	100	0.75	-124.67055199	49.49190036	1.13
2317	5	11.0	Rockweed	65	0.25				9	2.071	Rock	100	0.50	-124.67054208	49.49191713	0.66
2318	1	20.0	Sargassum	50	3.00				2	-0.65	Cobbles	0	0.00	-124.67215840	49.49346409	1.50
2318	2	20.0	Sargassum	60	3.00				7	-0.64	Sand	0	0.00	-124.67210858	49.49349514	1.80
2318	3	20.0	Sargassum	50	4.00				12	-0.33	Sand	0	0.00	-124.67205875	49.49352620	2.00
2318	4	20.0							17	-0.02	Sand	0	0.00	-124.67200893	49.49355726	0.00

Transect	Quadrat	Spawn Width	Vegetation 1	Percent Cover 1	Spawn Layers 1	Vegetation 2	Percent Cover 2	Spawn Layers 2	Distance	Depth	Substrate	Percent Cover	Spawn Layers	Longitude	Latitude	Average Spawn Layers
2319	1	40.0	Stringy Algae	35	2.50	Sargassum	50	2.75	3	-0.32	Cobbles	40	1.50	-124.67520341	49.49492732	2.85
2319	2	40.0	Stringy Algae	15	1.75	Sargassum	35	3.00	8	-0.01	Sand	0	0.00	-124.67515910	49.49496174	1.31
2319	3	40.0	Rockweed	35	2.50	Sargassum	45	2.00	13	0.906	Rock	70	2.50	-124.67511479	49.49499616	3.53
2319	4	40.0	Rockweed	65	0.50				18	1.521	Rock	0	0.00	-124.67507048	49.49503058	0.33
2319	5	40.0	Rockweed	35	0.01				23	1.526	Rock	0	0.00	-124.67502617	49.49506500	0.00
2319	6	40.0	Rockweed	75	0.25				28	4.272	Rock	100	0.25	-124.67498186	49.49509942	0.44
2319	7	40.0	Rockweed	60	0.25				33	3.972	Rock	100	0.01	-124.67493755	49.49513384	0.16
2319	8	40.0	Rockweed	80	0.25				38	3.974	Rock	100	0.01	-124.67489323	49.49516826	0.21
2322	1	65.0	Grasses	20	0.01				2	-3.00	Sand	0	0.00	-124.68501234	49.50186236	0.00
2322	2	65.0	Grasses	40	0.01				17	-2.08	Sand	0	0.00	-124.68489617	49.50197434	0.00
2322	3	65.0	Grasses	70	0.25				32	-0.86	Sand	0	0.00	-124.68478314	49.50208214	0.18
2322	4	65.0	Sargassum	100	4.00				47	0.04	Sand	0	0.00	-124.68466384	49.50219517	4.00
2323	1	36.0	Stringy Algae	25	0.25				2	-6.06	Sand	0	0.00	-124.68960548	49.50418609	0.06
2323	4	36.0	Sargassum	100	6.00				26	0.02	Cobbles	0	0.00	-124.68941040	49.50436519	6.00
2323	5	36.0	Rockweed	90	1.50				34	1.55	Boulders	100	1.00	-124.68934825	49.50441813	2.35
2324	1	16.0	Sargassum	5	0.01				2	-1.54	Cobbles	0	0.00	-124.69277083	49.50575563	0.00
2324	2	16.0	Sargassum	10	0.01				5	-1.55	Cobbles	0	0.00	-124.69274409	49.50577732	0.00
2324	3	16.0	Flat Kelp	10	0.01	Sargassum	10	3.00	8	-1.25	Cobbles	0	0.00	-124.69271952	49.50579792	0.30
2324	4	16.0	Sargassum	80	6.00				11	-0.64	Cobbles	0	0.00	-124.69269313	49.50581996	4.80
2324	5	16.0	Sargassum	100	6.00				14	-0.04	Cobbles	0	0.00	-124.69266820	49.50583984	6.00
2325	1	25.0	Sargassum	30	1.25				1	-0.98	Cobbles	60	0.75	-124.69735368	49.50701280	0.83
2325	2	25.0	Sargassum	90	3.25				10	-0.07	Cobbles	60	0.75	-124.69730050	49.50708611	3.38
2325	3	25.0	Sargassum	100	3.25				19	0.53	Cobbles	40	0.75	-124.69724887	49.50715787	3.55

Transect	Quadrat	Spawn Width	Vegetation 1	Percent Cover 1	Spawn Layers 1	Vegetation 2	Percent Cover 2	Spawn Layers 2	Distance	Depth	Substrate	Percent Cover	Spawn Layers	Longitude	Latitude	Average Spawn Layers
2326	1	8.0	Sargassum	10	2.50				1	0.00	Sand	0	0.00	-124.70138309	49.50974072	0.25
2326	2	8.0	Sargassum	90	2.50				4	0.31	Sand	0	0.00	-124.70135880	49.50976426	2.25
2326	3	8.0	Sargassum	15	2.00				7	0.30	Cobbles	0	0.00	-124.70133713	49.50978594	0.30
2328	1	28.0	Sargassum	20	1.90				2	-0.08	Boulders	0	0.00	-124.70775671	49.51273016	0.38
2328	2	28.0	Sargassum	80	1.00				10	0.513	Boulders	0	0.00	-124.70786709	49.51273016	0.80
2328	3	28.0	Sargassum	70	1.50				18	0.505	Boulders	0	0.00	-124.70797747	49.51273016	1.05
2328	4	28.0	Sargassum	10	1.00				26	1.404	Boulders	0	0.00	-124.70808786	49.51273016	0.10
2329	1	23.0	Stringy Algae	10	0.25	Sargassum	30	0.50	1	0.32	Cobbles	0	0.00	-124.70962925	49.51360393	0.18
2329	2	23.0	Stringy Algae	10	0.75	Sargassum	40	0.75	11	0.62	Cobbles	0	0.00	-124.70952370	49.51354493	0.38
2329	3	23.0	Sargassum	15	0.50				21	0.91	Cobbles	0	0.00	-124.70942052	49.51348593	0.08
2330	1	68.0	Sargassum	60	3.00				4	0.33	Cobbles	60	0.01	-124.70845929	49.51691282	1.81
2330	2	68.0	Sargassum	70	3.50				19	0.93	Cobbles	80	0.01	-124.70825316	49.51690351	2.46
2330	4	68.0	Sargassum	20	0.25				49	1.20	Cobbles	0	0.00	-124.70784356	49.51687957	0.05
2331	1	57.0	Flat Kelp	20	1.25	Sargassum	40	3.50	3	-0.47	Cobbles	0	0.00	-124.70923542	49.51960111	1.65
2331	2	57.0	Sargassum	85	6.00				15	0.42	Cobbles	85	0.25	-124.70907323	49.51961965	5.31
2331	5	57.0	Leafy Algae	25	0.01				51	1.61	Pebbles	0	0.00	-124.70859128	49.51968337	0.00
2332	1	100.0	Sargassum	20	0.75				7	-0.45	Cobbles	0	0.00	-124.71080336	49.52298183	0.15
2332	2	100.0	Stringy Algae	15	2.50	Sargassum	40	3.00	22	0.14	Cobbles	0	0.00	-124.71060228	49.52301508	1.58
2332	3	100.0	Sargassum	30	3.75				37	0.42	Cobbles	0	0.00	-124.71040436	49.52304674	1.13
2332	4	100.0	Sargassum	90	3.75				52	0.41	Cobbles	0	0.00	-124.71020328	49.52307683	3.38
2332	5	100.0	Sargassum	65	4.25				67	0.68	Cobbles	0	0.00	-124.70999428	49.52310691	2.76
2334	1	47.0	Sargassum	80	3.75				1	-0.10	Sand	0	0.00	-124.71176247	49.52905440	3.00
2334	2	47.0	Sargassum	65	4.50				21	0.18	Sand	0	0.00	-124.71150415	49.52911631	2.93
2334	3	47.0	Stringy Algae	15	2.50	Sargassum	55	3.25	41	0.77	Boulders	0	0.00	-124.71124200	49.52918127	2.16

Transect	Quadrat	Spawn Width	Vegetation 1	Percent Cover 1	Spawn Layers 1	Vegetation 2	Percent Cover 2	Spawn Layers 2	Distance	Depth	Substrate	Percent Cover	Spawn Layers	Longitude	Latitude	Average Spawn Layers
2335	1	100.0	Sargassum	30	3.00				3	-0.88	Cobbles	0	0.00	-124.71320467	49.53192446	0.90
2335	2	100.0	Sargassum	40	0.50				18	-0.28	Cobbles	0	0.00	-124.71300305	49.53195510	0.20
2335	3	100.0	Sargassum	30	2.50	Flat Kelp	40	0.50	33	-0.29	Pebbles	0	0.00	-124.71280142	49.53198574	0.95
2335	4	100.0	Sargassum	35	2.00				48	-0.61	Cobbles	0	0.00	-124.71259979	49.53201638	0.70
2335	5	100.0	Grasses	60	0.01				63	-0.01	Sand	0	0.00	-124.71239816	49.53204702	0.01
2335	6	100.0	Sargassum	50	5.00				78	0.898	Sand	0	0.00	-124.71219653	49.53207766	2.50
2335	7	100.0	Sargassum	70	5.50				93	1.193	Rock	0	0.00	-124.71199490	49.53210830	3.85

Table A7. Converted Dive Survey Data.

Transect	Quadrat	Longitude	Latitude	Dominant Vegetation	Dominant Substrate	Spawn Abundance	Depth
2315	1	-124.66273385	49.48837895	Sargassum	Rock	1	-0.1899
2315	2	-124.66272811	49.48842372	Sargassum	Rock	1	0.4252
2315	3	-124.66272237	49.48846848	Sargassum	Rock	1	0.4304
2315	4	-124.66271664	49.48851324	Stringy Algae	Rock	1	0.4362
2315	5	-124.66271090	49.48855801	Sargassum	Rock	0.01	0.762
2316	1	-124.66784578	49.49045819	Stringy Algae	Sand	0.01	-0.4694
2316	2	-124.66780300	49.49049342		Sand	0	-0.4633
2316	3	-124.66776023	49.49052865	Sargassum	Cobbles	0.01	0.1494
2316	4	-124.66771745	49.49056388	Rockweed	Boulders	0.01	0.7654
2316	5	-124.66767468	49.49059912	Rockweed	Rock	0.01	1.6828
2316	6	-124.66763190	49.49063435	Rockweed	Rock	0.01	2.9154
2316	7	-124.66758912	49.49066958	Rockweed	Rock	0.01	3.2339
2316	8	-124.66754635	49.49070481	Rockweed	Rock	0.01	3.5424
2317	1	-124.67058171	49.49185005	Stringy Algae	Cobbles	2+	-0.0942
2317	2	-124.67057180	49.49186682	Stringy Algae	Boulders	2+	-0.0838
2317	3	-124.67056190	49.49188359	Rockweed	Rock	2+	0.8376
2317	4	-124.67055199	49.49190036	Rockweed	Rock	1	1.4542
2317	5	-124.67054208	49.49191713	Rockweed	Rock	1	2.0705
2318	1	-124.67215840	49.49346409	Sargassum	Cobbles	2	-0.6501
2318	2	-124.67210858	49.49349514	Sargassum	Sand	2	-0.641
2318	3	-124.67205875	49.49352620	Sargassum	Sand	2	-0.3301
2318	4	-124.67200893	49.49355726		Sand	0	-0.0195
2319	1	-124.67520341	49.49492732	Sargassum	Cobbles	2+	-0.3243
2319	2	-124.67515910	49.49496174	Sargassum	Sand	1	-0.014
2319	3	-124.67511479	49.49499616	Sargassum	Rock	2+	0.9059
2319	4	-124.67507048	49.49503058	Rockweed	Rock	0.01	1.521
2319	5	-124.67502617	49.49506500	Rockweed	Rock	0.01	1.5258
2319	6	-124.67498186	49.49509942	Rockweed	Rock	0.01	4.2718
2319	7	-124.67493755	49.49513384	Rockweed	Rock	0.01	3.9718
2319	8	-124.67489323	49.49516826	Rockweed	Rock	0.01	3.9743
2322	1	-124.68501234	49.50186236	Grasses	Sand	0.01	-3.00
2322	2	-124.68489617	49.50197434	Grasses	Sand	0.01	-2.08
2322	3	-124.68478314	49.50208214	Grasses	Sand	0.01	-0.86
2322	4	-124.68466384	49.50219517	Sargassum	Sand	2+	0.04
2323	1	-124.68960548	49.50418609	Stringy Algae	Sand	0.01	-6.06
2323	4	-124.68941040	49.50436519	Sargassum	Cobbles	2+	0.02
2323	5	-124.68934825	49.50441813	Rockweed	Boulders	2	1.55
2324	1	-124.69277083	49.50575563	Sargassum	Cobbles	0.01	-1.54
2324	2	-124.69274409	49.50577732	Sargassum	Cobbles	0.01	-1.55
2324	3	-124.69271952	49.50579792	Flat Kelp/Sargassum	Cobbles	0.01	-1.25
2324	4	-124.69269313	49.50581996	Sargassum	Cobbles	2+	-0.64
2324	5	-124.69266820	49.50583984	Sargassum	Cobbles	2+	-0.04

Transect	Quadrat	Longitude	Latitude	Dominant Vegetation	Dominant Substrate	Spawn Abundance	Depth
2325	1	-124.69735368	49.50701280	Sargassum	Cobbles	1	-0.98
2325	2	-124.69730050	49.50708611	Sargassum	Cobbles	2+	-0.07
2325	3	-124.69724887	49.50715787	Sargassum	Cobbles	2+	0.53
2326	1	-124.70138309	49.50974072	Sargassum	Sand	0.01	0.00
2326	2	-124.70135880	49.50976426	Sargassum	Sand	2	0.31
2326	3	-124.70133713	49.50978594	Sargassum	Cobbles	0.01	0.30
2328	1	-124.70775671	49.51273016	Sargassum	Boulders	0.01	-0.0802
2328	2	-124.70786709	49.51273016	Sargassum	Boulders	1	0.5133
2328	3	-124.70797747	49.51273016	Sargassum	Boulders	1	0.5054
2328	4	-124.70808786	49.51273016	Sargassum	Boulders	0.01	1.4036
2329	1	-124.70962925	49.51360393	Sargassum	Cobbles	0.01	0.32
2329	2	-124.70952370	49.51354493	Sargassum	Cobbles	0.01	0.62
2329	3	-124.70942052	49.51348593	Sargassum	Cobbles	0.01	0.91
2330	1	-124.70845929	49.51691282	Sargassum	Cobbles	2	0.33
2330	2	-124.70825316	49.51690351	Sargassum	Cobbles	2	0.93
2330	4	-124.70784356	49.51687957	Sargassum	Cobbles	0.01	1.20
2331	1	-124.70923542	49.51960111	Sargassum	Cobbles	2	-0.47
2331	2	-124.70907323	49.51961965	Sargassum	Cobbles	2+	0.42
2331	5	-124.70859128	49.51968337	Leafy Algae	Pebbles	0.01	1.61
2332	1	-124.71080336	49.52298183	Sargassum	Cobbles	0.01	-0.45
2332	2	-124.71060228	49.52301508	Sargassum	Cobbles	2	0.14
2332	3	-124.71040436	49.52304674	Sargassum	Cobbles	1	0.42
2332	4	-124.71020328	49.52307683	Sargassum	Cobbles	2+	0.41
2332	5	-124.70999428	49.52310691	Sargassum	Cobbles	2+	0.68
2334	1	-124.71176247	49.52905440	Sargassum	Sand	2+	-0.10
2334	2	-124.71150415	49.52911631	Sargassum	Sand	2+	0.18
2334	3	-124.71124200	49.52918127	Sargassum	Boulders	2	0.77
2335	1	-124.71320467	49.53192446	Sargassum	Cobbles	1	-0.8815
2335	2	-124.71300305	49.53195510	Sargassum	Cobbles	0.01	-0.2822
2335	3	-124.71280142	49.53198574	Flat Kelp	Pebbles	1	-0.2923
2335	4	-124.71259979	49.53201638	Sargassum	Cobbles	1	-0.6072
2335	5	-124.71239816	49.53204702	Grasses	Sand	0.01	-0.0073
2335	6	-124.71219653	49.53207766	Sargassum	Sand	2+	0.8976
2335	7	-124.71199490	49.53210830	Sargassum	Rock	2+	1.1933