Big Bay Experimental Herring Video Survey

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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 Big Bay. Nominal shore-normal transect line spacing was 350 m. Surveys were carried out in water depths from -1.4 m to 19.0 m depth.

A data record of substrate, vegetation type, herring spawn percent cover, and herring spawn egg layers was produced for each second of video imagery using a classification system similar to that used by the DFO herring dive surveys.

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.

The following observations were made regarding the experimental herring video survey at Big Bay:

1. The depth of the region surveyed ranged from -1.4 m to 19.0 m. Overall, the survey area consisted of a relatively flat, shallow bay with a rocky shoreline and rocky outcrops.
2. Bottom hardness values for the site ranged from 1.5 to 8.0. Hardness values were highest in areas around the rocky outcrops and the rocky points. Hardness values decreased as the sediment layer increased towards the center of the bay.
3. Based on video observations, the site substrate consisted largely of sand, with areas of cobble in and around the rocky outcrops and points.
4. The vegetation type which had the greatest occurrences of herring spawn was flat kelps. Seagrasses had the second greatest occurrences of herring spawn.
5. Flat kelps and stringy algae were largely found in association with the rocky outcrops and points, in regions with mostly cobble substrate and high bottom hardness values.
6. Seagrasses were found in areas of sandy substrate with low bottom hardness values.
7. Eleven grab samples were collected along the length of the shore parallel transect. The grab samples appeared to be fairly representative of the survey site as seen during the video survey. Egg deposition on the algae was very patchy, with regions of up to four egg layers coexisting with egg-free patches on the same blade. Average egg layers for a blade ranged from 0.01 (trace) to 1.5 in the eleven samples.
8. It was not possible to count the number of egg layers in the herring spawn directly using the images from the video survey, as this would have involved visualizing each blade in several different orientations. However, a reasonable estimate of egg layers was possible using the egg distribution patterns and egg layer colorations (e.g., translucent white through to pale yellow).
9. The towed video system is very good at assessing the percent cover of vegetation with herring spawn when there is less than 100% cover. However, it was impossible to estimate much beyond 200% cover without being able to lift up individual blades. As a result, the maximum percentage cover used in the calculations for herring spawn intensity was 200%.
10. Spawn intensity was not uniform throughout the survey area. Spawn intensity was much higher in areas with cobble substrates, high bottom hardness values, and a predominantly flat kelp vegetation type. These areas were specifically Shattock Point, Simpson Point, Swallow Island, Curlew Rock, and an area SE of Curlew Rock.
11. Based on estimates from the video survey, the average spawn intensity for the regions of Big Bay encompassed by the video survey was 84098 eggs/m^2. The total spawn was 2.533×10^{11} eggs. The estimated tonnes of spawning fish were 2533.
12. Based on estimates from the dive survey, the average spawn intensity for the regions of Big Bay encompassed by the dive survey was 33635 eggs/m^2. The total spawn was 7.357×10^{10} eggs. The estimated tonnes of spawning fish were 736.

13. Although overlap between the video survey and the dive survey was relatively limited, where overlap did occur, there was good agreement both spatially and quantitatively. Both surveys indicated that spawn intensity was highest at Simpson Point, Swallow Island, and Curlew Rock. The estimated tonnes of spawning fish in the area of overlap between the two surveys was 338 and 291, respectively, for the video survey and the dive survey.
14. It was recommended that a full scale towed benthic video analysis be used only for scientific herring research. A modified, down-scaled survey was recommended for stock assessments. Rather than recording video for the entire length of a transect, it was suggested that short video segments, or even drop videos, be taken at intervals along a transect. This design would be more comparable to the herring dive survey, and would be faster and cheaper to perform.

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 diver surveys determined that herring spawn was present.

The following report addresses two main aspects of this work:

1) The methodologies used by Ocean Ecology to carry out the experimental herring spawn survey and process the video data from the survey are described. Limitations, as specific to Ocean Ecology's video system and the environmental conditions present at Big Bay during the time of the video survey are discussed. A comparison is made between the data collected by both the video survey and the dive survey.
2) The pros and cons of various commercially available towed video systems are described. This is a general discussion, and it is recognized that the specific limitations for any video survey will depend on the particular video system used for the survey, which will ultimately depend on the purpose of the survey and the survey design.

2 Survey Methodology

2.1 Towed Benthic Video Survey Design

2.1.1 Towed Video System

A DGPS-positioned, towed video system was used to collect imagery of the seabed (similar to the Seabed Imaging and Mapping System 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.

2.1.2 Video Recording System

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

2.1.3 Survey Design

On April 8th, 2009, the commercial herring gillnet fishery in the Big Bay area was closed after a one day fishery opening. On the 12th and 13th of April, a herring spawn dive survey was carried out in the Big Bay area. The proposed design for this survey consisted of 17 shore perpendicular transects, and followed the DFO Herring Spawn Survey Manual[1] protocols. The approximate locations of these transects are shown in Figure 1.

The video survey was designed to duplicate the dive survey transects as closely as possible in order to permit meaningful comparison between the results of the two surveys. Thus, the proposed video survey consisted of one shore-parallel transect to define the extent of the herring spawn along the shore, and 17 shore-perpendicular transects (see Figure 2). The shore-perpendicular transects were in the same approximate location as the dive survey transects, and 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.

[1] Fort, C., Daniel, K., and Thompson, M. 2008. Herring Spawn Survey Manual. Fisheries and Oceans. Science.

The video survey was carried out on April 17th and 18th, after a short delay due to stormy weather conditions.

2.1.4 Bottom Sampling

To validate egg layer estimates from the video data, eleven bottom samples along the shore-parallel transect were taken (see Figure 3). A Ponar grab was used to collect spawn samples in areas with soft bottom substrates. A five-prong grapple was used to collect spawn samples in areas with hard bottom substrates. The sample was quickly assessed for number of egg layers, photographed, and then returned to the water.

2.2 Bathymetric Survey Design

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

2.3 Classification and Mapping

2.1.1. 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.

2.1.2. 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 "Bottom type", "Vegetation type", "Herring spawn percent cover", and "Herring spawn egg layers". The classification system used was as follows:

1) "Bottom type" was classified as "Shell", "Mud", "Sand", "Pebbles", "Cobbles", "Boulders", or "Rock".
2) "Vegetation type" was classified as "Flat kelps", "Leafy algae", "Stringy algae", "Sargassum", "Stalked kelps", "Seagrasses", "Rockweed", or "Grunge".
3) "Herring spawn percent cover" ranged from 5 to 100%, in 5% increments, unless stalked or flat kelp were present, in which case the percent cover on each layer of kelp was estimated and added together.
4) "Herring spawn egg layers" were recorded in 0.25 layer increments. Trace amounts of herring spawn were recorded as 0.01 of a layer.

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

2.1.3. 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.

2.1.4. 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.

2.1.5. Herring Spawn Maps

Spawn intensity was calculated from the observed dive data using Schweigert’s equation for estimating herring egg density during SCUBA surveys[2]:

$$Eggs_{ij} = 1033.6694 * L_{ij}^{0.7137} * P_{ij}^{1.5076} * V_{ij} * Q_j$$

where

- $Eggs_{ij}$ = estimated number of eggs in thousands per m^2 on vegetation type i in quadrat j
- L_{ij} = number of layers of eggs in the video frame
- P_{ij} = proportion of video frame covered by spawn
- V_{ij} has the following values, depending on the substrate or dominant vegetation type
  - V_{1j} = 0.9948 for Seagrasses
  - V_{2j} = 1.2305 for Rockweed
  - V_{3j} = 0.8378 for Flat kelps
  - V_{4j} = 1.1583 for other brown algae (Stalked Kelps, Sargassum)
  - V_{5j} = 0.9824 for Leafy algae
  - V_{6j} = 1.0000 for Stringy algae
  - V_{7j} = 0.3289 for Grunge
  - V_{8j} = 0.3289 for no algae (e.g., spawn on substrate)
- Q_j = 0.5668 parameter for 1.00 m^2 quadrats,
- Q_j = 0.5020 parameter for 0.50 m^2 quadrats,
- Q_j = 1.0000 parameter for 0.25 m^2 quadrats.

[2] Schweigert, J.F., C.W. Haegele, and M. Stocker. 1990. Evaluation of sampling strategies for SCUBA surveys to assess spawn deposition by Pacific herring. North American J. of Fish. Manage. 10: 185-195.

Total egg density (thousands of eggs per m^2) for each quadrat is then estimated by summing the egg density estimates over the vegetation types,

$$Eggs_j = \sum_i Eggs_{ij}$$

Since there were relatively few data points to be processed for the dive survey (less than 200), processing was done using Microsoft Excel.

Approximate locations of dive survey quadrats were mapped using ArcGIS based on the approximately location of the dive transects as provided by DFO, the data provided from the dive survey data sheets, and the protocol for the survey as described in the DFO Herring Spawn Survey Manual[3].

As an initial estimate, spawn intensity was calculated from the observed video data using a modified form of Schweigert's equation for estimating herring egg density during SCUBA surveys[4]:

$$Eggs = 1033.6694 * L^{0.7137} * P^{1.5076} * V * Q$$

where

$Eggs$ = estimated number of eggs in thousands per m^2 in the video frame

L = number of layers of eggs in the video frame

P = proportion of video frame covered by spawn

V has the following values, depending on the substrate or dominant vegetation type

- V = 0.9948 for Seagrasses
- V = 1.2305 for Rockweed
- V = 0.8378 for Flat kelps
- V = 1.1583 for other brown algae (Stalked Kelps, Sargassum)
- V = 0.9824 for Leafy algae
- V = 1.0000 for Stringy algae
- V = 0.3289 for Grunge
- V = 0.3289 for no algae (e.g., spawn on substrate)

$Q = 2.8288q^2 - 4.1136q + 1.8516$

where q = video frame area (in m^2).

The video frame area can be calculated as follows:

$$q = \frac{(video\ frame\ width)(video\ frame\ height)}{(distance\ between\ laser\ spots)^2} \times 0.0016\ m^2$$

[3] Fort, C., Daniel, K., and Thompson, M. 2008. Herring Spawn Survey Manual. Fisheries and Oceans. Science.

[4] Schweigert, J.F., C.W. Haegele, and M. Stocker. 1990. Evaluation of sampling strategies for SCUBA surveys to assess spawn deposition by Pacific herring. North American J. of Fish. Manage. 10: 185-195.

where video frame width, video frame height, and distance between laser spots are measured in the same units on the computer screen. For the calculation of Q, an average value of q from the video data was used.

Only one vegetation type (the dominant type) was recorded for each video frame. The reasons for this were as follow:

1) Due to the large number of video frames processed per survey (10,000+), and the requirement for rapid video analysis, the information collected per frame was kept as simple as possible
2) The actual size of the video frame (0.1 m^2 to 0.2 m^2) at the distance required for egg identification and quantification is somewhat smaller than the smallest quadrat (0.25 m^2) normally used by the diver survey. As a result, most frames were dominated by a single vegetation type, and relatively few frames had more than one vegetation type.
3) Due to the broad nature of the vegetation type categories, there were relatively few situations in which different vegetation types were coexisting in the same video frame.

No attempt was made to quantify the number of eggs per *Macrocystis* (or other stalked kelp) plant. The reasons for this were as follow:

1) As a result of entanglement issues, the camera was generally not towed through kelp beds. Kelp beds are areas where divers will be required for accurate surveys.
2) Since the camera is unable to view an entire kelp plant in one frame, there is no way to measure the height of the plant or count the number of fronds on the plant.
3) Ultimately, it was intended that video camera surveys of herring spawn be used to supplement diver surveys in deeper water where divers cannot survey. These deeper areas will not have *Macrocystis* or other stalked kelps present.

It is recognized that the empirically derived values in Schweigert's equation may not provide the best accuracy for the towed video camera survey; however, the necessary calibration experiments required to develop new values for the camera system were beyond the scope of this particular study.

Since there were a large number of data points to be processed for the video survey (greater than 44,000), processing was done using ArcGIS.

Herring spawn intensity maps were generated using the fixed kernel density estimation procedure. Spawn observations were weighted by the "Eggs" value calculated using Schweigert's equation. In order to allow overlap of polygons between transects, the search radius (a.k.a. the smoothing factor) was set to the distance between transects (e.g., approximately 350 m). A density plot of the herring spawn intensity was produced, and contours indicating the regions in which 50%, 90%, 95%, and 99% of the herring spawn was expected to be located were drawn.

A herring spawn contour map was also generated from the "Eggs" value using Surfer. A raster image in ArcGIS with a cell size of 10 m x 10 m was created from this contour map. This raster image was then used to calculate the average spawn intensity (eggs/m^2) in the study area, and the total spawn (eggs) in the study area. Total egg deposition was then converted to tonnes of spawning fish based on an estimate of 100 eggs per gram of herring on average[5].

For further information on the software and calculations used in developing the herring spawn maps, see Appendix 1.

[5] Hay, D. E. 1985. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). Can. J. Fish. Aquat. Sci. 42 (Suppl. 1): 111-126.

3 Survey Results

3.1 Benthic Video Survey

The transect lines for the survey as carried out are shown in Figure 4. There were 18 transects in total, with a total length of 14.6 km. The field time taken for this survey was approximately 2.64 days (approximately 70 minutes per transect or 5 s per m). Depth coverage was from -1.4 m (lower intertidal zone) to 19.0 m. It was not possible to complete the transects at the head of Salmon Bight due to the shallow water depths.

As a result of tidal stirring of the bottom sediments, the turbidity of the water was occasionally quite high; however, the video system was able to capture video images of sufficient quality to quantify the herring spawn throughout the survey.

The wavelengths of light produced by the high intensity LEDs in the towed video system were strongly reflected by the herring eggs, making the eggs appear white in contrast against the darker background of the seaweeds to which they were attached. This effect was confirmed by observations of herring spawn obtained from grab samples which were then examined immersed in a bucket of seawater. The specific color of the herring spawn depended on the number of egg layers. A single layer of eggs appeared translucent white. Two layers of eggs appeared as a more opaque white. As the layers increased beyond two, the spawn took on a creamy white to pale yellowish coloration.

Four DVDs of raw video data were generated from the survey. Processing and annotation of the video data produced two DVDs containing the clipped and converted videos and viewers to visualize the data. The first DVD contained all the shore perpendicular transects, which corresponded to the dive survey transects. The second DVD contained the shore parallel transects.

3.2 Bathymetric Survey

The results of the bathymetric survey are shown in Figure 5 (depth) and Figure 6 (hardness).

Some observations regarding the bathymetry of the Big Bay site are:

1. The depth of the region surveyed ranges from -1.4 m to 19.0 m. Overall, the survey area consists of a relatively flat, shallow bay with a rocky shoreline and rocky outcrops.
2. Bottom hardness values for the site ranged from 1.5 to 8.0. The maximum range for bottom hardness is 0 to 8.0. As expected, hardness values were highest in areas around the rocky outcrops and the rocky points. Hardness values decreased as the sediment layer increased towards the center of the bay.

3.3 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 7).

3.4 Vegetation

Distributions of algae on which herring spawn occurred are shown in the following figures: (1) Figure 8 – flat kelps; (2) Figure 9 – seagrasses;(3) Figure 10 - stringy algae; (4) Figure 11 - leafy algae, and (5) Figure 12 - rockweed..

Table 1 lists the various types of vegetation identified at the site on which herring spawn occurred, and their abundances in terms of number of observations with spawn present.

Table 1. Abundances of vegetation types with spawn present.

Vegetation identification	Number of Observations
Flat kelps	12169
Seagrasses	9236
Stringy algae	3152
Leafy algae	290
Rockweed	30

Some observations regarding vegetation at the Big Bay site are:

1. The vegetation type which had the greatest occurrences of herring spawn was flat kelps. Seagrasses had the second greatest occurrences of herring spawn.
2. Flat kelps and stringy algae were largely found in association with the rocky outcrops and points, in regions with mostly cobble substrate and high bottom hardness values (see Figure 8 and Figure 10).
3. Seagrasses were found in areas of sandy substrate with low bottom hardness values.
4. Leafy algae had a bimodal distribution. Leafy green algae tended to be associated with sandy substrates whereas leafy red algae tended to be associated with cobble substrates.
5. Rockweed was the least abundant seaweed type in the survey area. It was only observed in the area between Shattock Point and One Foot Rocks. The low number of observations of rockweed during the video survey was largely due to the fact that rockweed is a mid-intertidal species, and the survey only reached the lower intertidal zone. Observations from deck during the survey indicated that rockweed was very abundant in areas not reached by the survey, and furthermore, that there were significant amounts of herring spawn on the rockweed based on the large number of birds feeding in the mid-intertidal zone.

3.5 Bottom Sampling

Eleven bottom samples were collected along the length of the shore parallel transect (transect 18). Sampling was attempted using both a Petite Ponar grab and a five-prong grapple. The grapple was very successful at collecting flat kelps, leafy algae, and stringy algae, but was unable to sample seagrasses. Attempts were made to sample the sandy substrate where the seagrass was located using the Ponar grab, but these were also largely unsuccessful due to the sparse nature of the eelgrass beds (the Ponar grab would only retrieve a few eelgrass blades at a time, which was an insufficient sample for analysis).

The eleven samples were photographed, the layers of eggs determined, and then the samples were returned to the water. The sample locations are shown in Figure 3. Clicking on these locations in the ArcMap project using the "Hyperlink" tool will pop up a link to a page containing the photographs.

The grab samples appeared to be fairly representative of the survey site as seen during the video survey, except for the problems with collection of seagrass samples. Eight of the eleven samples contained flat kelps (also the most abundant vegetation in the video). Samples containing stringy algae, leafy algae, and rockweed were also obtained.

Egg deposition on the algae was very patchy, with regions of up to four egg layers coexisting with egg-free patches on the same blade. Average egg layers for a blade ranged from 0.01 (trace) to 1.5 in the eleven samples.

The patterns of egg deposition and colorations associated with egg layer density were studied closely, both in the air and immersed in a bucket of seawater, in order to develop a guide for analyzing the video data.

3.6 Spawn Intensity

3.6.1 Video Survey

It was not possible to count the number of egg layers in the herring spawn directly using the images from the video survey, as this would have involved visualizing each blade in several different orientations. However, a reasonable estimate of egg layers was possible using the egg distribution patterns and egg layer colorations (e.g., translucent white through to pale yellow). It is believed that this coloration effect was the result of reflection/refraction of the blue-white LED light from the video system off the egg membranes, rather than absorption of the light by the eggs themselves. The amount of reflection appeared to be roughly proportional to the amount of reflecting surfaces (e.g., density of eggs). Thus, the reflection was more intense as the egg layers increased in thickness. Very thick egg layers appeared yellowish, possibly resulting from a small amount of the blue light being absorbed by the eggs, making the reflected light slightly yellowish rather than blue-white. The actual color of the eggs may vary with age, diatom overgrowth, and other factors, but this was not observed during the Big Bay survey. Other organisms may also reflect light (e.g., encrusting bryozoans); however, they generally have a different surface texture than herring spawn. Also, herring spawn can be resolved into individual eggs in some video frames; whereas small encrusting organisms, such as bryozoans, are never resolved into individual colony members.

Very dense vegetation also presented something of a problem, as it was impossible to estimate much beyond 200% cover without being able to lift up individual blades. As a result, the maximum percentage cover used in the calculations for herring spawn intensity was 200%.

A statistical map of the distribution of herring spawn intensity based on the video observations is shown in Figure 13. The red coloration indicates areas of high spawn intensity. The contour lines indicate regions within which a certain percentage of the total spawn in the survey area was expected to occur. This figure clearly illustrates that the spawn intensity is not uniform throughout the survey area. Spawn intensity is much higher in areas with cobble substrates, high bottom hardness values, and a predominantly flat kelp vegetation type. These areas are specifically Shattock Point, Simpson Point, Swallow Island, Curlew Rock, and an area SE of Curlew Rock.

Figure 14 shows contour lines of spawn intensity (1000 eggs/m^2) for the survey region. This map does not apply any statistical analyses to the data. It simply plots contours based on the video observations. Maximum spawn intensity for the site was approximately 3800. Minimum spawn intensity was 0. As with the statistical spawn intensity map, this map clearly shows that spawn intensity at the survey site was not uniform, and that the spawn “hot spots” were Shattock Point, Simpson Point, Swallow Island, Curlew Rock, and an area SE of Curlew Rock.

Based on the data from the contour map, average spawn intensity for the site was 84098 eggs/m^2. The total area of the survey site was 3011989 m^2. Therefore, the total spawn at the site was 2.533×10^{11} eggs. The estimated tonnes of spawning fish at the survey site were 2533.

3.6.2 Dive Survey

Data from the herring spawn dive survey in Big Bay was provided by DFO. The transect lines for the survey as carried out are shown in Figure 15. There were 14 transects in total, with a total length of 6.3 km.

A statistical map of the distribution of herring spawn intensity based on the dive observations is shown in Figure 16. The red coloration indicates areas of high spawn intensity. As with the map generated from the video data, this figure clearly illustrates that the spawn intensity is not uniform throughout the survey area. Spawn intensity is highest at Simpson Point, Swallow Island, and Curlew Rock.

Figure 17 shows contour lines of spawn intensity (1000 eggs/m^2) for the survey region based on the dive observations. There was insufficient data from the dive survey to allow the contouring program to generate contour lines in the region between Shattock Point and the point to the north of Swallow Island. Maximum spawn intensity for the site was approximately 270. Minimum spawn intensity was 0. As with the statistical spawn intensity map, this map shows that the spawn "hot spots" were in the region between Curlew Rock and Simpson Point.

Based on the data from the contour map, average spawn intensity for the site was 33635 eggs/m^2. The total area covered by the contour map was 2187382 m^2. Therefore, the total spawn at the site was 7.357×10^{10} eggs. The estimated tonnes of spawning fish at the survey site were 736.

4 Discussion and Recommendations

The following discussion looks at the values and limitations of using video systems for quantifying herring spawn. No assumptions are made regarding the type of video system which may be used for future work, and thus the discussion is broad-based and covers a number of different commercially available systems. Limitations to the use of video surveys for quantification of herring spawn, where they exist, will depend largely on the particular type of video system being used, and ultimately, the selection of the video system should reflect the type of environment in which the survey is to be carried out. A number of recommendations have been made to help guide HCRS in the future use of video systems.

4.1 Comparison of Dive and Video Herring Spawn Surveys

Originally, for the purpose of comparing the dive and video survey results, the intent of the video survey had been to replicate the transects as carried out by the dive survey. To this end, DFO provided Ocean Ecology with a map showing the dive transect locations for the Big Bay site (see Figure 1). However, due to inclement weather, which forced the two surveys to be carried out 5 days apart, and limited communication of data between the two groups, Ocean Ecology did not have information regarding the extent of the dive survey coverage (see Figure 15) until long after the window of opportunity for completing the field work was over. Furthermore, the very shallow nature of the Big Bay site limited how close inshore the video survey could be safely performed. As a result of all of these factors, the overlap between the two surveys was quite poor. Figure 18 shows the areas of coverage for both surveys, and the regions where the two surveys overlapped. Except for three relatively small areas, the dive survey was carried out almost entirely inshore of the video survey. The comparisons that this report makes between the two surveys are based largely on these small areas of overlap.

4.1.1 Qualitative Comparison

In terms of spatial coverage and areas indicated as spawn “hot spots”, both surveys appeared to be largely in agreement (see Figure 13 and Figure 16). Specifically, both surveys found high levels of spawn at Simpson Point, Curlew Rock, and Swallow Island. However, as expected, the dive survey reported spawn from locations closer inshore than the video survey, due to the shallow nature of the inshore regions which prevented the video system from being safely deployed in these regions. Somewhat unexpectedly, the video survey reported significant amounts of spawn in slightly deeper water areas and in the region around Shattock Point. These areas were indicated as part of the regular dive transects for the site, but for some reason were not covered during the 2009 dive survey. It is likely that the dive survey would have reported spawn from these regions, had they carried out their transects as shown in Figure 1.

4.1.2 Quantitative Comparison

Based on the data from the contour map generated by the video survey (see Figure 14), the average spawn intensity for the region of overlap between the two surveys was 77570 eggs/m^2. The total area covered by the overlap region was 435681 m^2. Therefore, the total spawn in the overlap region was 3.380 x 10^{10} eggs. The estimated tonnes of spawning fish at the survey site were 338.

Based on the data from the contour map generated by the dive survey (see Figure 17), the average spawn intensity for the region of overlap between the two surveys was 66681 eggs/m^2. The total area covered by the overlap region was 435681 m^2. Therefore, the total spawn in the overlap region was 2.905 x 10^{10} eggs. The estimated tonnes of spawning fish at the survey site were 291.

Given the limited amount of overlap between the two surveys, the quantitative values that were generated from each survey appear to be quite similar. No statistical confidence levels can be given for these values, as this was a single, unreplicated, experimental comparison between the two survey methods.

The estimated tonnes of spawning fish as calculated by the video survey was slightly higher than the value calculated by the dive survey. There are several possible explanations for this:

1) The equations used to calculate spawning intensity were empirically derived from dive data. These equations were not calibrated for the towed video system, as the amount of work required for calibration was outside the scope of this project. It is quite likely that a new empirical equation will have to be developed for towed video systems. This would involve taking video images from a marked region of the seafloor (e.g., an area defined by a quadrat), and then carefully collecting and analyzing all of the spawn found within that quadrat. For statistical purposes, this type of calibration analysis would have to be carried out a number of times in a variety of habitats. From this information, a new equation for the video system could be generated which relates the amount of spawn visualized to the amount of spawn actually present.
2) The level of coverage in the overlap region was significantly different between the two surveys. For the dive survey, there were 31 data points in the overlap region, whereas for the video survey, there were 11,237 data points in the overlap region. As a result, it is quite possible that the video survey was finding more spawn in regions which were missed by the dive survey.
3) Since the video survey is a rapid, non-contact survey, there is a greater chance of incorrect identification of spawn, and a lower level of confidence in estimation of spawn layers, than in the dive survey, where divers can closely examine both sides of each piece of vegetation within the quadrat region.
4) As a result of inclement weather conditions, there was a delay of 5 days between the dive survey and the video survey. There is a slight possibility that more spawning took place during these 5 days, and this is being reflected in the higher tonnage value calculated by the video survey.

Recommendation: that HCRS look at the possibility of doing further calibration studies with towed video systems should it be decided that such systems will be of value to HCRS in evaluation of herring spawn.

4.2 Towed Video System

4.2.1 Towed Body Design

The body designs of towed video systems can be roughly grouped into three main categories, each of which has specific pros and cons:

1. Depressor wing body. This type of towed body is modeled after the stabilizers used on ships to reduce roll in rough weather. They have a delta-wing shape, and are designed to tow somewhat behind the ship while simultaneously pulling downwards.

   Pros:
   - Commercially available, off-the-shelf units.
   - Relatively lightweight portable units which can be deployed from small skiffs and used in shallow water environments.
   - Relatively stable flight-path when towed at sufficient speed.

Cons:

- Since they tow at some distance behind the ship, layback calculations must be used to correct the position of the unit relative to the ship's GPS data.
- Are only suitable in shallow water (20 m - 40 m).
- Require forward momentum for stability, and become unstable at low tow speeds. Therefore, they are not suitable in environments with extreme vertical topography (e.g., fjord walls).
- Are usually not heavily armored, and can be easily damaged in rocky environments.

2. Sled style body. This type of towed body consists of an armored camera frame mounted on two "skis". These units are designed to be towed in contact with the seabed.

   Pros:
   - Commercially available, off-the-shelf units.
   - Units hold the camera in a fixed, known position relative to the bottom.
   - Can be used in very deep water environments.
   - Are heavily armored and can tolerate significant abuse.

   Cons:
   - Since they tow at some distance behind the ship, layback calculations must be used to correct the position of the unit relative to the ship's GPS data.
   - Cannot be used to collect mid-water data.
   - Are very heavy and must use larger ships for deployment. Therefore, they are not suitable for very shallow water environments.
   - Cause some damage to the benthic environment as they are towed over the seabed.

3. Custom design body. This category includes a large number of unique units which have been designed for specific purposes.

   Pros:
   - Units can be designed to meet very specific survey requirements.
   - Units can frequently be built at a cheaper cost than off-the-shelf-units.

   Cons:
   - Are not commercially available. Require in-house expertise to design and build.
   - Generally require a lengthy period of calibration and modification ("tweaking") to reach their full potential.

This experimental herring survey in Big Bay was carried out using a custom design towed video system built by Ocean Ecology. The system was developed for work in steep fjord environments at relatively low tow speeds, and with very little layback. It can operate in depths up to 150 m. This system is not commercially available.

Recommendation: that HCRS determine the types of environments (e.g., deep or shallow water, etc.) in which towed video surveys will be most useful, and use this information to assist in decision making regarding the type of towed unit which should be used.

4.2.2 Camera System

There are two types of video cameras available for use in towed video systems: digital and analog.

Digital video cameras produce high quality digital (e.g., pixilated) images. These images can be recorded directly to digital media (e.g., hard drives, DVDs, etc.) without conversion. They generally have very high resolution, and each individual video frame is clear and sharp.

However, these cameras are still quite large and bulky in size, requiring much larger housing systems. They generally do not come in weather or waterproof models. Video compression is poor for digital video, and large amounts of storage are required for the data.

Analog video cameras produce analog or scan-line images. These images need to be converted to a digital format before being recorded to digital media. Resolution is lower than for digital cameras; however video compression is very good, and large amounts of data require relatively little storage space. Furthermore, analog cameras come in very small models, which are ideal for low-volume housings, and are considerably cheaper, and thus more replaceable, than digital cameras. Many high quality analog cameras require very low light levels to operate, and come with built-in software to improve image contrast.

Recommendation: that analog cameras remain the best choice for underwater towed video systems until further improvements in technology create cheaper, smaller, more robust digital cameras with better video compression.

4.3 Survey Design

The purpose of this survey was to carry out a full scale towed benthic video analysis of a site with herring spawn in order to access the accuracy of the system in quantifying spawn and the viability of using such a system for future spawn surveys. Thus, the survey was designed to completely cover the entire length of all the dive survey transects, as well as provide an additional shore parallel transect. The study also included some low-level bathymetry of the site, and eleven grab samples to assist in calibrating the video analysis. Ultimately, 18 video transects were carried out, providing a total coverage distance of 14.6 km. The survey took three days to complete.

The costs of the various components of the survey are given in Table 2 below.

Table 2. Towed video survey costs.

Survey component	Cost
Video survey	$4,672.80
Video processing	$3,817.80
Bathymetry processing	$328.75
Grab sampling	$685.00

This survey provided a large amount of good quality scientific data; however, it may not be necessary to carry out such extensive surveys for the purpose of stock assessment.

Recommendation: that full scale towed benthic video analysis be used only for scientific herring research. A modified, down-scaled survey is recommended for stock assessments. Rather than recording video for the entire length of a transect, it is suggested that short video segments, or even drop videos, be taken at intervals along a transect. This design would be more comparable to the herring dive survey, and would be faster and cheaper to perform.

4.4 Spawn Quantification

4.4.1 Herring Spawn Percent Cover

In general, the towed video system is very good at assessing the percent cover of vegetation with herring spawn, particularly when there is less than 100% cover. However, as the number of multiple layers of vegetation increase, and the total percent cover exceeds 100%, the video camera system becomes less accurate than a dive survey. This is largely due to the inability to manipulate the vegetation and count overlapping layers. As a result, the video survey never recorded percent cover greater than 200%, which was the highest amount of cover which could be accurately observed. Since there may have been areas of flat kelp where the percent cover exceeded 200%, the video survey would tend to underestimate spawn intensity to some degree in these areas.

Recommendation: that the "Herring spawn percent cover" categories be modified for the towed video survey to reflect the decreased accuracy of the system at higher percent cover levels. A suitable series of categories would be: 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95%, 100%, 125%, 150%, 175%, 200%.

4.4.2 Herring Spawn Egg Layers

It was not possible to count the number of egg layers in the herring spawn directly using the images from the video survey, as this would have involved visualizing each blade in several different orientations. However, a reasonable estimate of egg layers was possible using the egg distribution patterns and egg layer colorations (e.g., translucent white through to pale yellow). The accuracy of the video camera system decreased as the spawn exceeded more than 2 layers. Again, the video survey would tend to underestimate spawn intensity to some degree in areas where the spawn is very thick.

Recommendation: that the "Herring spawn egg layers" categories be modified for the towed video survey to reflect the decreased accuracy of the system as spawn layers increase. A suitable series of categories would be: 0, 0.01, 0.25, 0.5, 0.75, 1.00, 1.25, 1.50, 1.75, 2.00, 2.50, 3.00, 4.00.

4.5 Video Processing

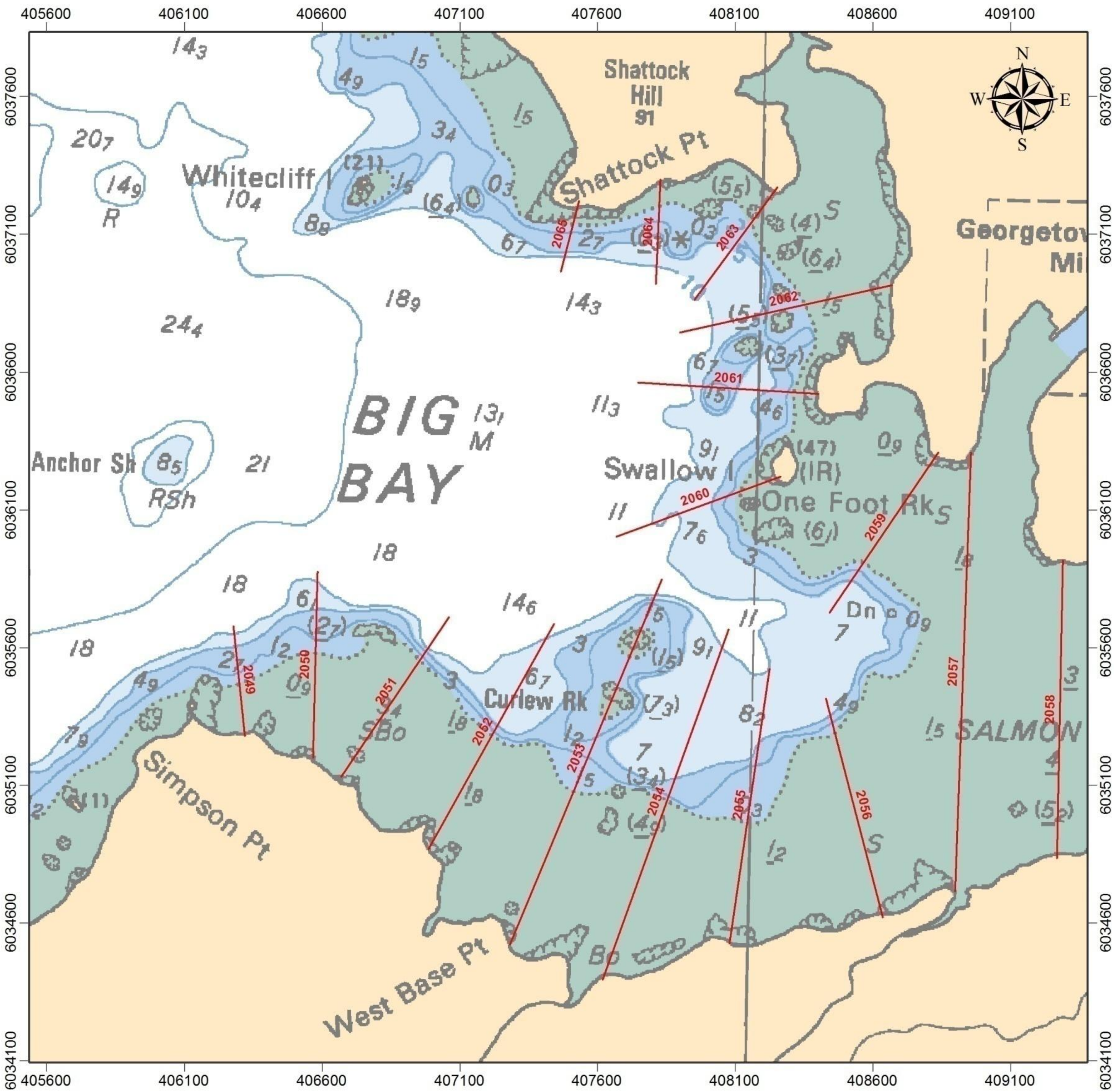
Video processing can be a long and tedious process. Even with a highly optimized processing system, one can expect to spend two hours of video processing for every hour of video footage taken in the field. Inappropriate or inadequate software can further slow this process. Well designed surveys can reduce the amount of video footage collected in the field while still retaining the necessary level of data collection for statistical analyses. Expertise with various software programs and data management can further ease the load.

To fully realize the value of benthic video surveys, the following elements in the video processing are necessary:

- The video data needs to be in a digital form (e.g., not on a VHS tape) which can be randomly accessed (e.g., one can jump directly to any section of the video without rewinding or forwarding).
- The video needs to be analyzed using some type of annotation software that can link analysis coding to positions within the video.
- The data from the video analysis must be convertible into a flat database or spreadsheet (e.g., Access or Excel).
- Ultimately, the data from the video analysis should be georeferenced, and thus available for mapping in GIS systems.

Recommendation: that HCRS fully investigate the different products (e.g., databases, maps, etc.) that can be generated from the processing of video data, and determine which products best fit their needs. This will be important both in dealing with contractors who may be performing video analysis for HCRS, or in deciding to develop an in-house system for HCRS.

Figures



Big Bay Experimental Herring Video Survey

Figure 1. Herring spawn dive survey transects.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

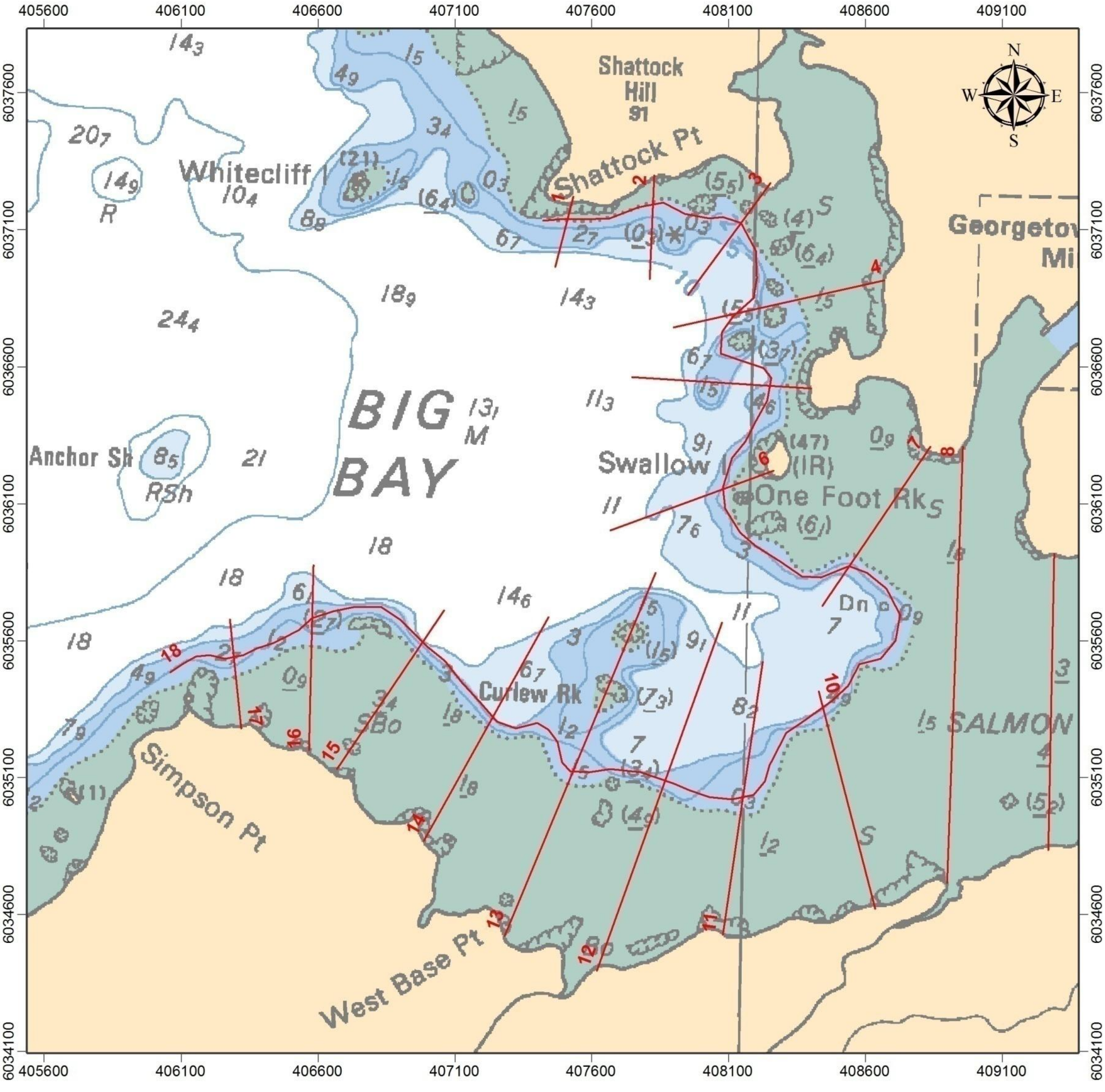
Scale: 1:19,500

Legend

Dive survey transects

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 2. Video survey design.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

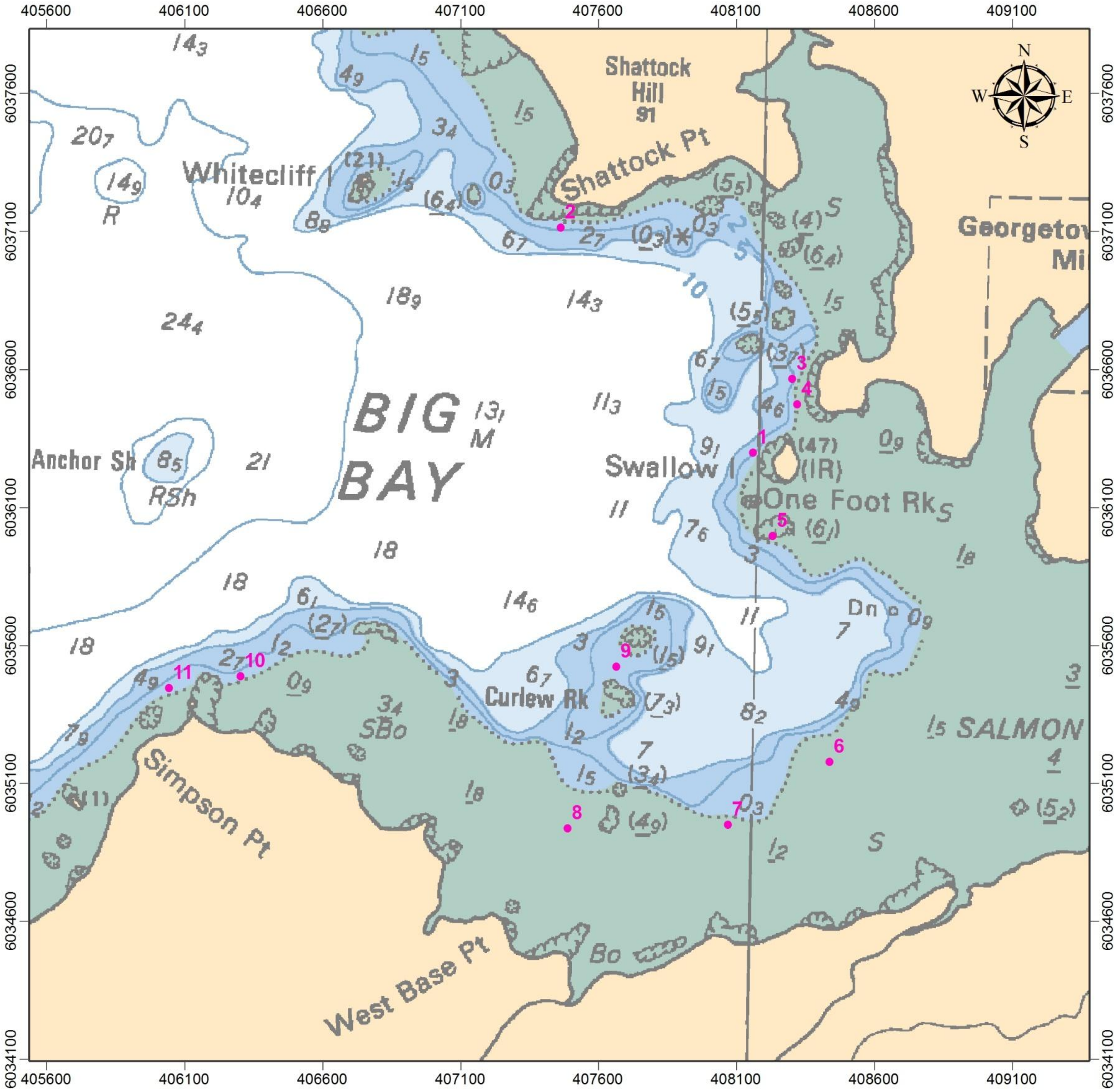
Scale: 1:19,500

Legend

Video survey proposed transects

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 3. Bottom sampling locations.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

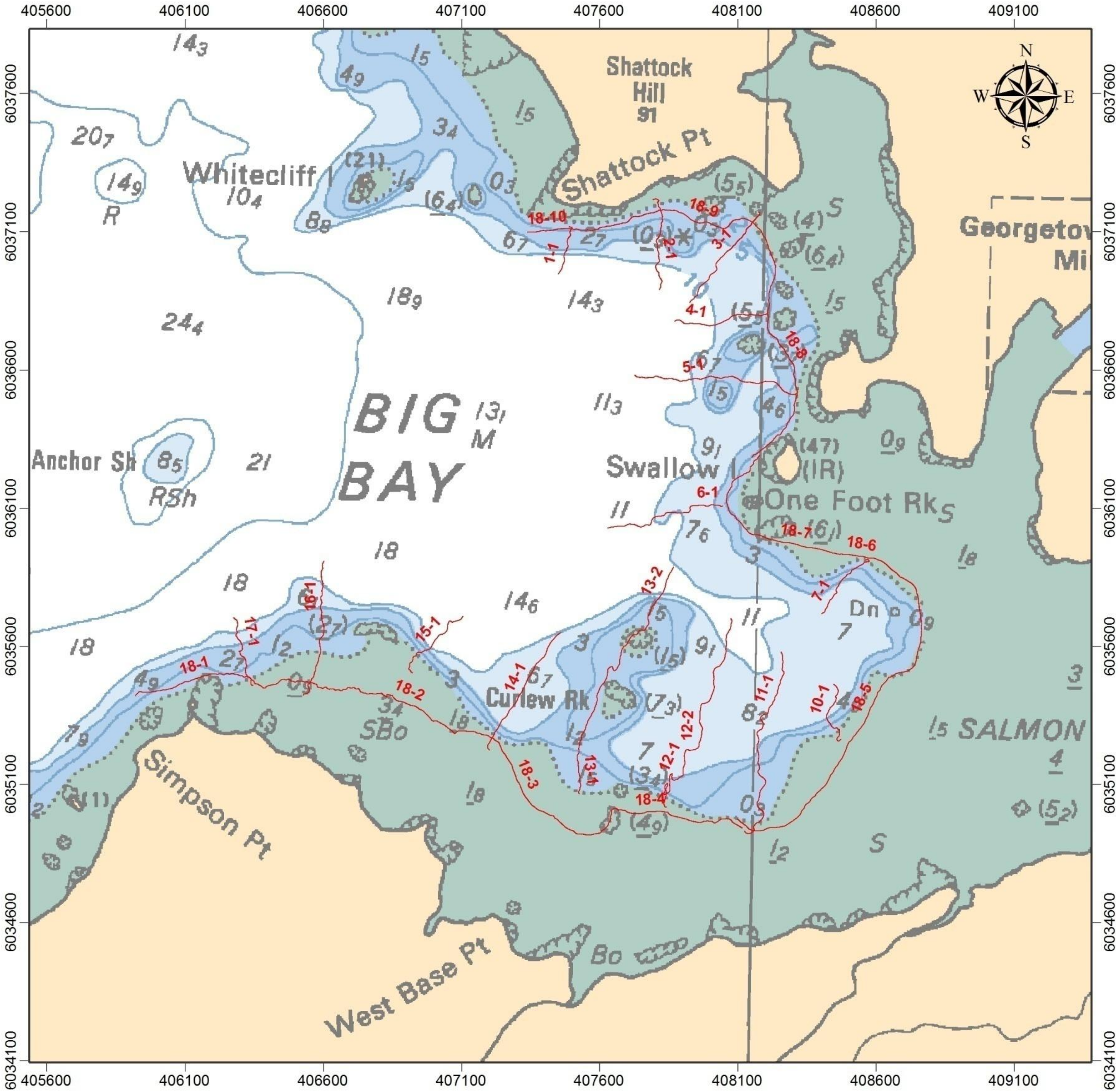
Scale: 1:19,500

Legend

● Bottom samples

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 4. Completed survey showing transects.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

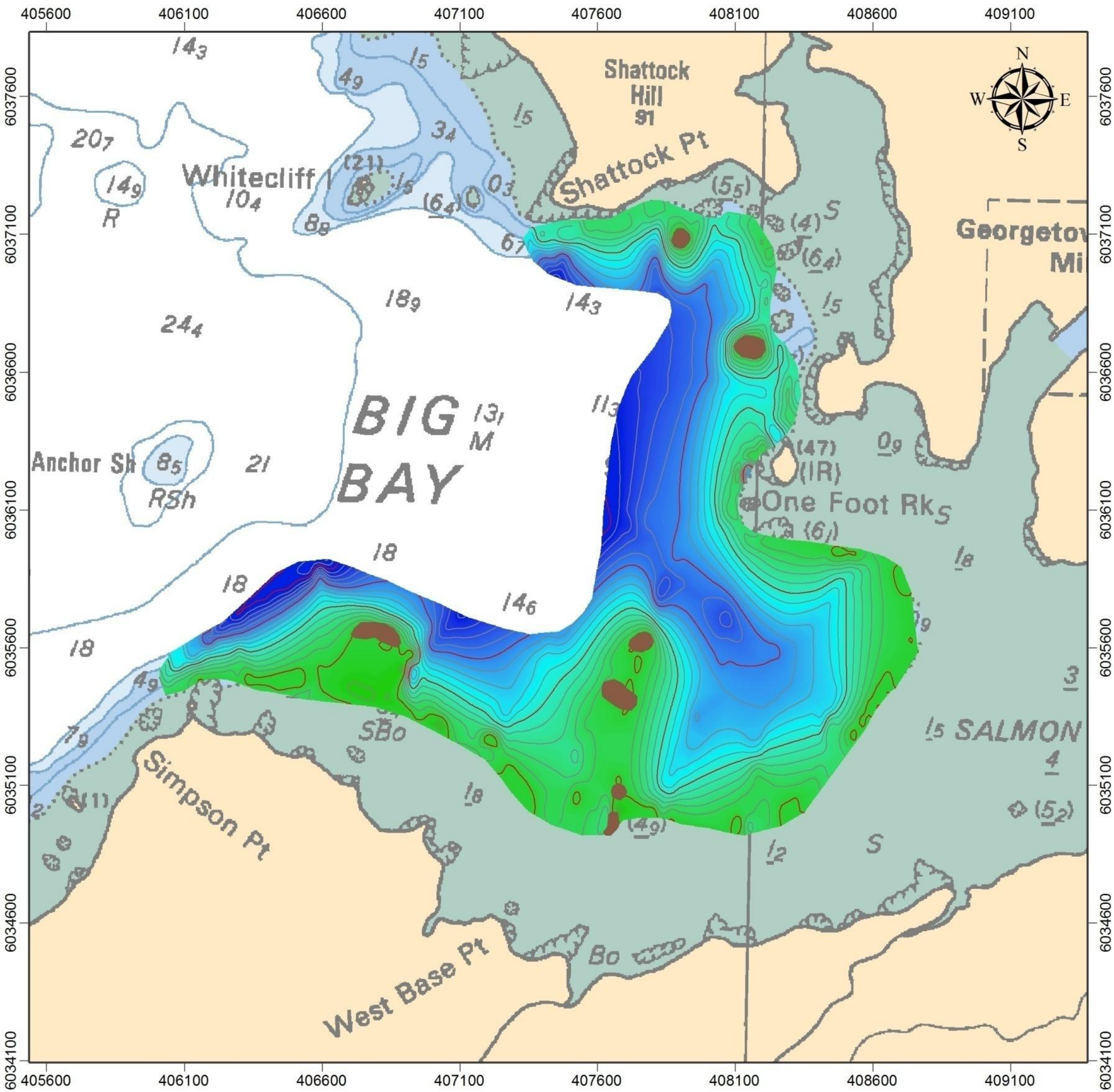
Scale: 1:19,500

Legend

Completed transects

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 5. Depth contours.

Bathymetric system:
JRC 130 single-beam echosounder

Transducer:
50 kHz operating at 1 kW power

Beam angle: 9 degrees

Positioning system:
Electronic charting software using DGPS

Survey resolution:
Approximately 350 m between shore-normal transects.

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

Chart used for navigation:
CHS 396301
(Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Contour interval: 1.0 m

Legend

Depth contours (1.0 m)

Depth contours (5.0 m)

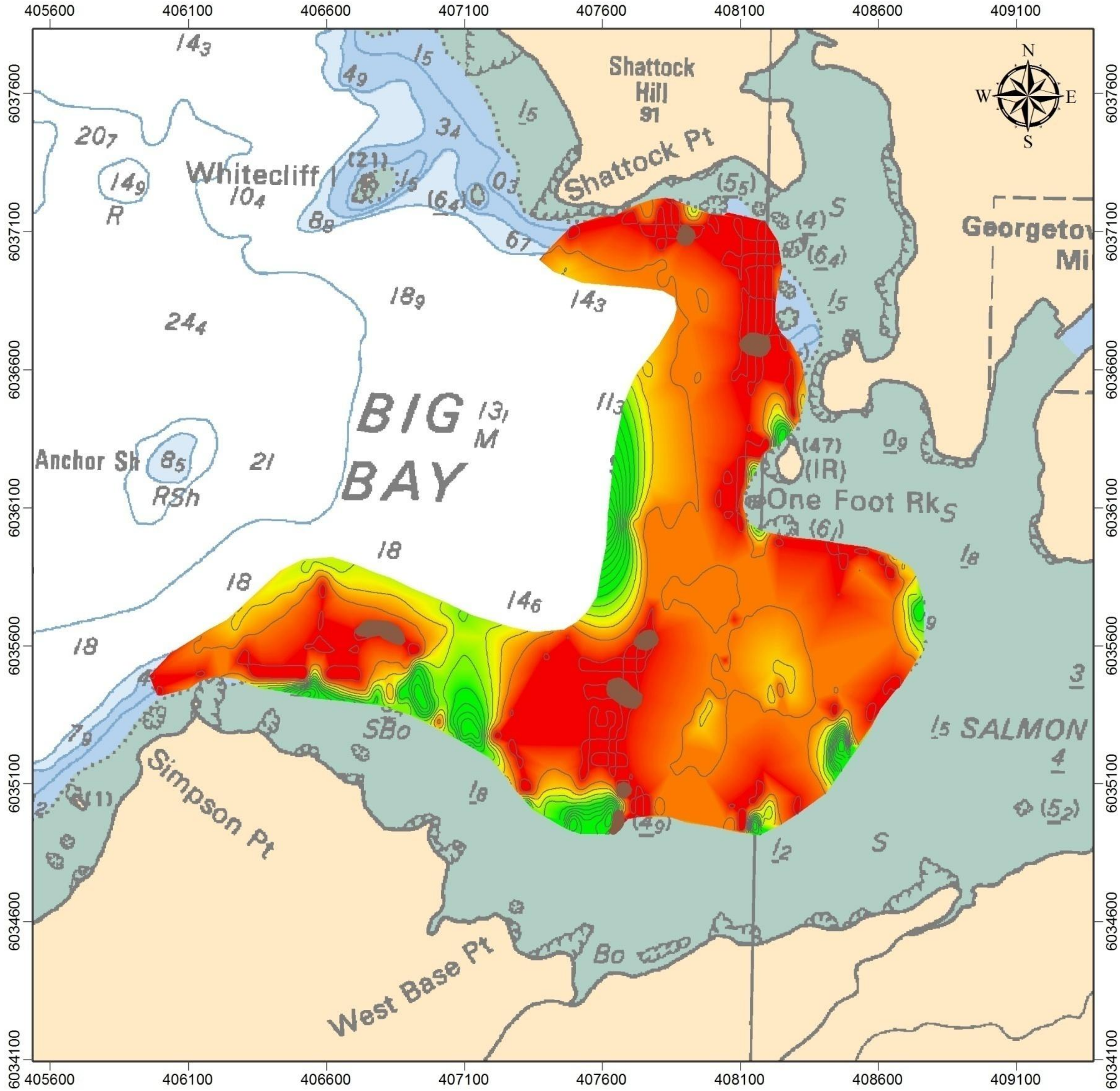
1 m

-17 m

Rocks

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 6. Hardness map.

Bathymetric system:
JRC 130 single-beam echosounder

Transducer:
50 kHz operating at 1 kW power

Beam angle: 9 degrees

Positioning system:
Electronic charting software using DGPS

Survey resolution:
Approximately 350 m between shore-normal transects.

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

Chart used for navigation:
CHS 396301
(Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Contour interval: 1.0

Legend

Hardness contours (1.0)

Hardness

High : 8

Low : 1.5

Rocks

0 125 250 500 Meters

OCEAN ECOLOGY

Big Bay Experimental Herring Video Survey

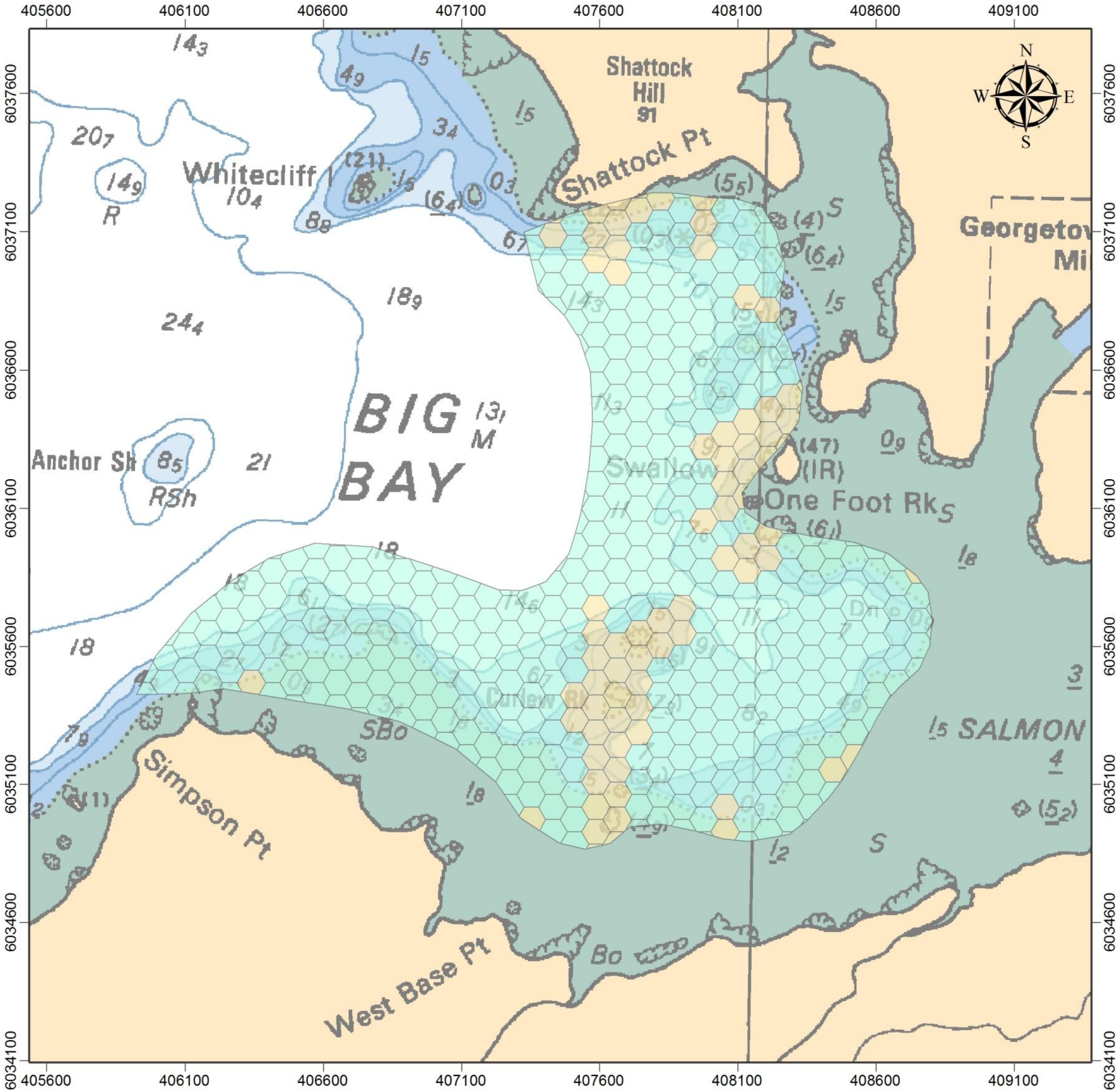


Figure 7. Substrate map.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

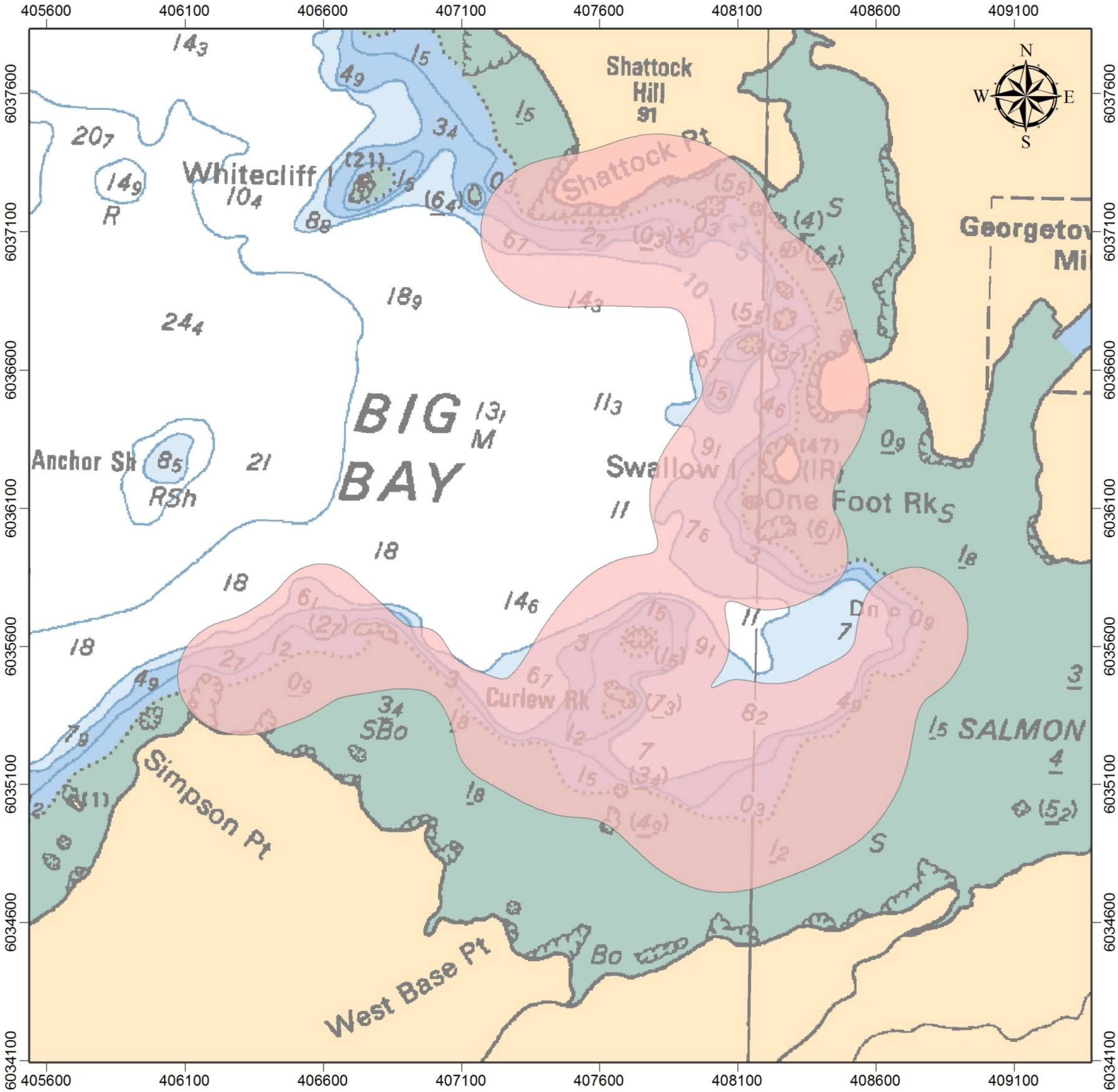
Legend

Substrate

- Cobbles
- Sand

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 8. Range map for flat kelps.

Chart used for navigation:
CHS 396301
(Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Legend

Flat kelps

0 125 250 500 Meters

OCEAN ECOLOGY

Big Bay Experimental Herring Video Survey

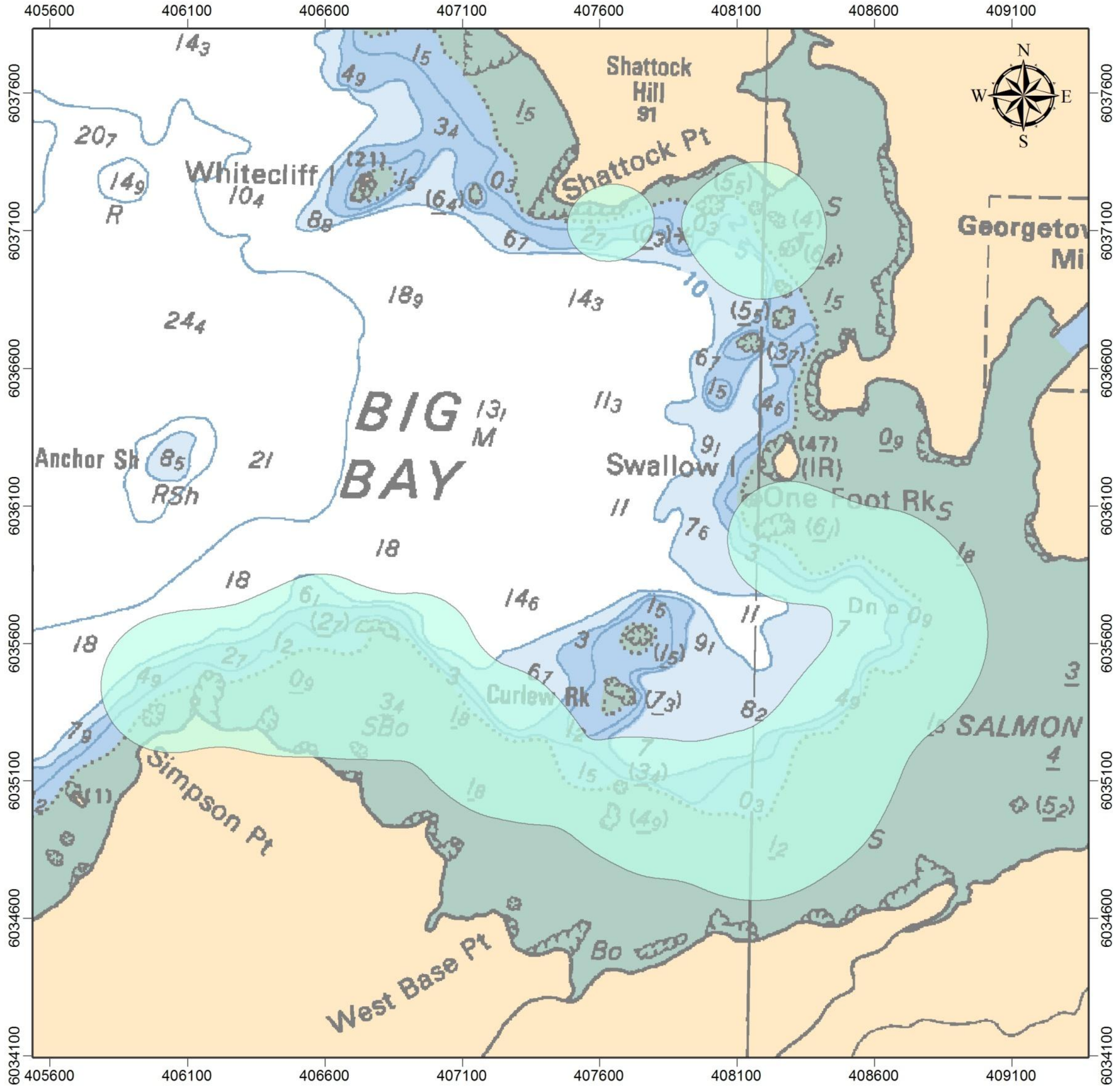


Figure 9. Range map for seagrasses.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

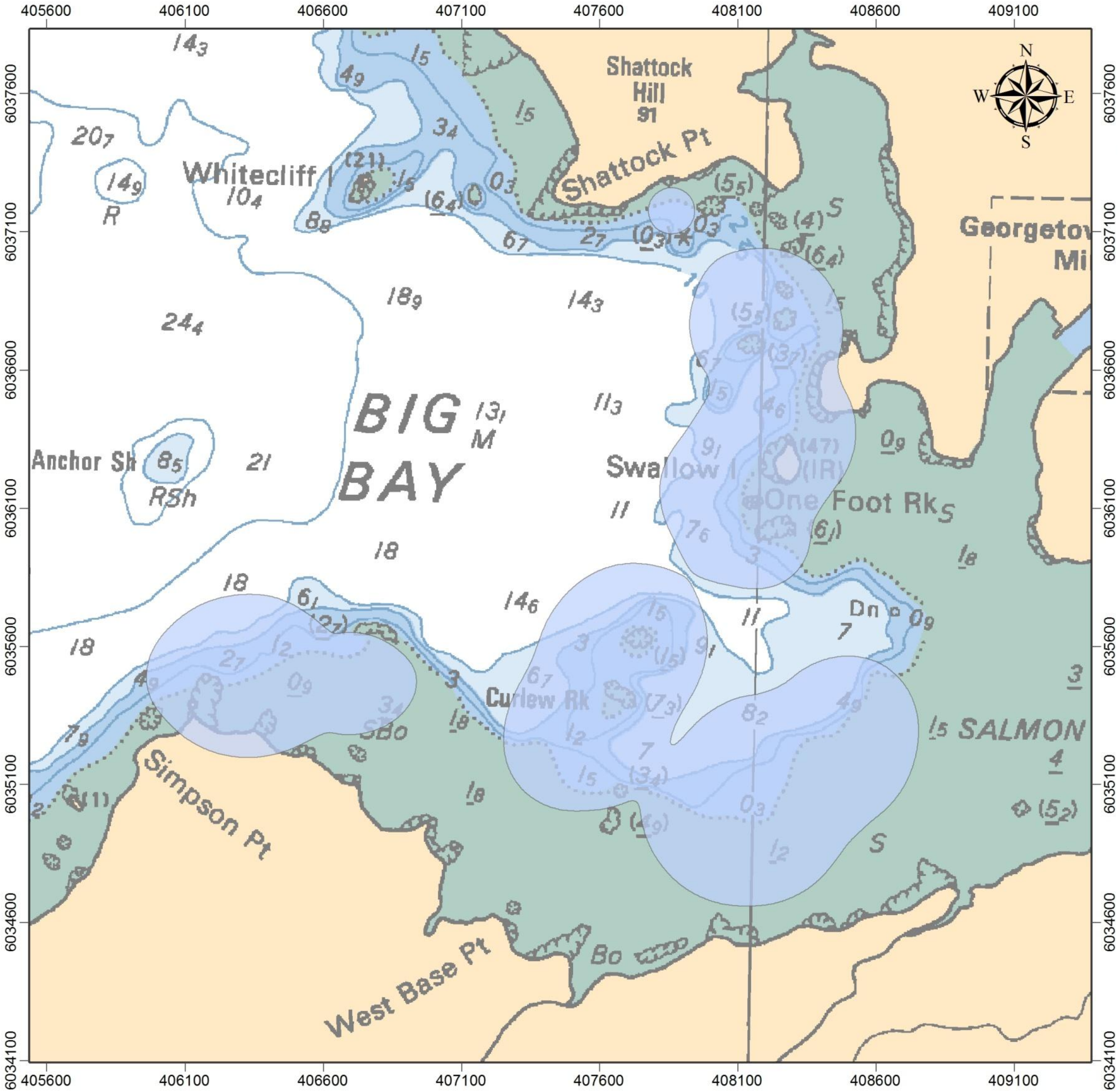
Scale: 1:19,500

Legend

Seagrasses

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 10. Range map for stringy algae.

Chart used for navigation:
CHS 396301
(Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

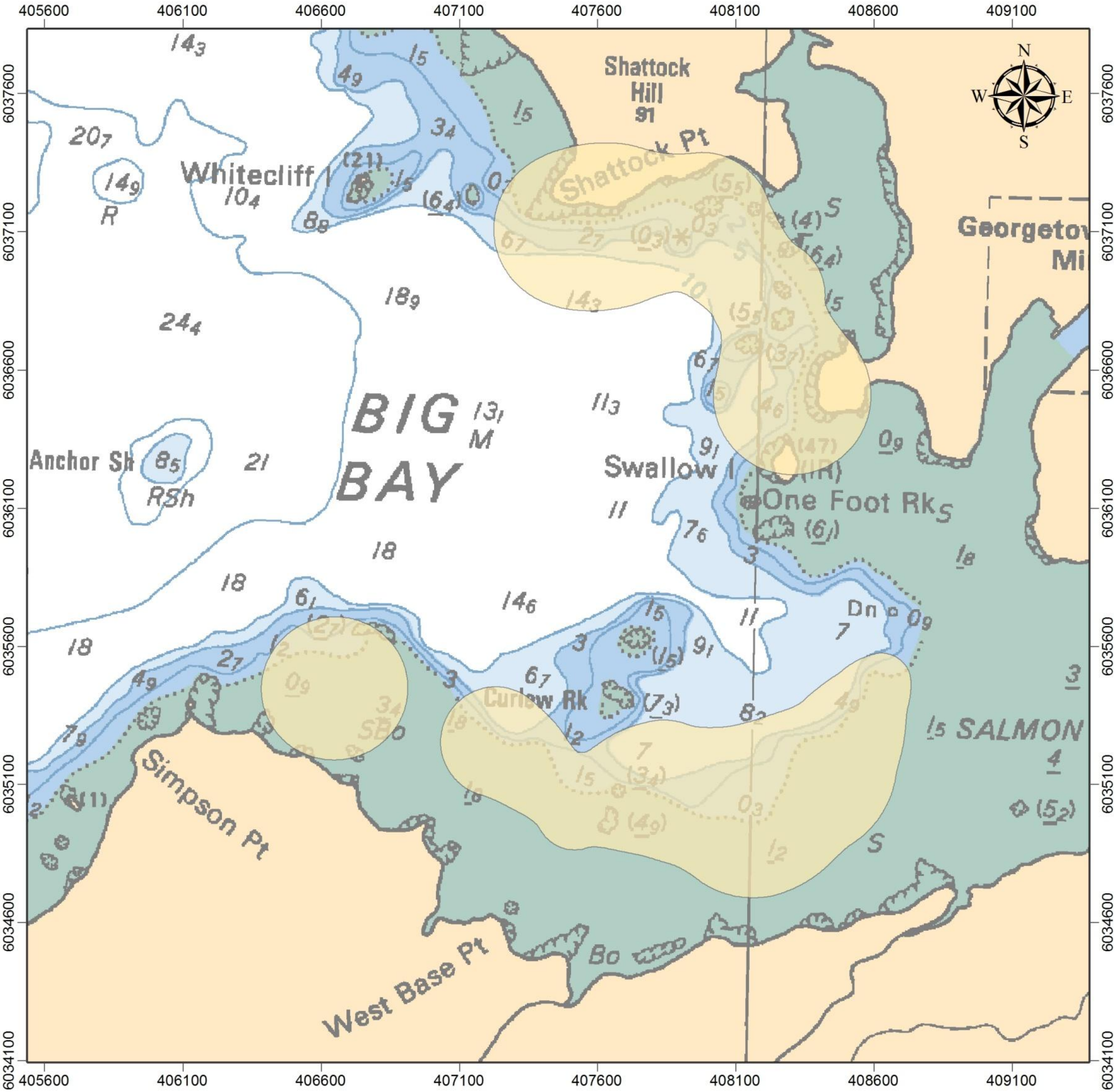
Scale: 1:19,500

Legend

Stringy algae

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 11. Range map for leafy algae.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

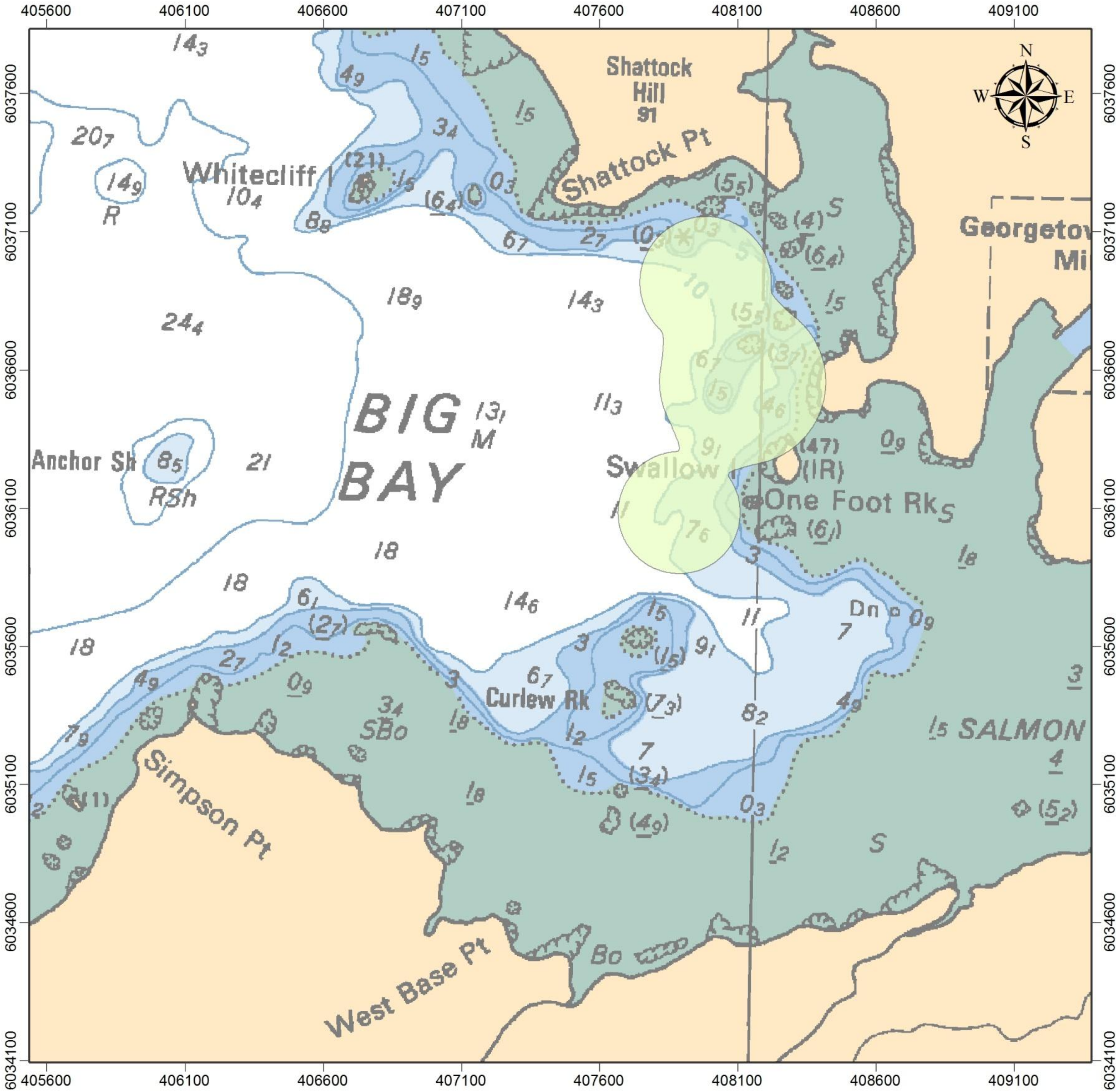
Scale: 1:19,500

Legend

Leafy algae

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 12. Range map for rockweed.

Chart used for navigation:
CHS 396301
(Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

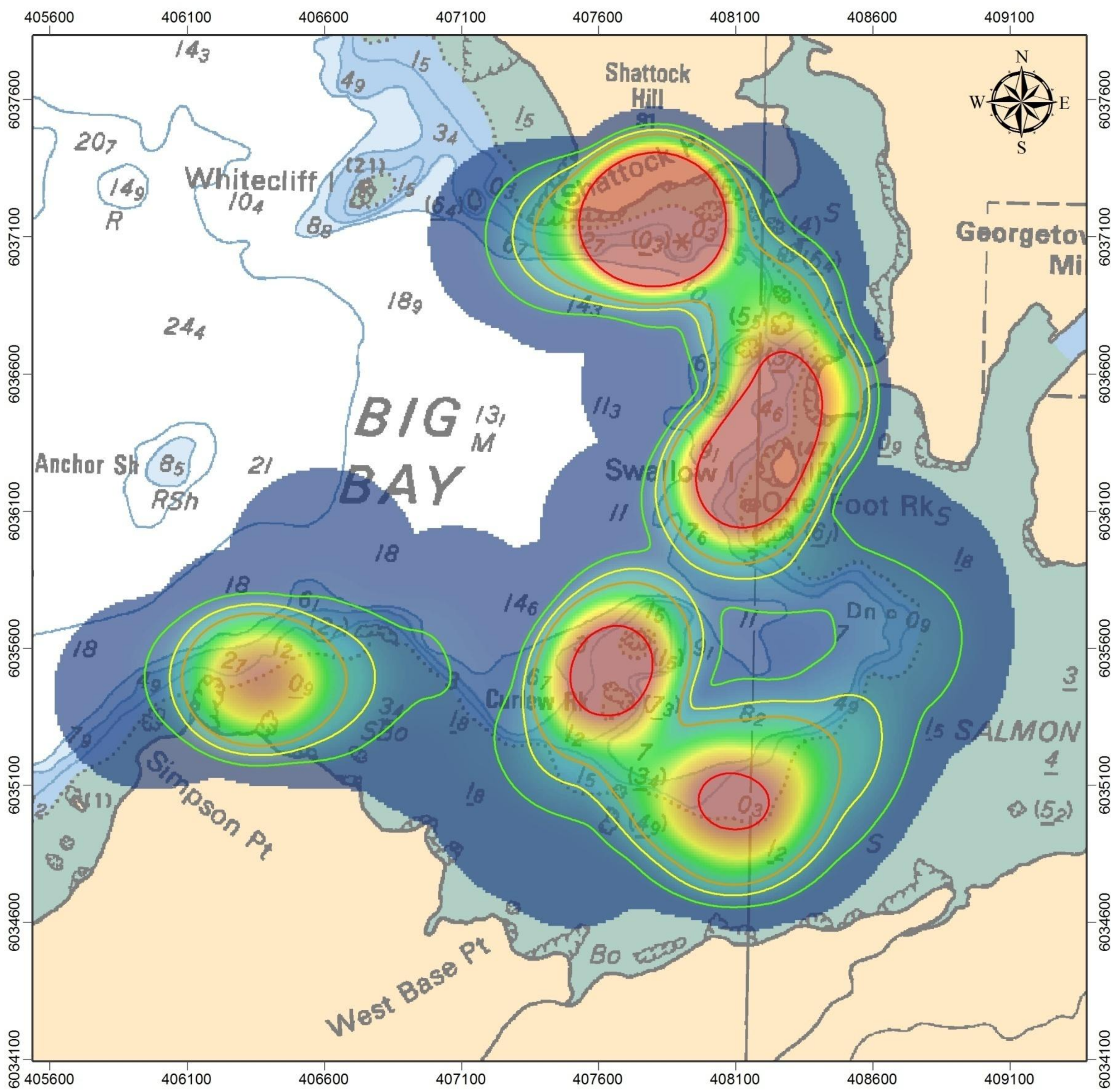
Scale: 1:19,500

Legend

Rockweed

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 13. Statistical map of distribution of herring spawn intensity.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Legend

Spawn density distribution

446

0

99% total spawn

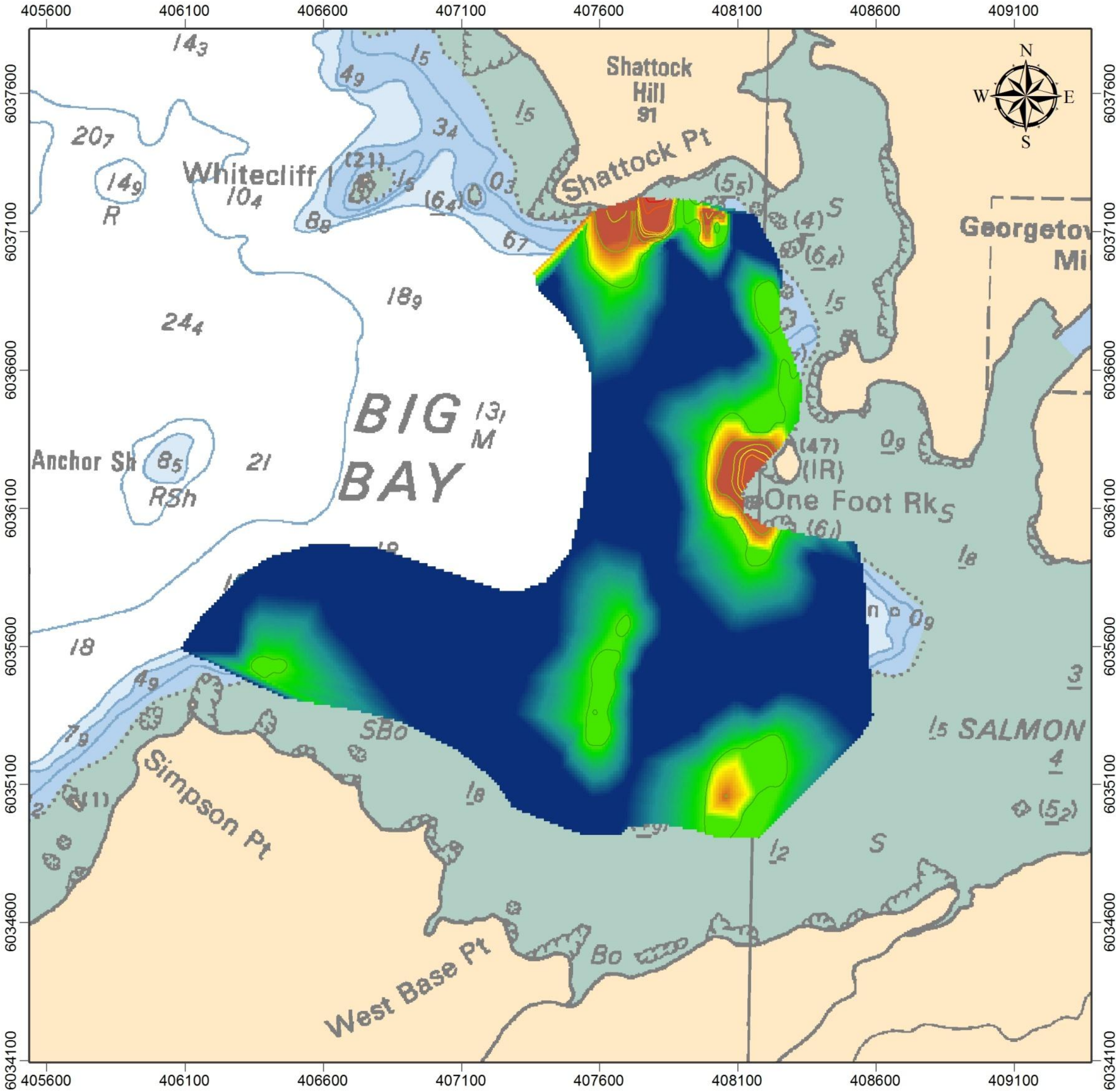
95% total spawn

90% total spawn

50% total spawn

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 14. Contour map of distribution of herring spawn intensity.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Legend

Spawn map

1000 eggs/m2

3800

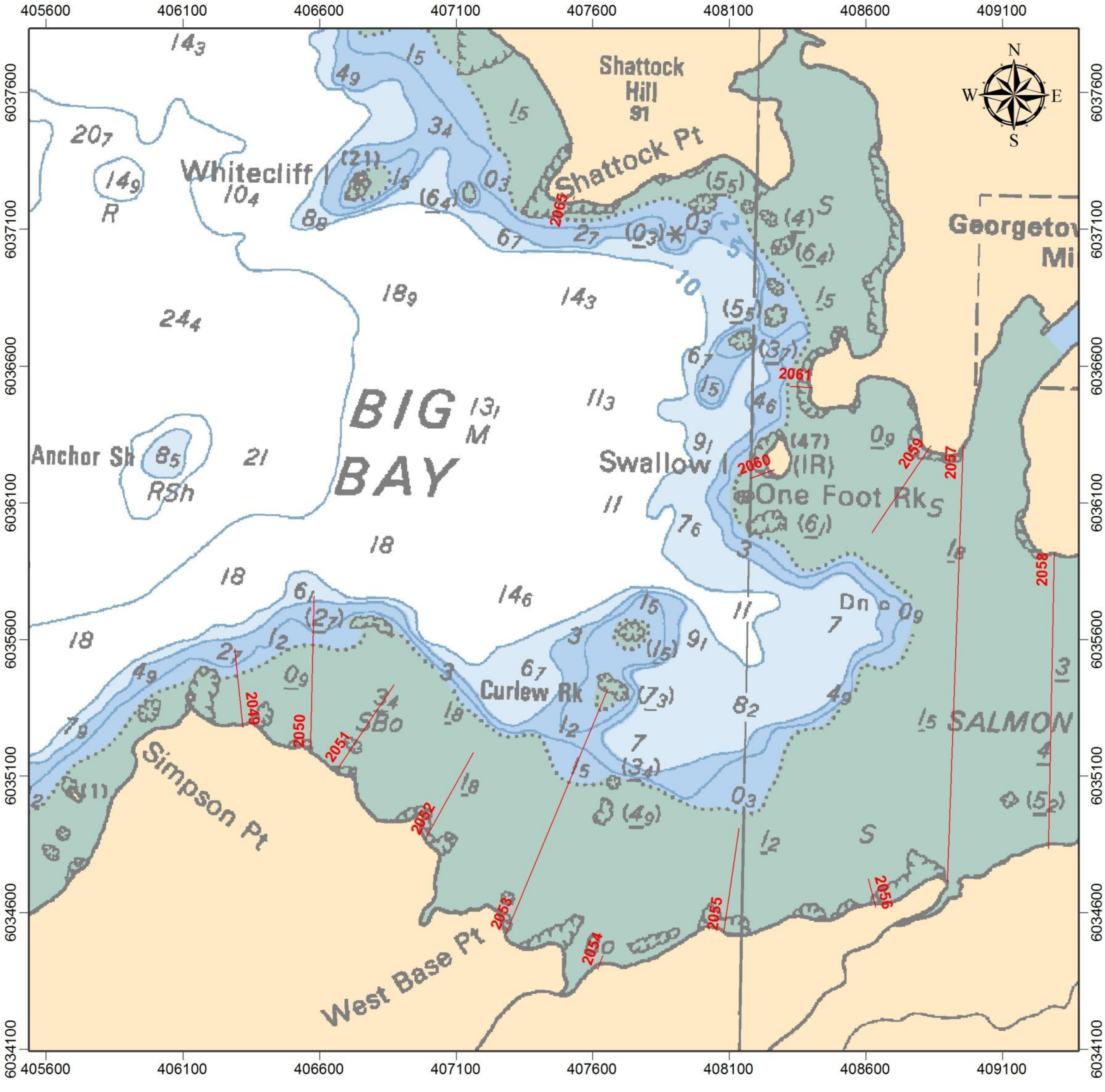
0

Spawn contours

200
400
600
800
1000
2000
3000

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 15. Completed dive survey showing transects.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

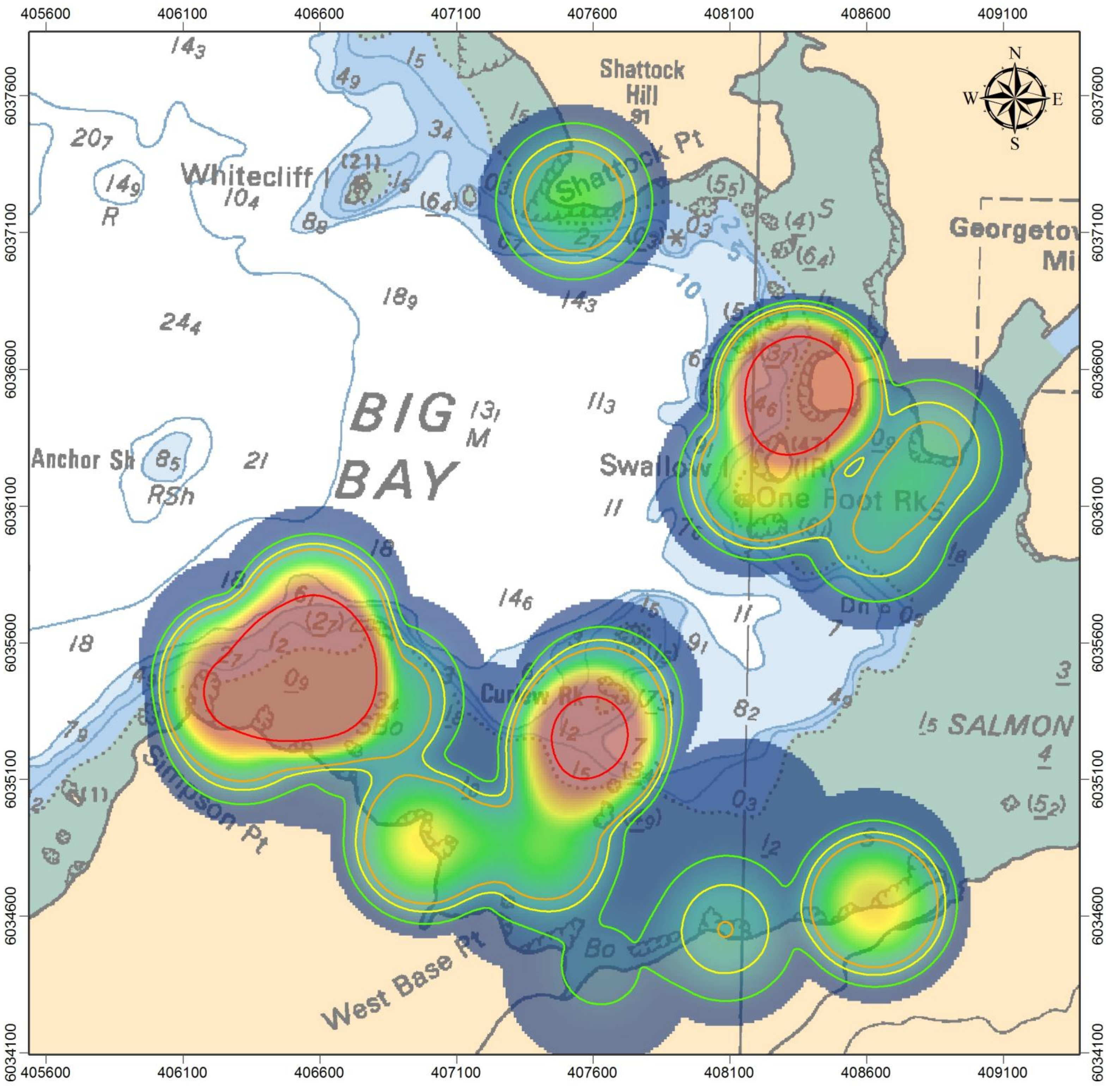
Scale: 1:19,500

Legend

Completed dive transects

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 16. Statistical map of distribution of herring spawn intensity from dive data.

Chart used for navigation:
CHS 396301
(Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Legend

Spawn density distribution

105

0

99% total spawn

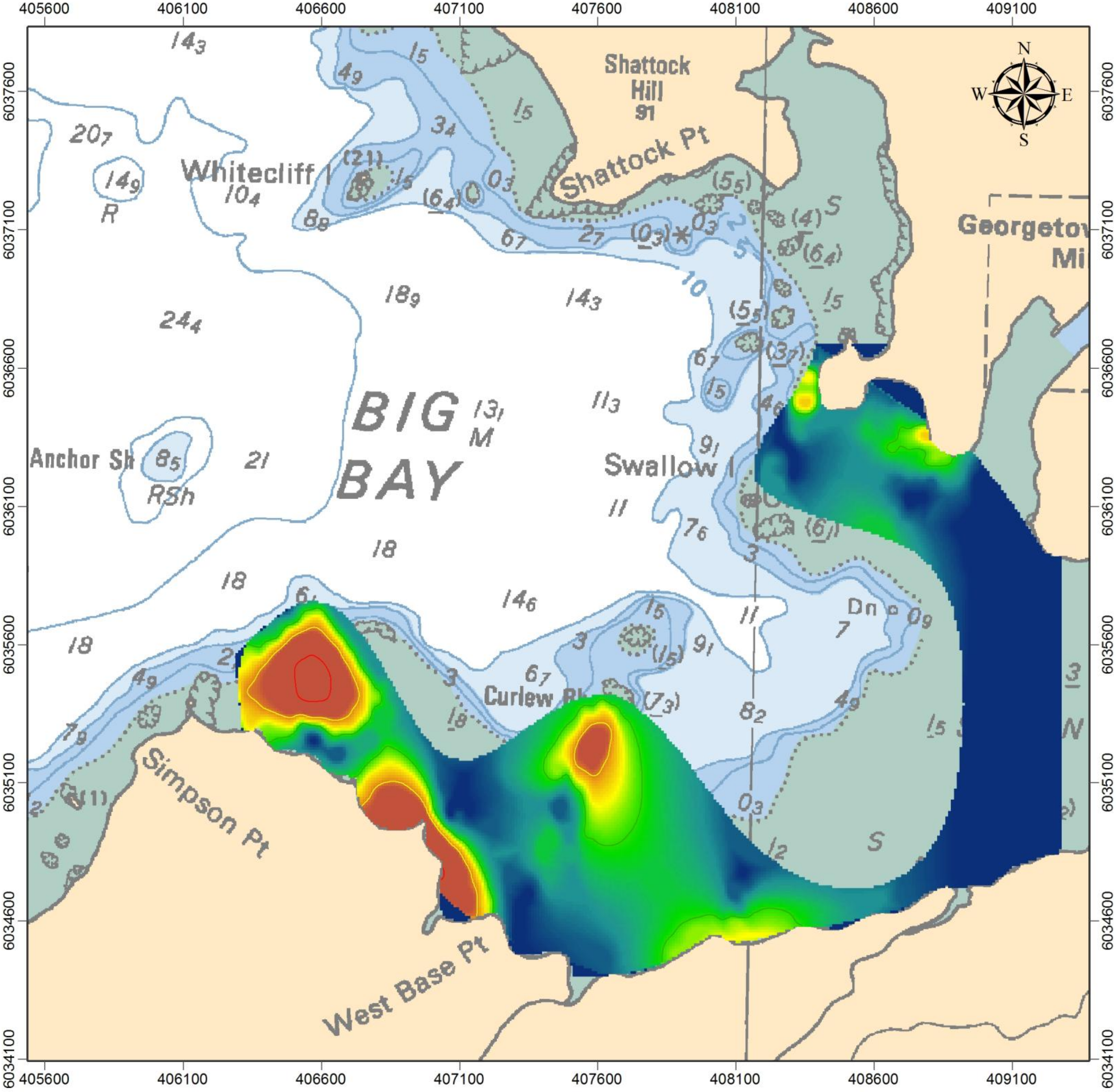
95% total spawn

90% total spawn

50% total spawn

0 125 250 500 Meters

OCEAN ECOLOGY



Big Bay Experimental Herring Video Survey

Figure 17. Contour map of distribution of herring spawn intensity from dive data.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Legend

Spawn map

1000 eggs/m2

270

0

Colored spawn contours

50

100

200

0 125 250 500 Meters

OCEAN ECOLOGY

Big Bay Experimental Herring Video Survey

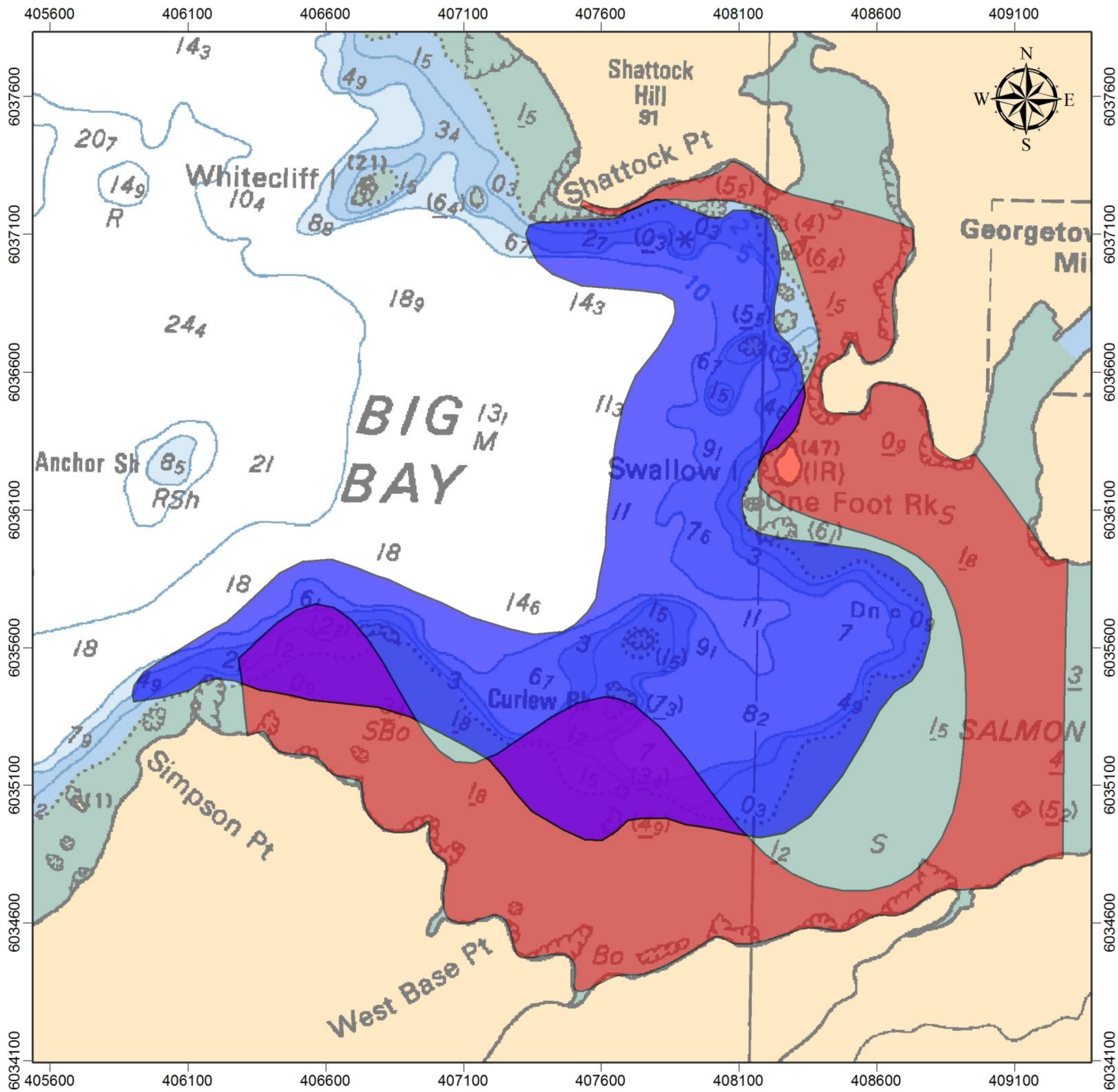


Figure 18. Comparison of video and dive survey boundaries.

Chart used for navigation: CHS 396301 (Work Channel)

Chart datum: LNT

Projection: WGS 1984 UTM Zone 9N

Scale: 1:19,500

Legend

- Video survey boundary
- Dive survey boundary
- Overlap regions between surveys

0 125 250 500 Meters

OCEAN ECOLOGY

Project Deliverables

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

1. Four DVD's containing raw georeferenced seabed video imagery* (overlaid with time, latitude, and longitude) of the survey site.
2. One CD containing:
    a. a georeferenced, classified Access database* of substrate, vegetation type, herring spawn intensity, and sounder and DGPS data.
    b. an electronic ArcGIS project* containing maps of analyzed video, grab sampling, and bathymetric data.
    c. a report describing and explaining the results of the experimental herring video survey.
3. Two DVDs containing:
    a. java-based software which links video and GPS data, allowing simultaneous viewing of the camera's geographical position on a map and the video images captured by the camera at that location.
    b. a library of video* annotations

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

Disclaimer

The findings presented in this report are based upon data collected during the period April 17th to April 19th, 2009 using the methodology described in the Survey Methodology section of this report. Ocean Ecology has exercised reasonable skill, care, and diligence to collect and interpret the data, but makes no guarantees or warranties as to the accuracy or completeness of this data.

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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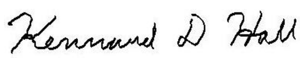
Reviewed By:



Kennard Hall, Captain
Partner, Ocean Ecology

Appendix 1 - 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 intensity were generated using Surfer 8. The production of the contours involved four steps:

1) Files containing latitude, longitude, and egg 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 intensity contours as follows:

1) Using the 3D Analyst extension, the herring spawn intensity 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.

Raster statistics, such as average spawn intensity, were calculated using the Zonal Statistics function of the Hawth’s Analysis Tools extension. Calculation of areal coverage of surveys was done using the Add Area/Perimeter Fields function of the Hawth’s Analysis Tools extension.

Statistical maps of herring spawn intensity distribution were generated using the Fixed Kernel Density Estimator function of the Hawth’s Analysis Tools extension. This function was used to take the locations at which herring spawn was observed, weight these locations by the egg density data, and then create a statistical map showing where the greatest spawn intensity occurred. The Kernel method of the function was set to “Quartic”. The Smoothing Factor was set to 350 m. The raster cell size was set to 10. The function was asked to calculate 99, 95, 90, and 50 percent volume contours. All other settings were left at default values.