Drop Camera Video Survey of Site 2 for the Canpotex Potash Terminal Project Disposal at Sea Application

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Barb Faggetter, Ph.D., R.P.Bio
Ocean Ecology
1662 Parmenter Ave.
Prince Rupert, BC V8J 4R3
Telephone: (250) 622-2501
Email: blueseas@oceanecology.ca

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Prepared for: Sandra Webster, PhD, R.P.Bio.
Senior Biologist, Environmental Management
Stantec
4370 Dominion Street 5th Floor
Burnaby BC V5G 4L7

Prepared by: Ocean Ecology

Table of Contents

List of Figures

List of Tables

Executive Summary

A DGPS-positioned, drop video camera system was used to collect imagery of the seabed. The survey design consisted of 35 drops with an approximate spacing of 200 m between drops. Surveys were carried out in waters up to approximately 177 m depth.

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

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

The following substrate and biota features were observed:

1. Coverage for the site was excellent, with 36 successful drops.
2. Based on the drop camera observations, the site substrate was homogenously silt-mud with trace amounts of shell.
3. Significant currents were observed along the sea floor at the majority of the camera drops. Fine-grained sediments and plankton were often in continuous motion across the camera's field of view. Based on the movement of particles across the camera's field of view, it was estimated that at some drops the velocity of the bottom current was as high as 1.5 m/s (5.4 km/h or 2.9 knots). Examination of the local topography around Site 2 showed that there is a well-defined trough leading from outside the Rachael Islands to the mouth of Inverness Passage. This trough probably forms a conduit for deep water movement from offshore to replenish losses due to estuarine entrainment, and also acts as a funnel, thus increasing the velocity of bottom currents along the route. Site 2 is located directly along this potential path of deep water flow, and this is most likely the explanation for the strong currents observed by the drop camera survey.
4. Due to the depth of the site, no flora was observed.
5. The most dominant fauna in terms of number of observations were krill. The most dominant fauna in terms of area were unmounded holes. Unmounded holes represent the observed surface disturbances caused by a number of unidentified infauna, including burrowing polychaetes, some bivalve species, and mud shrimp.
6. Krill were more abundant at the northwest end of the site than at the southeast end of the site, and formed very dense aggregations just to the south of the central deep region of the site. Krill are an important prey item for north Pacific Humpback whales. During the period November 15th to November 28th, 2010, Ocean Ecology observed a large number of humpback whales feeding in the area around both Site 1 and Site 2. The presence of humpback whales in this area is not an uncommon phenomenon. Local whale watching tours often take clients out to this region to view feeding humpback whales. Ford *et al.* (2009) have photo-identifications of whales in the vicinity of Site 2 from data collected during 1984-2007. It seems likely that the dense krill population at Site 2 may make this region a good feeding area for humpback whales. The humpback whale (Pacific population) was designated Threatened in Schedule 1 of SARA; however, in May 2011, this status was downgraded to a designation of Special Concern by COSEWIC.

7. Spot prawns were located in a region near the northwest end of the site. While relatively few spot prawns were seen using the drop camera, this was not unexpected, as spot prawns are highly mobile and will rapidly leave an area when startled. The camera will only record those prawns which do not become started when the lander impacts the sea floor. Thus, it is likely that the population of spot prawns was much higher than recorded by the drop camera. The only commercial species observed at the site was spot prawns. Statistical data can be obtained from DFO regarding the aggregated prawn catch and effort for the years 2001 to 2004 in the region around Site 2. The DFO data show that Site 2 is located in an area with the highest prawn catch and effort data values north of Banks Island.
8. Sea whips were only found at the northwest end of the site. However, from the camera footage, it was clear that there was a large field of sea whips in the region of drop 2-1. Thus, it is possible that sea whips may have a fairly extensive areal coverage at this end of the site.
9. The overall Shannon's diversity index for the site was 1.979, and the species richness was 10. Due to differences in methodology, these diversity indices are not comparable with those produced by analysis of data from the towed benthic video camera survey.
10. Maximum species richness for the site occurred towards the northwest end of the site, and in the deeper regions of the site. Most likely these are the areas where the current flow is strongest and plankton abundance is greatest.
11. The greatest overall organism abundance occurred near the center of the site, just to the south of the central deep region.

1 Introduction

Canpotex and the Prince Rupert Port Authority (PRPA) are proposing to dispose of ~724,000 m^3 of dredgate at one or two new disposal sites within the PRPA harbour boundaries. Baseline information is required for the environmental assessment (EA) of this project, and by Environment Canada as part of the permit application process for disposal at a new site.

As a part of the baseline study for the project, a drop camera video survey was carried out at the larger and deeper of the two proposed disposal sites, referred to as Site 2 (see Figure 1).

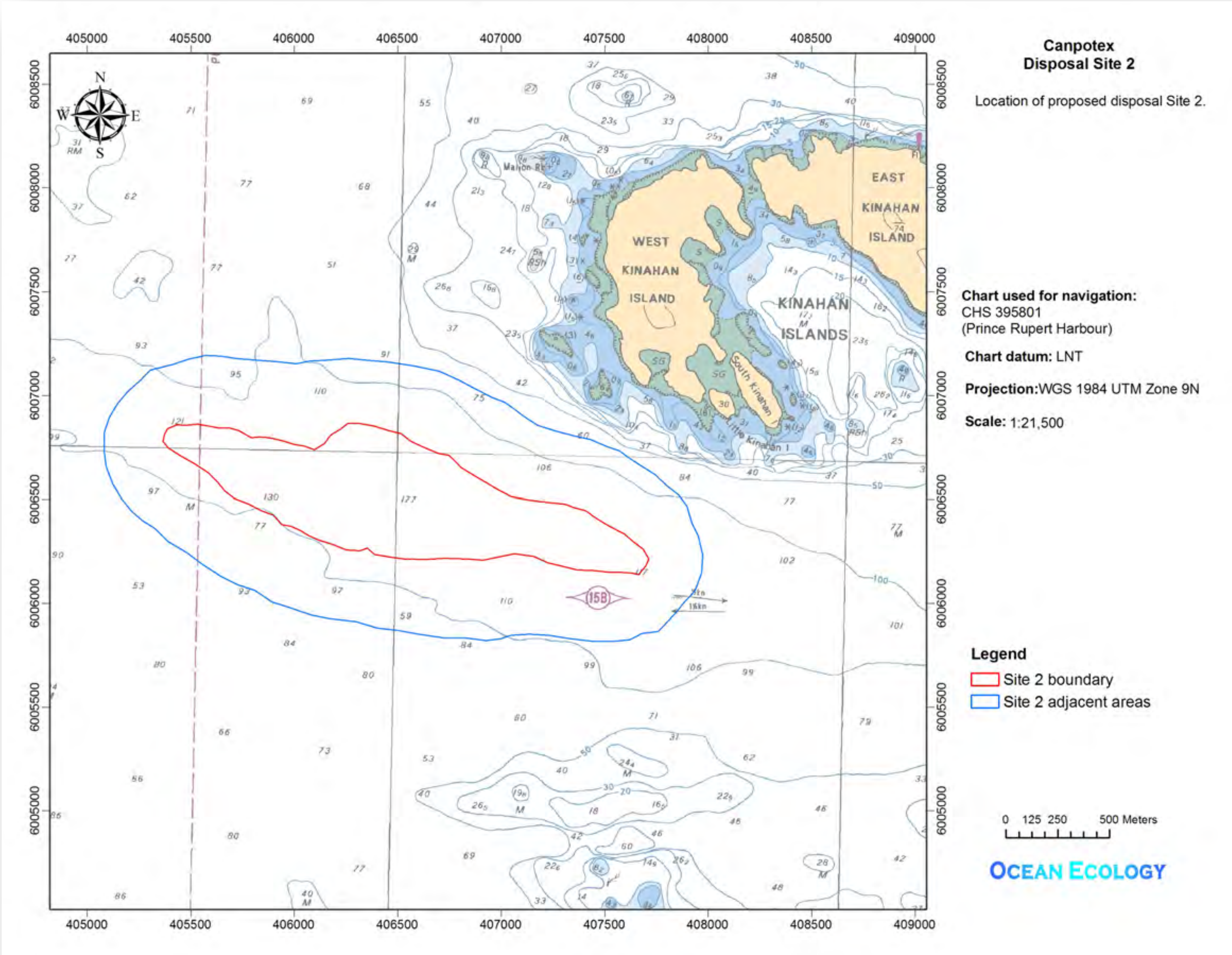

Figure 1. Location of proposed disposal Site 2.

2 Canpotex Disposal Site 2 Survey Methodology

2.1 Drop Camera Video Survey

2.1.1 Drop Camera System

A DGPS-positioned, drop video camera system was used to collect imagery of the seabed. This system was a custom-built model (e.g., not commercially available) designed specifically for taking video footage of the seafloor in deep water environments of up to 600 m depth (see Figure 2). The drop video camera system consisted of a single video camera with a downward-looking orientation 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 video was reduced. The lander frame had a 0.25 m^2 base footprint, which matches the standard quadrat size used by many shore survey protocols. 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 had a Sony 1/3" super HAD color CCD with 480 lines horizontal resolution (768 x 494 pixels) and 0.003 lux low light performance. High intensity white LEDs were mounted on the camera to provide additional illumination.

The drop camera system was lowered from the vessel's A-frame using a hydraulic winch until it contacted the sea floor. Depending on the drift speed of the vessel, the drop camera was left in position for approximately 2 to 5 minutes, after which time it was brought back to the surface. The DGPS position of the drop was logged using ArcMap.

The camera was deployed for periods of 3 hours, after which time the system's onboard batteries required recharging. During the recharging period, acquired video footage was checked for quality and success of the video drops.

Figure 2. Drop video camera system about to be deployed.

2.1.2 Video Recording System

The analog camera signal was recorded using an onboard digital video recorder (DVR) directly onto an SD card. The DVR placed a date and time stamp on the video during the recording process. After the survey was completed, the raw video data was copied onto DVDs.

2.1.3 Survey Design

The drop video survey of Site 2 was carried out on July 6th and 7th, 2011. The survey design consisted of 35 drops with an approximate spacing of 200 m between drops (see Figure 3). Surveys were carried out in waters up to approximately 177 m depth.

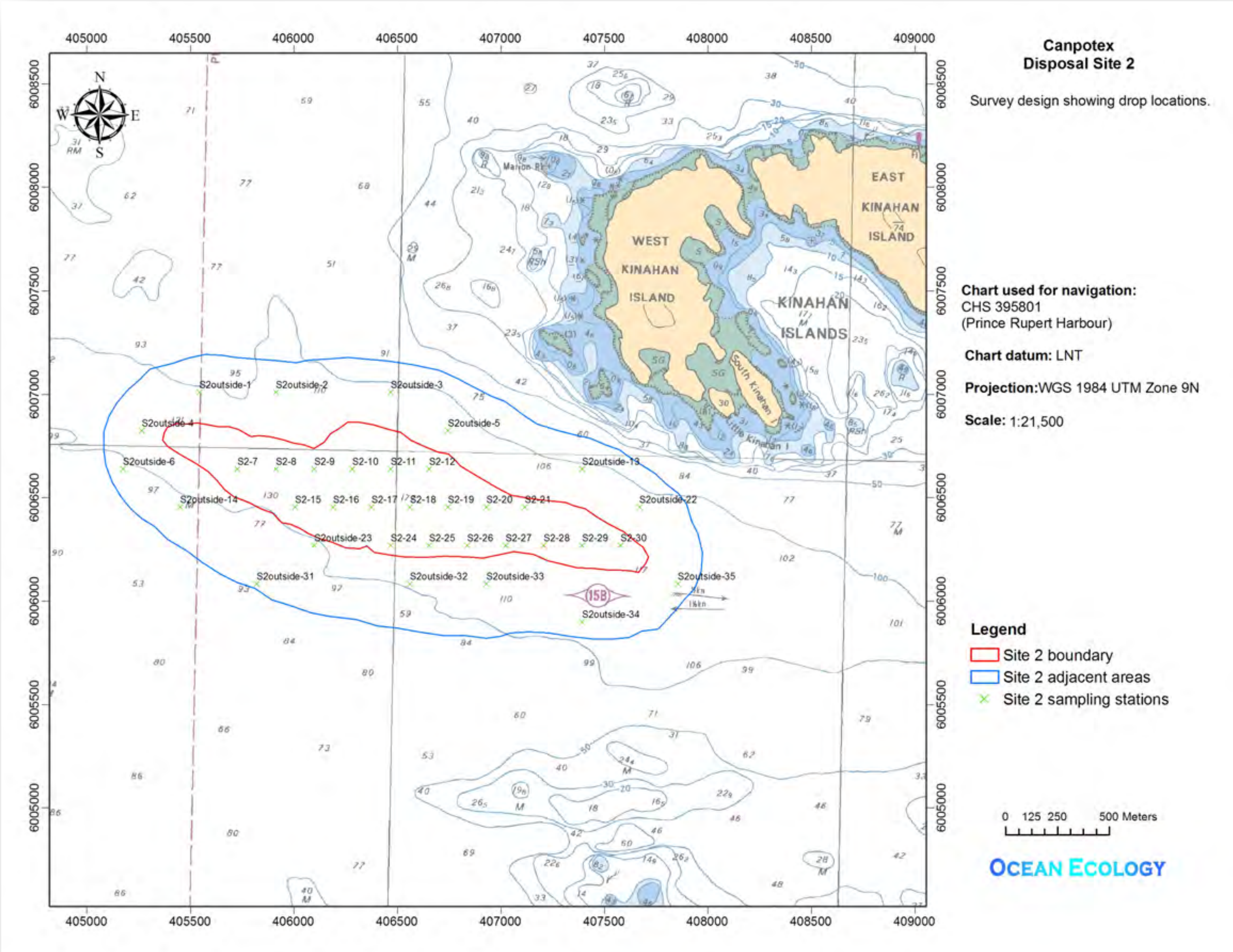

Figure 3. Survey design showing drop locatons.

2.2 Classification and Mapping

2.2.1 Database of Species and Substrate Classifications

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

The geology database contains information on substrate type (Table 3 in the Appendix) and percentage substrate cover (Table 5 in the Appendix). Anthropogenic features were mapped as part of the geological inventory.

The biological database captured detail on seabed biota within two general categories, vegetation (Table 6 in the Appendix) and fauna (Table 8 in the Appendix). Up to three faunal and floral types were evaluated for each second of video and given distribution codes. Vegetation coverage classes (Table 7 in the Appendix) and faunal distribution classes (Table 9 in the Appendix) were also recorded. Note that very small species (e.g., barnacles, small tube worms, small algal species, plankton), infauna (e.g., clams), cryptic fauna (e.g., flatfish, decorator crabs), or hidden fauna (e.g., under kelp fronds) were often not identified in the video footage, and were therefore not included in the database.

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

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

2.2.2 ArcGIS Mapping

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

2.2.3 Range Maps

Range maps for fauna were generated using the fixed kernel density estimation procedure. Fauna observations were weighted by distribution (see Table 9 in the Appendix). In order to allow overlap of polygons between drops, the search radius (a.k.a. the smoothing factor) was set to the distance between drops (e.g., 200 m). For each organism, a 50% and a 90% volume contour were generated. These consisted of polygons covering a geographical area in which either 50% or 90% of the estimated population was expected to be found. A density map showing the locations where the greatest population density occurred was also generated for each organism.

2.2.4 Diversity Analysis Using Range Maps

Calculations of Shannon's diversity index, Shannon's evenness, and Simpson's dominance index were carried out in ArcMap using the range map polygons. Note that the diversity values generated from the range map data should be considered minimum values for the site, as very small species (e.g., barnacles, small tube worms, plankton), infauna (e.g., clams), cryptic fauna (e.g., flatfish, decorator crabs), or hidden fauna (e.g., under kelp fronds) are often not identified in the video footage, and are therefore may not included in the diversity calculations.

2.2.5 Species Richness Map

A hexagonal grid (composed of hexagonal polygons with widths of 50 m) was overlaid on a shape file containing the fauna range map polygons. Using polygon in polygon analysis, each hexagonal polygon was assigned a number equal to the number of range map polygons with which it overlapped. This assigned number was equal to the species richness in a given hexagonal polygon, since each range map polygon represented a different species. The coded hexagonal polygons were used to generate a species richness map.

2.2.6 Overall Organism Abundance Map

The population density map for each organism was cropped to the adjacent areas boundary of Site 2, and then normalized to the maximum fauna distribution code recorded for that organism. All the organism density maps were then summed together to form a single raster which represented the overall organism abundance observed at the site.

3 Canpotex Disposal Site 2 Survey Results

3.1 Benthic Video Survey

The camera drops for the survey as carried out are shown in Figure 4. Coverage for the site was excellent, with 36 successful drops. Other factors which had an effect on the survey quality and resolution were:

1. ***Turbid water*** – the site is affected by the plume of the Skeena River, resulting in relatively high turbidity. As a result, the visibility at the site seldom exceeded 1 m. High intensity LEDs were used to provide light during the video drops; however back-scattering of light from the silt particles and plankton often created a “halo effect”, causing additional visibility issues. This reduced the resolution of the video camera, producing a grainy image quality. In spite of these problems, the image quality was deemed sufficient for organism identification.
2. ***Strong currents*** – strong currents increased vessel drift speed during the camera drops, often resulting in reduced camera bottom time.
3. ***Fine-grained benthic sediments*** - very fine-grained benthic sediments were easily suspended by the impact of the lander frame on the sea floor. These sediments often took some time to settle and created drifting clouds of sediment which frequently obscured the camera’s view of the sea floor.
4. ***Limited battery time*** - unlike Ocean Ecology’s towed benthic video system, the camera, light ring, and DVR recorder of the drop camera system were not powered remotely using a POC (power over coaxial) system; rather they were powered by self-contained batteries. This limited the deployment time of the camera to approximately 3 hours.
5. ***Lack of real-time visualization*** - there was no real-time camera feed to the vessel’s bridge from the drop camera. Thus, all drops were made “blind”, and the effectiveness of the drops could only be determined after the camera had been retrieved and the data was viewed on a computer.
6. ***Limited amount of sea floor visualized*** - 36 camera drops, each with a footprint of 0.25 m^2, visualized approximately a total of 9 m^2 of the sea floor. By comparison, the towed video survey at Site 1 had 7.9 km of transects. Given an average field of view width of 0.5 m, this amounted to approximately 3,950 m^2 of sea floor visualized. Clearly, while the drop camera had the structural capacity to reach and visualize the deep sea floor, this ability came at the cost of reduced sea floor coverage.
7. ***Limited ability to visualize mobile organisms*** - mobile organisms tend to swim away from the drop camera as it is lowered. Once it has reached the sea floor, the camera’s limited field of view means that is unlikely to capture images of mobile organisms as they swim by. A longer soak time may have allowed curious organisms to approach the lander; however this was not possible in the strong currents at Site 2.
8. ***Attraction of plankton by the camera’s lights*** - the low-level blue-shifted LED lighting used by the camera does not tend to attract organisms over large distances. However, some attraction of plankton, particularly krill, did occur over short distances. Since these organisms are not strong swimmers, and since the camera had a very short soak time, it can be assumed that these organisms only traveled a small distance (e.g., a few meters) to reach the camera. Thus, the plankton attracted to the camera was probably a reasonable representation of the plankton at the drop location.

One DVD was generated containing both (1) raw video data generated from the survey; and (2) processed and annotated video data and viewers to visualize the data.

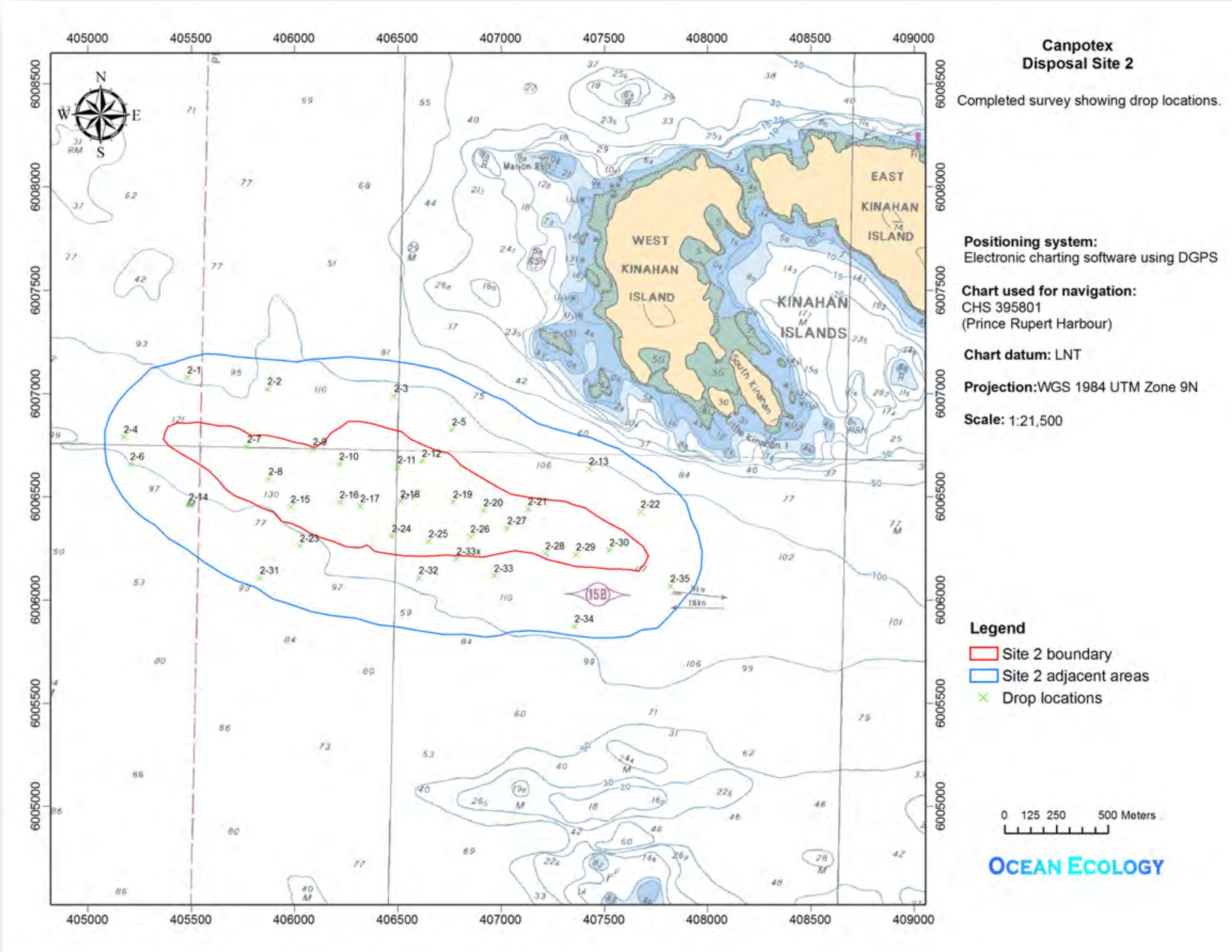

Figure 4. Completed survey showing drop locations.

3.2 Substrate

Based on the drop camera observations, the site substrate was homogenously silt-mud. Trace amounts of shell were observed at all but three of the drops (drops 2-13, 2-28, and 2-34 did not have any appreciable amounts of shell).

In the deepest region of Site 2, a small amount of drift kelp was seen. Figure 5 shows the locations of the 50 m diameter polygons in which drift kelp was observed from the drop camera survey. This kelp has been carried by currents from shallower nearshore regions and deposited in the depths of Site 2.

Significant currents were observed along the sea floor at the majority of the camera drops. Fine-grained sediments and plankton were often in continuous motion across the camera's field of view. Figure 6, which shows a sea whip bending in the currents at drop 2-9, gives a visual sense of the strength of the bottom currents. Based on the movement of particles across the camera's field of view, it was estimated that at some drops the velocity of the bottom current was as high as 1.5 m/s (5.4 km/h or 2.9 knots). The following description of current patterns in Chatham Sound explains how these deep water flows are generated.

Chatham Sound is influenced by fresh water from two large rivers, the Skeena and the Nass. The Nass River discharges into Portland Inlet, and fresh water flows from there into the northern end of Chatham Sound and eventually out through Dixon Entrance (Tera Planning Ltd., 1993). Water from the Skeena River enters Chatham Sound through a series of channels. Approximately 75% of the Skeena River flows equally through Marcus Passage (separating Smith and DeHorsey Islands from Kennedy Island) and Telegraph Passage, while the remaining 25% of the Skeena River flows through Inverness Passage (Trites, 1956).

As a result of the fresh water discharges of the Nass and Skeena Rivers, the whole of Chatham Sound is essentially a large estuary (Tera Planning Ltd., 1993). Figure 7 shows the regions in Chatham Sound affected by freshwater outflows from the Skeena and Nass Rivers. Generally, estuarine circulation occurs when a large volume of fresh water from a river flows out along the surface at the head of an inlet. As it moves seaward, this layer entrains saline water from the layer beneath it, and carries this entrained water seaward. The loss of water from the lower layer is replenished by a deep water flow which has a net landward movement (see Figure 8). However, as a result of the fresh water influx from two rivers, a highly irregular coastline, and a large horizontal extent, the circulation patterns in Chatham Sound are considerably more complex than most coastal BC inlets (Tera Planning Ltd., 1993).

Highest freshwater discharge (freshet) for the Skeena and Nass Rivers normally occurs from May through to June (Tera Planning Ltd., 1993). Although present throughout the year, estuarine circulation and the currents produced by this circulation are most pronounced during freshet. At this time of year, the amount of freshwater present in Chatham Sound can be 3 to 4 times the mean value (Cameron, 1948). During normal (non-freshet) river discharge conditions, approximately 70% of the Skeena River water moves northward past Tugwell Island, along the Tsimpsean Peninsula to merge with Nass River water (Trites, 1956). This water then exits Chatham Sound through Dundas Passage, with a smaller amount exiting through Hudson Bay Passage. Only a small proportion (30%) of the Skeena River discharge reaches Dixon Entrance and Hecate Strait through central and southern passages. This northward diversion of the Skeena River is due, in part, to the Coriolis effect, which diverts water to the right of the direction of flow in the northern hemisphere. Nass River water tends to be concentrated along the north shore of Chatham Sound, moving past Wales Island north of Dundas Island into Dixon Entrance. During freshet, fresh water flows through all the passages and channels exiting Chatham Sound is increased. Nass River water during freshet is thought to extend as far south as Melville Island, where it may interfere with the northern movement of Skeena River water past Dundas Island (Tera Planning Ltd., 1993; see Figure 9).

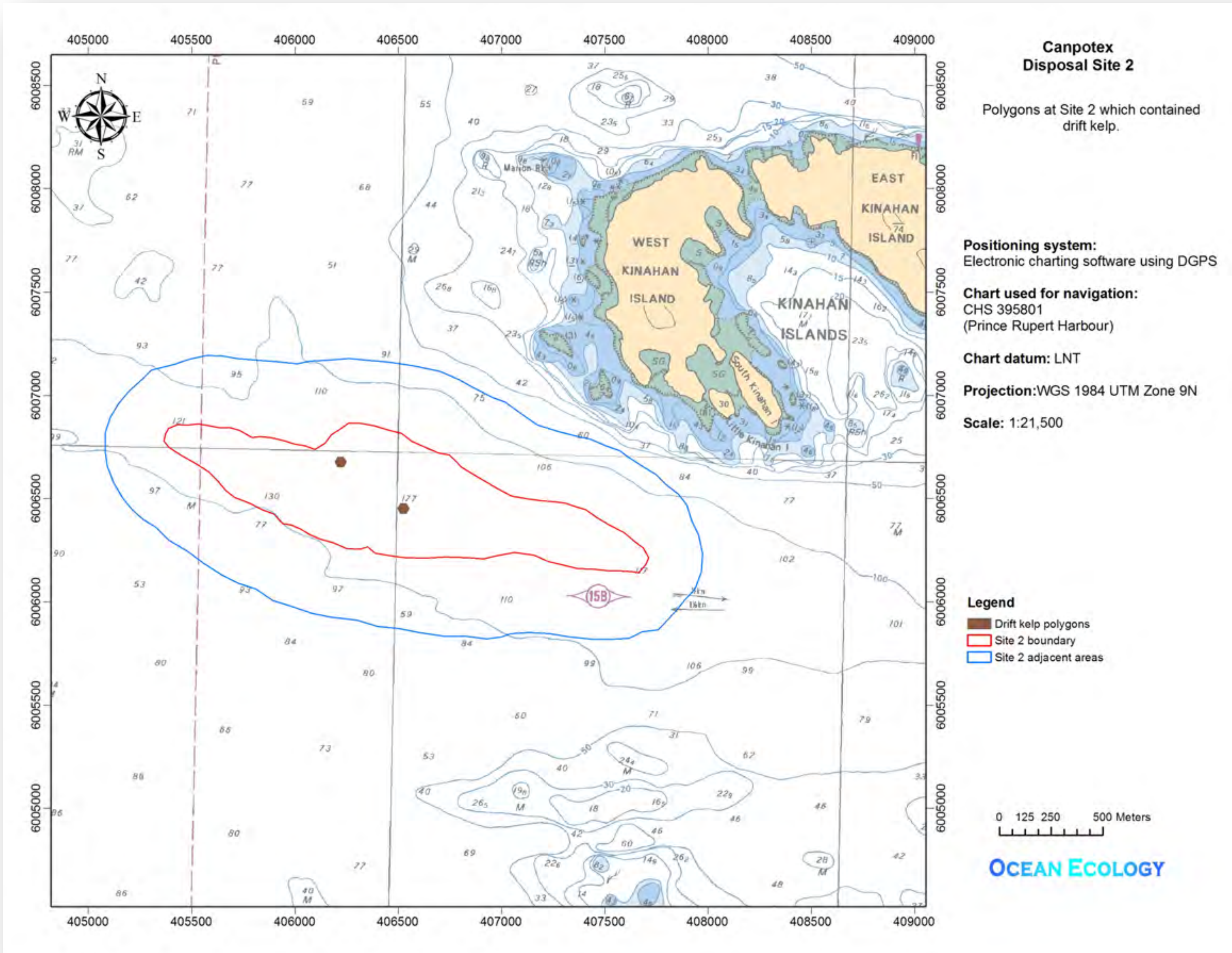

Figure 5. Polygons at Site 2 which contained drift kelp.

Figure 6. Sea whip bent over in strong currents at drop 2-9.

Based on the description of riverine inputs to Chatham Sound given above, it can be seen that the general pattern of surface flow in the sound around the area of Site 2 is a seaward flow in a more or less northwest direction. Thus, the corresponding landward deep water flow should occur in a general southeast direction. This deep water flow will be channeled and directed by local sea floor bathymetry, and will tend to be strongest in submarine canyons and troughs which have a northwest-southeast orientation.

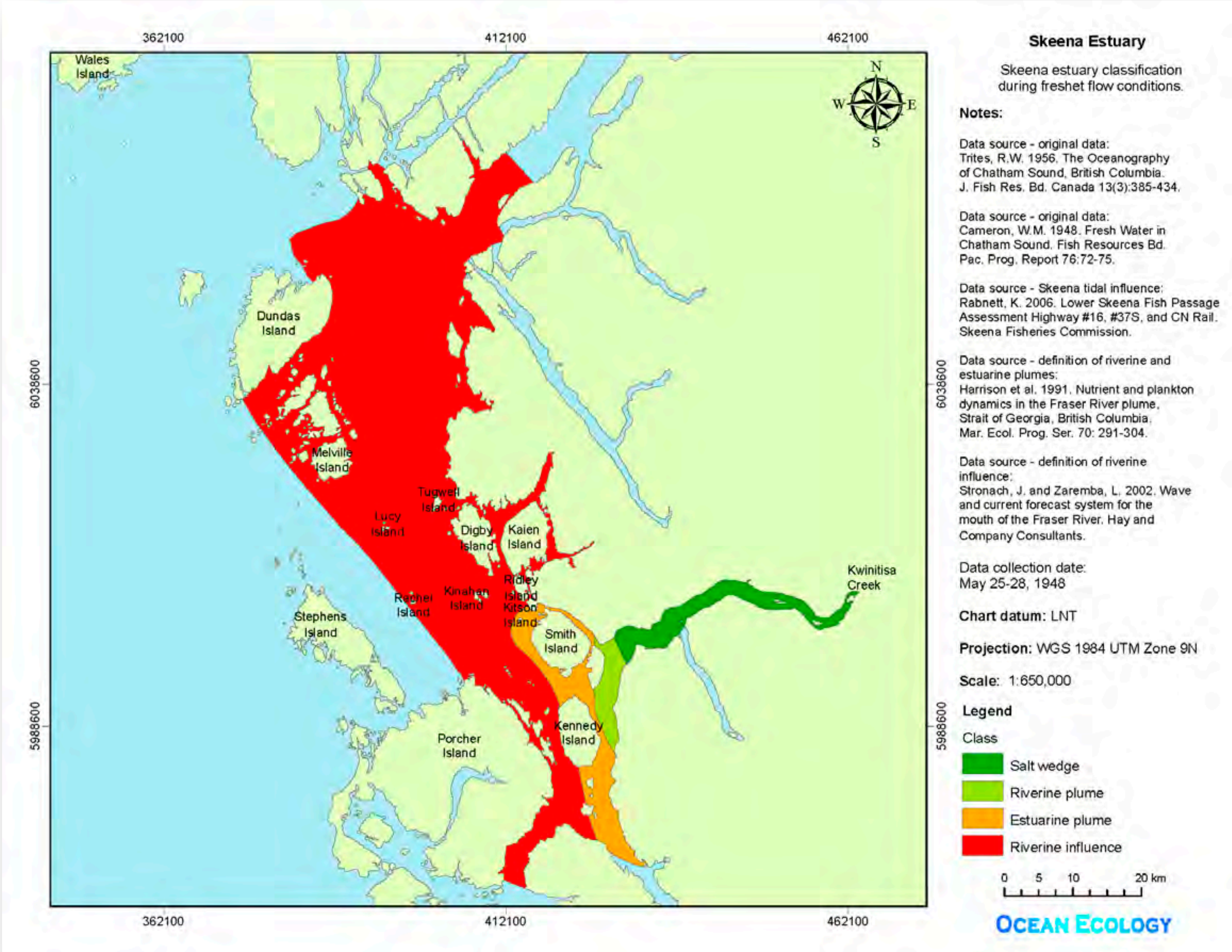

Figure 7. Skeena estuary classification during freshet flow conditions (Faggetter, 2011).

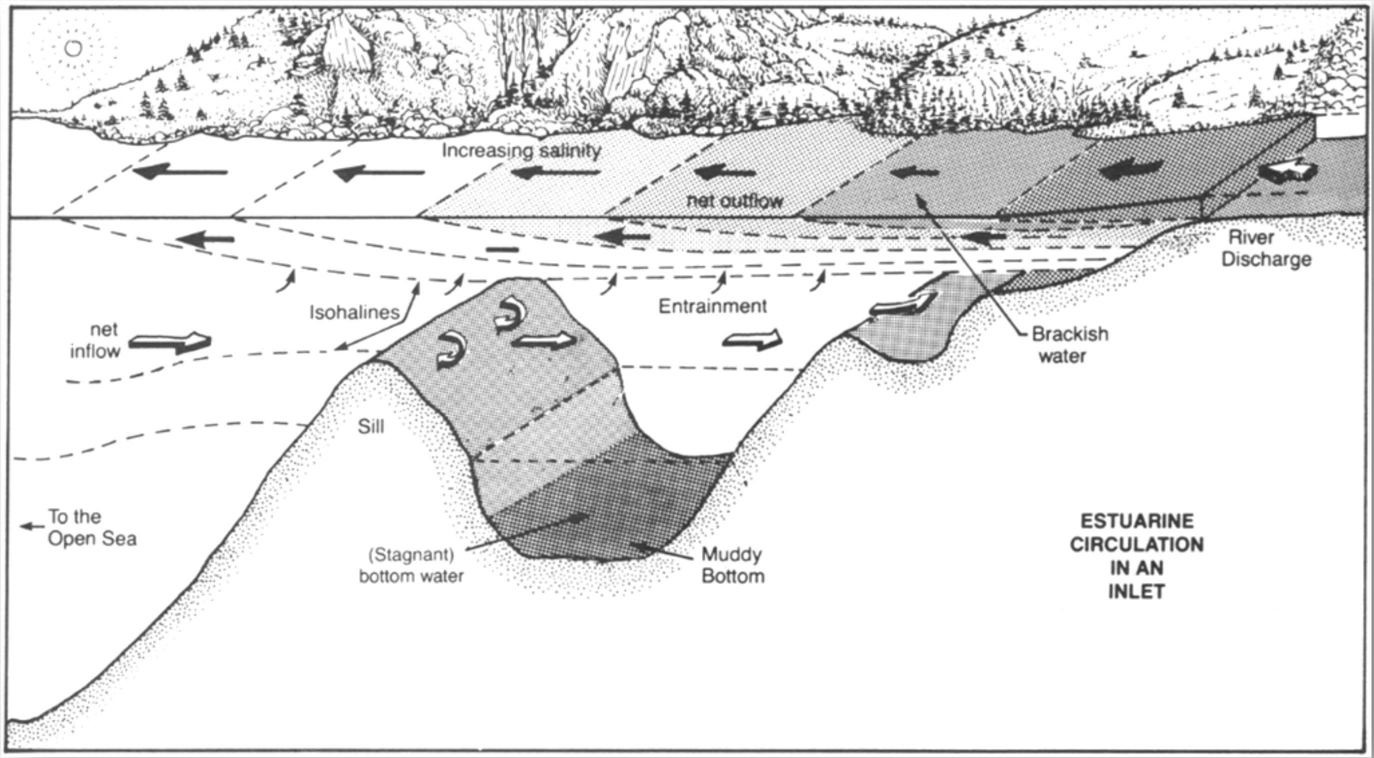

Figure 8. Estuarine circulation in a typical British Columbia inlet (Thomson, 1981).

While no detailed oceanographic models for the area around Site 2 currently exist, several larger domain models have been developed for the Hecate Strait/Chatham Sound region which confirm the general southeastward flow of deeper water in the area. Figure 10 shows the current patterns around Site 2 as predicted by three models

1. A model computed by Ballantyne *et al*. (1996) at a 3 m depth using forcing from tides and baroclinic pressure gradients calculated from a July 5th - August 18th, 1991 cruise.
2. A model computed by Jacques (1997) at a 10 m depth driven by tides, river runoff, and baroclinic pressure gradients calculated from the density field measured over the period June 24th - July 7th, 1991.
3. A model computed by DFO (Levings and Foreman, 2004) for average summer currents at 30 m.

All three models showed a general southeast current flow near Site 2, with current velocity decreasing with depth (note that the DFO model has a different scale for its current arrows than the other two models).

Examination of the local topography around Site 2 shows that there is a well-defined trough leading from outside the Rachael Islands to the mouth of Inverness Passage (see Figure 10). This trough probably forms a conduit for deep water movement from offshore to replenish losses due to estuarine entrainment, and also acts as a funnel, thus increasing the velocity of bottom currents along the route. Site 2 is located directly along this potential path of deep water flow, and this is most likely the explanation for the strong currents observed by the drop camera survey.

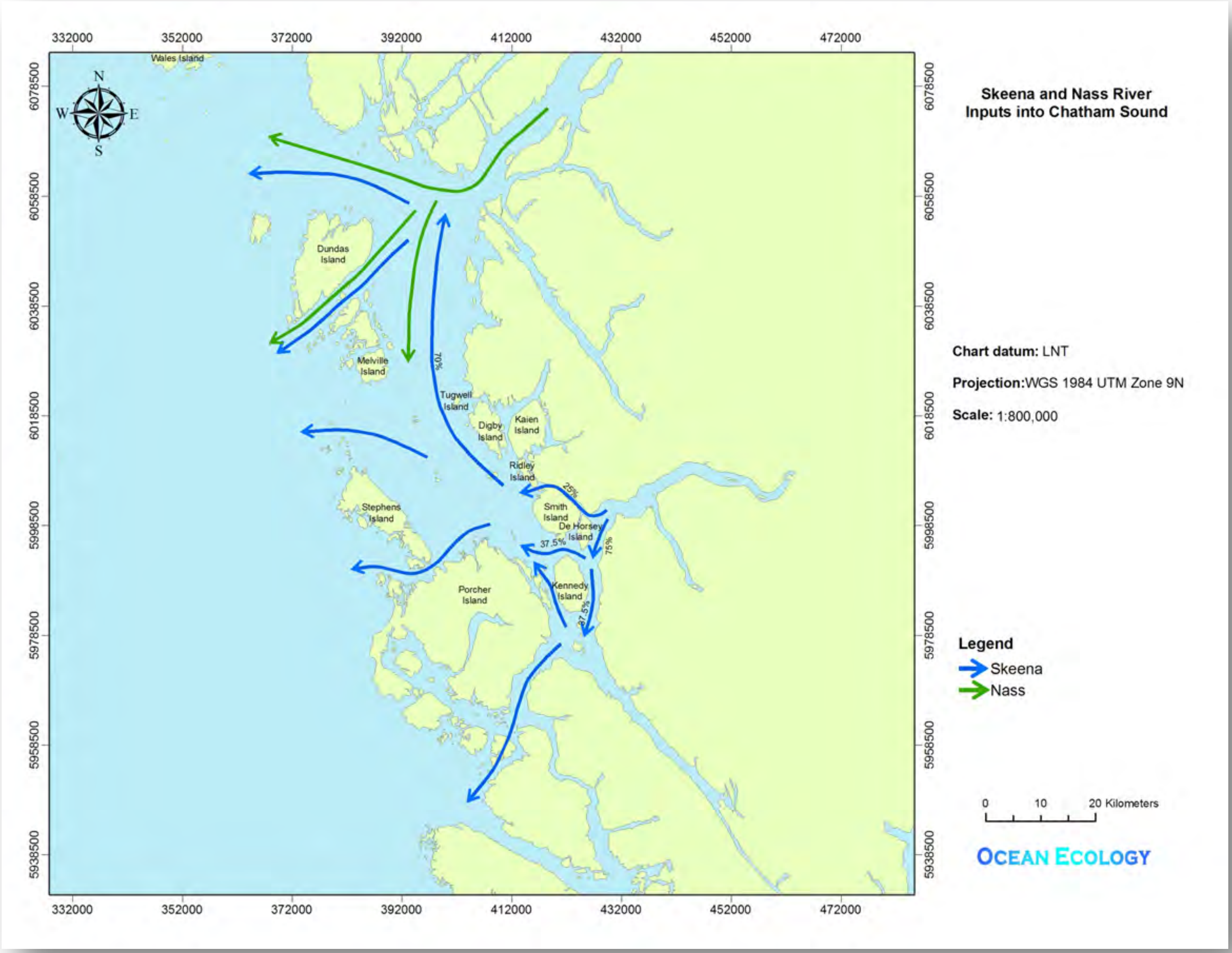

Figure 9. Skeena and Nass River inputs into Chatham Sound.

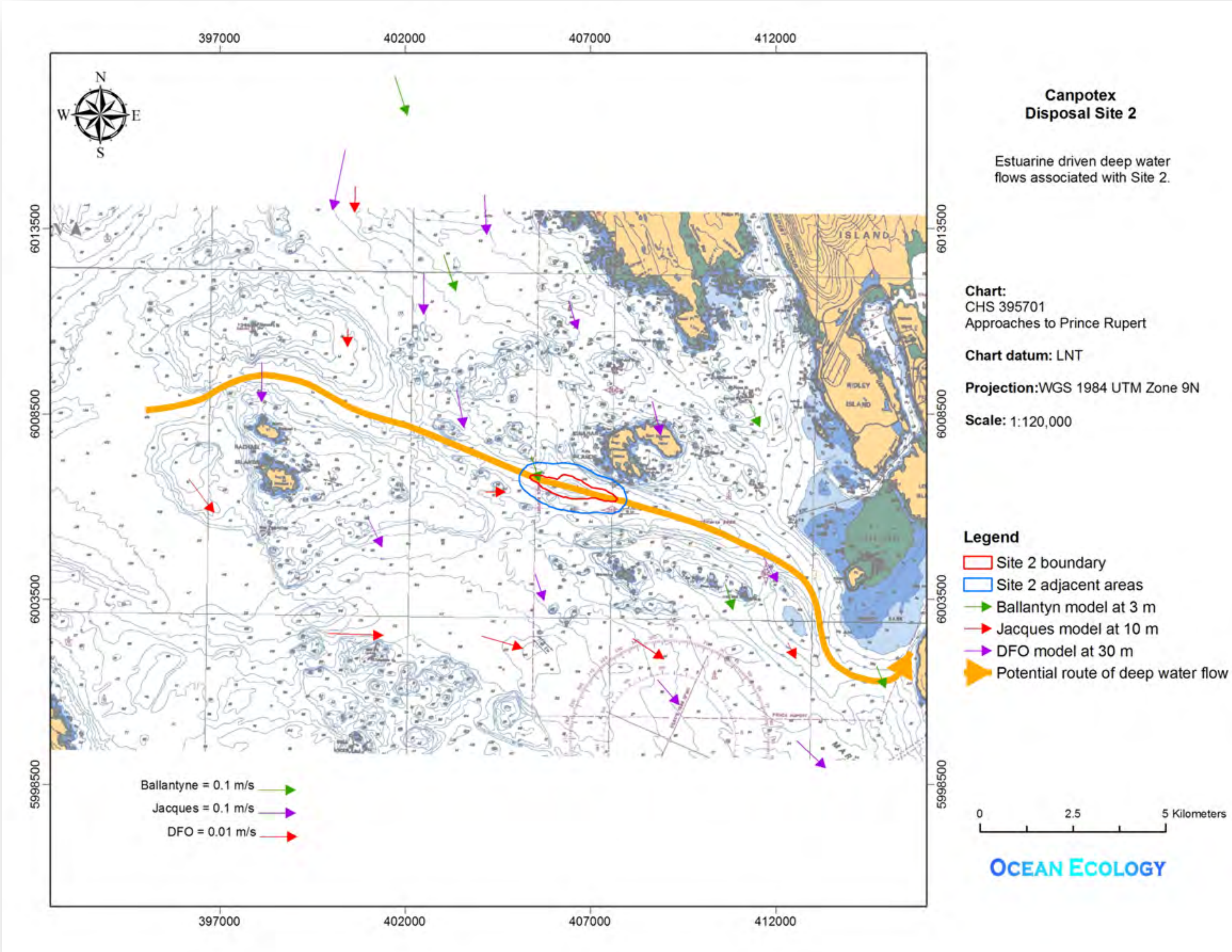

Figure 10. Estuarine driven deep water flows associated with Site 2.

3.1 Flora

Due to the depth of the site, no flora was observed.

3.2 Fauna

Table 1 lists the various groups of fauna identified at the site, and their abundances in terms of both total number of observations and percentage of total fauna abundance by area based on the range maps for each group. Note that since the drop camera is stationary, the value referred to by the term "*Number of Observations*" is calculated using a different formula than that used with the towed benthic video system. When using the towed video system, the Boolean value "*Species X presence*" is assigned either a 1 (present) or a 0 (absent) for each second of video footage. The term "*Number of Observations*" is then calculated as follows:

$$Number\ of\ Observations = \sum_{time=1}^{n} (Species\ X\ presence)$$

where *time* is in seconds. Since the camera is moving relatively rapidly over the sea floor, an organism is seldom in the camera's field of view for more than a second, and the numbers of "duplicate" counts for specific individuals are relatively few. However, the situation is quite different in the case of the drop camera system. Since the camera is not moving relative to the sea floor, if an organism did not move out of the camera's field of view, it would get counted for each second that it was present. As a result, stationary organisms would get counted many times. Thus, if the above formula were used, the value "*Number of Observations*" would be both an indication of the abundance of a particular species as well as how long individuals of that species were present in the camera's field of view. This would cause serious over-representation of sessile or non-moving organisms. For this reason, "*Number of Observations*" for the drop camera system was calculated as follows:

$$Number\ of\ Observations = \sum_{drops=1}^{n} (Species\ X\ presence)(Maximum\ value\ for\ Species\ X\ distribution\ code)$$

where *drops* refers to the number of camera drops, and the *Species X distribution code* is the faunal distribution class (Table 9 in the Appendix) for *Species X*. Thus, "*Number of Observations*" for the drop camera system is the number of drops in which a particular species was seen weighted by the relative abundance of that species in the drops where it occurred. As a result of the use of fauna distribution codes for weighting, it is important to note that "*Number of Observations*" is a relative value, and does not represent the total number of individuals present. For example, a fauna distribution code of 5 when applied to krill does not represent 5 individual krill, but rather a dense aggregation of krill which may contain over 100 individuals.

Table 1. Abundances of various fauna groups.

Fauna identification	Number of Observations	% of Total Fauna Abundance by Area
Krill	68	22.85
Unmounded hole	26	23.71
Chaetognath	22	10.38
Unidentified bivalve	13	15.27
Larvacean	10	11.75
Spot prawn	6	5.49
Sea whip	4	2.76
Unidentified amphipod	4	5.03
Unidentified brittlestar	1	1.38
Unidentified seastar	1	1.38

Some observations regarding fauna at Site 2 are:

1. The most dominant fauna in terms of number of observations were krill. The most dominant fauna in terms of area were unmounded holes. Unmounded holes represent the observed surface disturbances caused by a number of unidentified infauna, including burrowing polychaetes, some bivalve species, and mud shrimp.
2. The following distribution patterns were observed:
    a. Krill were more abundant at the northwest end of the site than at the southeast end of the site (see Figure 11). Krill formed very dense aggregations just to the south of the central deep region of Site 2 (see Figure 12).

       Krill (euphasiids) are an important prey item for north Pacific Humpback whales (*Megaptera novaeangliae*). Euphausiids were the most common prey reported in BC from stomach contents of humpback whales collected between 1949 and 1965 taken by commercial whalers (Nichol *et al.*, 2010). Of 287 stomachs that contained food remains, 263 (92%) contained only euphausiids, 12 (4%) contained only copepods, and 2 (0.7%) contained only fish. Two species of euphausiids were reported, *Euphausia pacifica* and *Thysanoessa spinifera*.

       During the period November 15th to November 28th, 2010, Ocean Ecology observed a large number of humpback whales feeding in the area around both Site 1 and Site 2. Up to 14 whales were observed simultaneously in three separate feeding groups. The actual number of whales present may have been even greater, as no attempt was made to individually track and identify each whale. The presence of humpback whales in this area is not an uncommon phenomenon. Local whale watching tours often take clients out to this region to view feeding humpback whales. Ford *et al.* (2009) have photo-identifications of whales in the vicinity of Site 2 from data collected during 1984-2007 (see Figure 13). Interestingly, one of these humpback whale siting locations was very close to Site 2 in the trough which may serve as a potential deep water conduit. It seems likely that the dense krill population at Site 2 may make this region a good feeding area for humpback whales.

       In 1985, the humpback whale (Pacific population) was designated Threatened in Schedule 1 of the Species at Risk Act (SARA; Species at Risk Public Registry, 2011). Under SARA it is prohibited to kill, harm, harass, capture or take an individual of this population and also to destroy any part of its critical habitat (DFO, 2009). In May 2011, COSEWIC (Committee on the Status of Endangered Wildlife in Canada) re-examined the status of this population of humpback whales and downgraded the designation to Special Concern (COSEWIC, 2011).

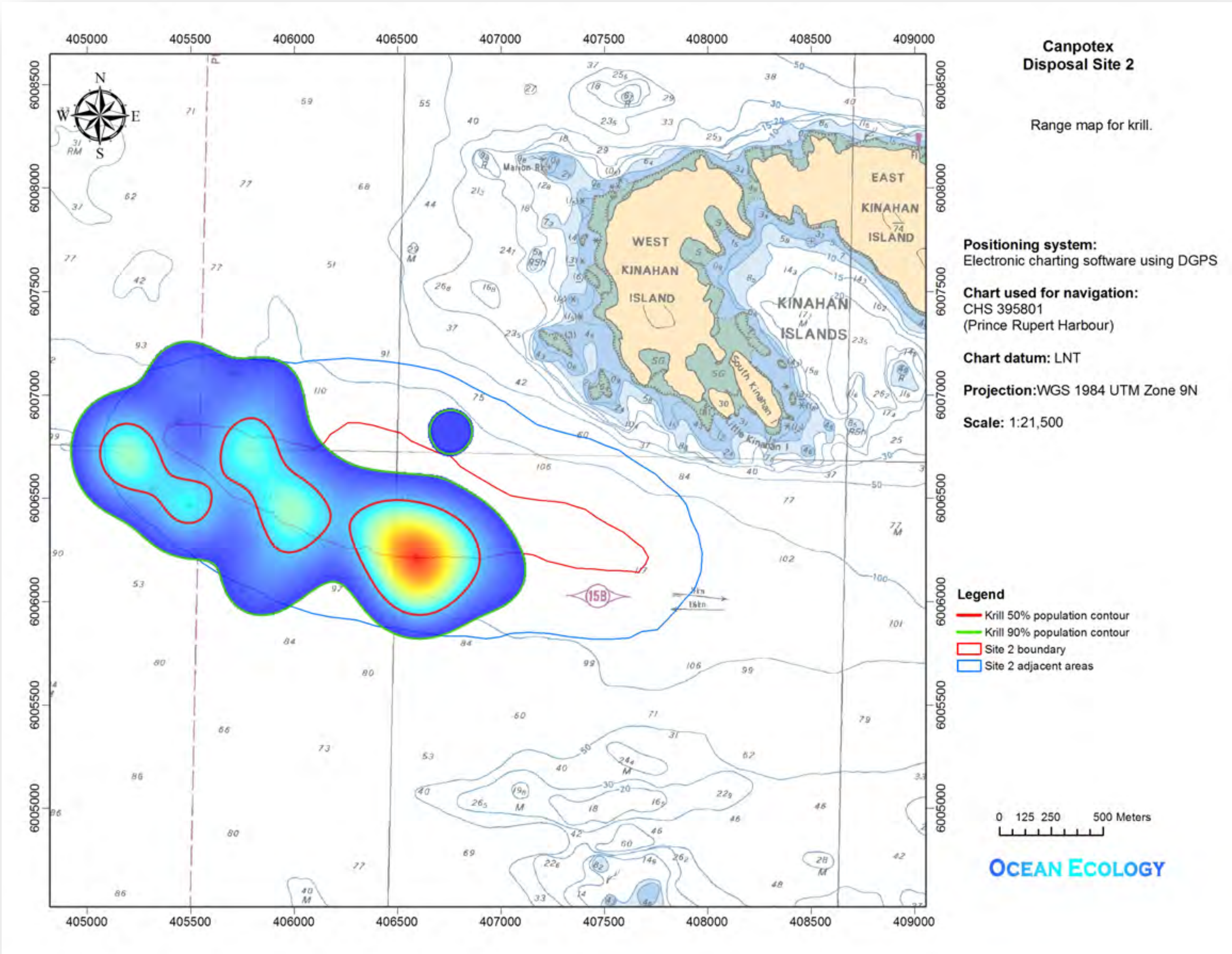

Figure 11. Range map for krill.

Figure 12. Dense aggregations of krill at drop 2-32.

b. Unmounded holes were present throughout most of the site, but were most abundant at the center of the site (see Figure 14). These holes probably represented a variety of infaunal organisms; however most cannot be accurately identified from video images. Based on the previous macroinvertebrate study done at the site during November 21st, 2010, some of the more conspicuous of these unmounded holes may be attributed to polychaete species such as fringed filament-worms (*Dodecaceria concharum*), robust sphaghetti-worms (*Neoamphitrite robusta*), small spaghetti worms (*Polycirrus* sp.), tusk coneworms (*Pectinaria granulate*), bamboo worms (*Praxillella gracilis*, *Euclymene zonalis*), and bristle worms (*Amage anops*, *Amphisamytha bioculata*), or infaunal sea cucumbers, such as the sweet potato sea cucumber (*Molpadia intermedia*).

c. Chaetognaths were very abundant at the site, both in terms of number of observations and areal coverage. Chaetognaths were more abundant at the southeast end of the site than at the northwest end of the site (see Figure 15). The high krill and the chaetognath populations were probably feeding on the abundant plankton observed in the water.

d. Unidentified bivalves were the third most abundant group in terms of areal coverage. They occurred throughout the site, but were most abundant just to the south of the central deep region of Site 2 (see Figure 16). Based on the previous macroinvertebrate study done at the site during November 21st, 2010, some of these bivalves may have been divaricate nutclams (*Acila castrensis*), stout cyclocardias (*Cyclocardia ventricosa*), round diplodons (*Diplodonta orbella*), broad yoldias (*Megayoldia thraciaeformis*), minute nutclams (*Nuculana minuta*), purple dwarf-venuses (*Nutricola tantilla*), butter clams (*Saxidomus gigantea*), Carpenter tellins (*Tellina carpenter*), plain tellins (*Tellina modesta*), or crisscrossed yoldias (*Yoldia scissurata*).

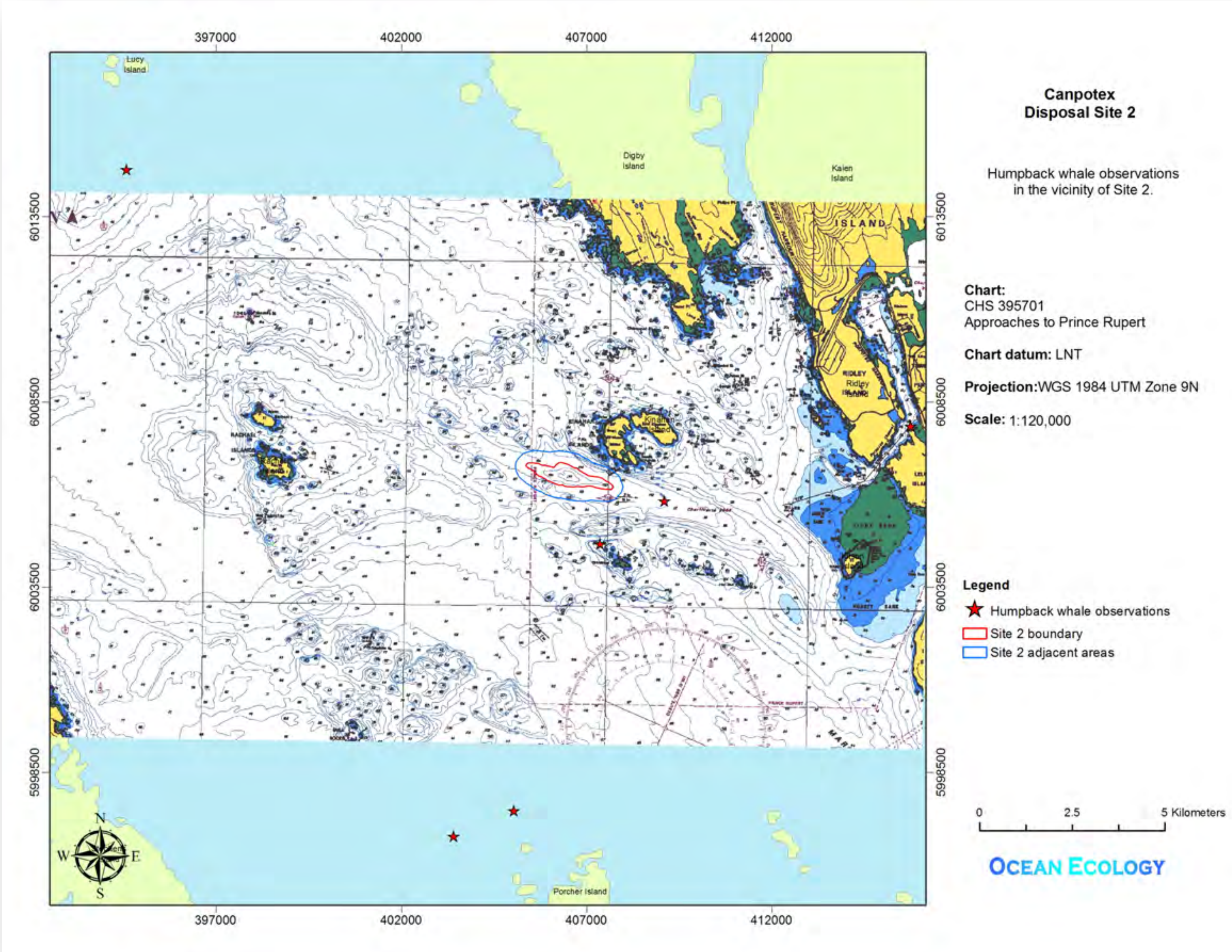

Figure 13. Humpback whale observations in the vicinity of Site 2 (Ford *et al.*, 2009).

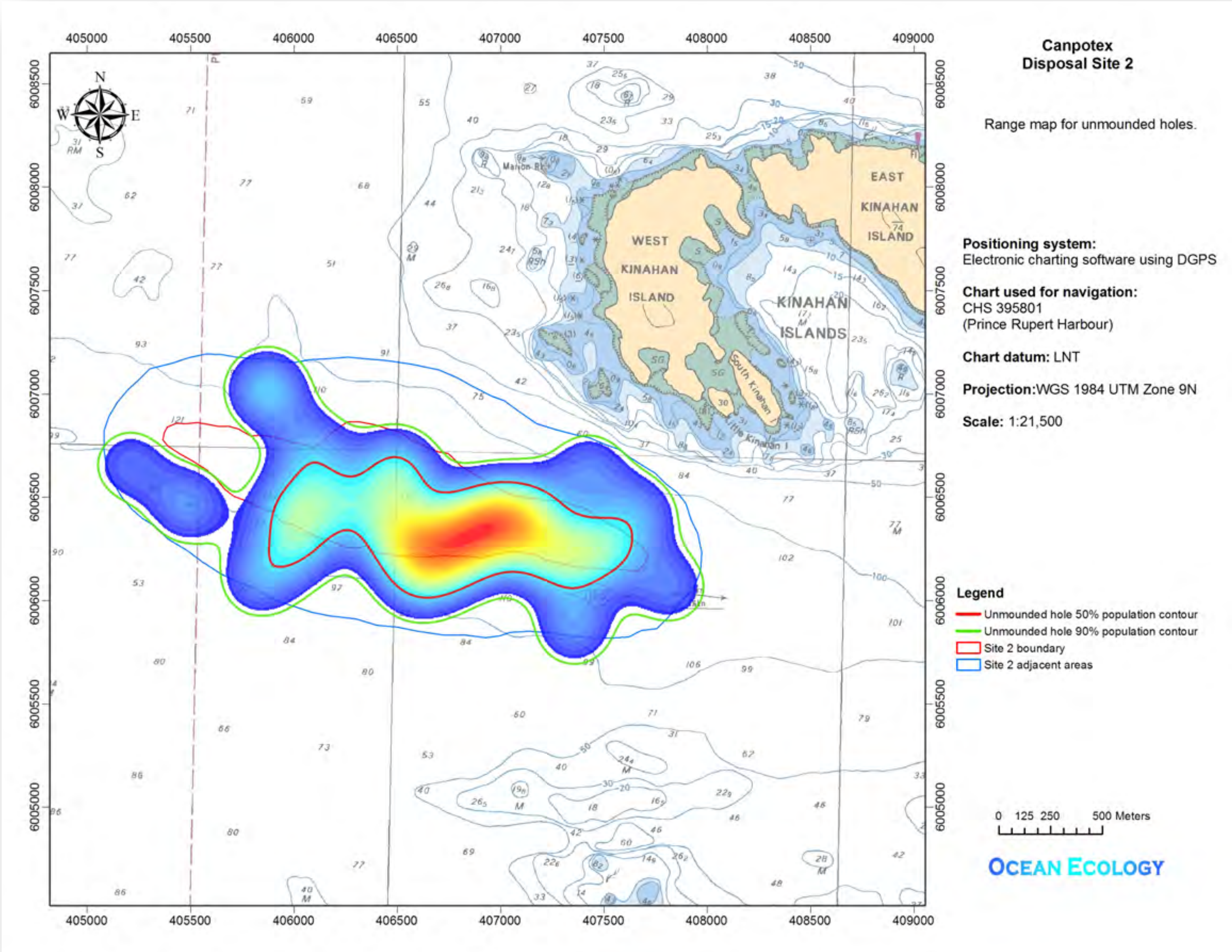

Figure 14. Range map for unmounded holes.

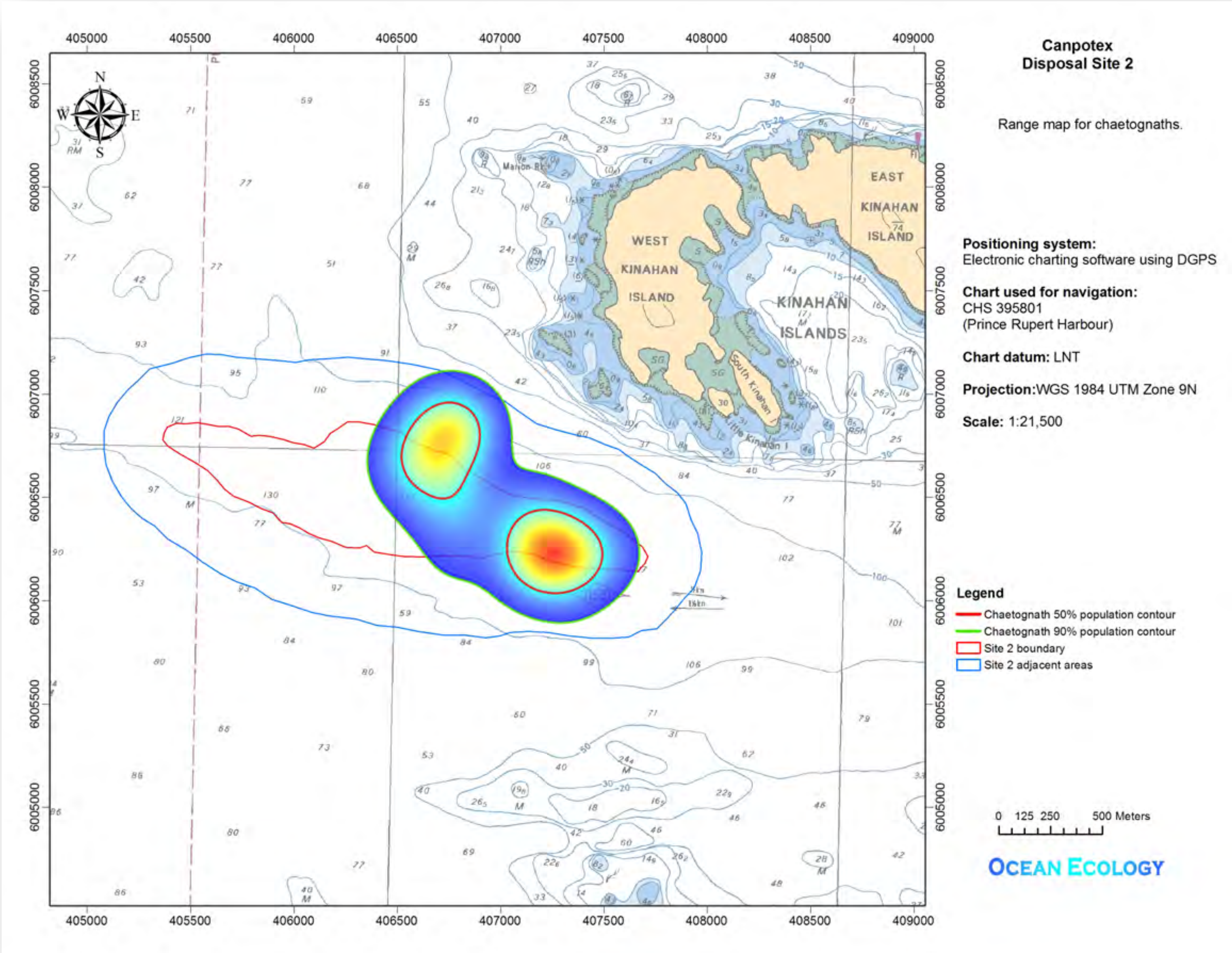

Figure 15. Range map for chaetognaths.

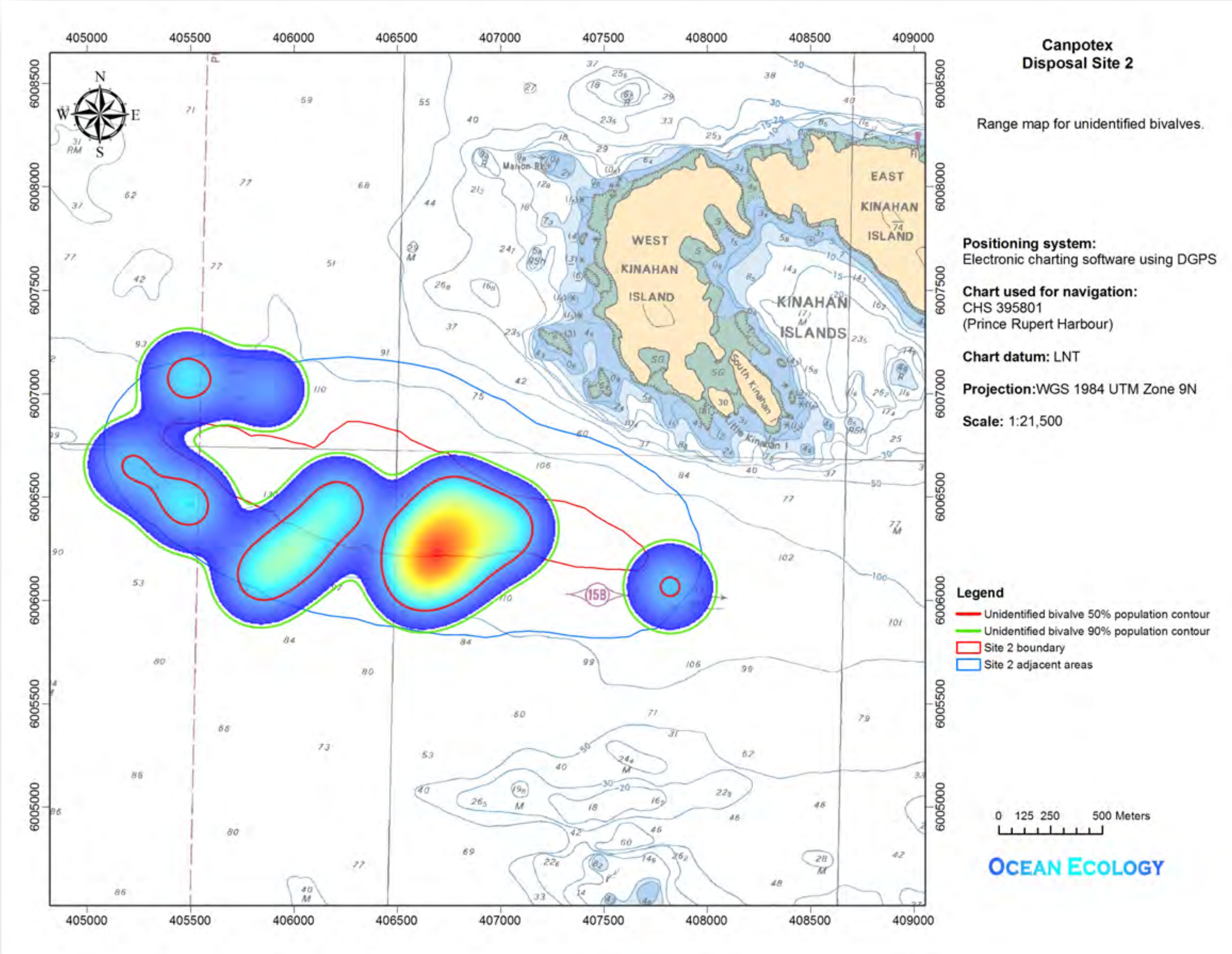

Figure 16. Range map for unidentified bivalves.

e. Larvaceans were distributed throughout the site. They were most abundant in the southeast region of the site (see Figure 17). Larvaceans filter feed on nanoplankton using a complex filter arrangement in a secreted, external mucous "house". The abundant plankton at Site 2 probably accounts for their presence at the site.

f. Spot prawns were located in a region near the northwest end of the site (see Figure 18). While relatively few spot prawns were seen using the drop camera, this was not unexpected, as spot prawns are highly mobile and will rapidly leave an area when startled. The camera will only record those prawns which do not become started when the lander impacts the sea floor. Thus, it is likely that the population of spot prawns was much higher than recorded by the drop camera.

g. Sea whips were only found at the northwest end of the site (see Figure 19). As the camera landed and lifted-off at drop 2-1, it was clear that the sea whip observed at this drop was part of a much larger field of sea whips. Thus, it is possible that sea whips may have a fairly extensive areal coverage at this end of the site.

h. A small number of unidentified amphipods were found throughout the site (see Figure 20). These crustaceans are relatively difficult to differentiate from krill when they are swimming rapidly, so it is quite likely that there were more of them than has been recorded.

i. A single unidentified brittlestar was observed towards the northwest end of the site (see Figure 21). Based on the previous macroinvertebrate study done at the site during November 21st, 2010, there is a good likelihood that this brittlestar belonged to the species *Amphiodia urtica*, *Amphioplus strongyloplax*, or *Ophiura luetkeni*.

j. A single unidentified seastar was observed near the center of Site 2 (see Figure 22).

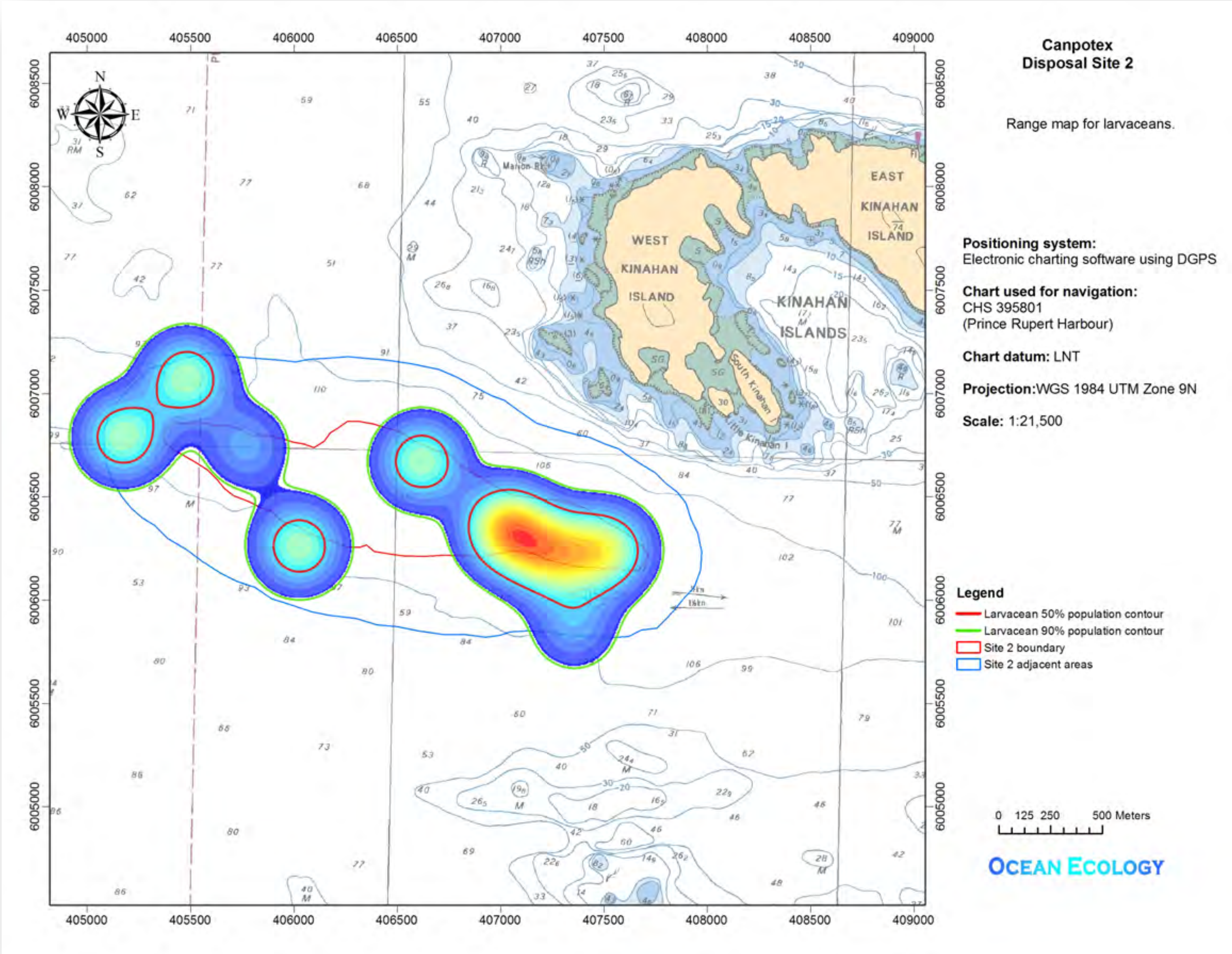

Figure 17. Range map for larvaceans.

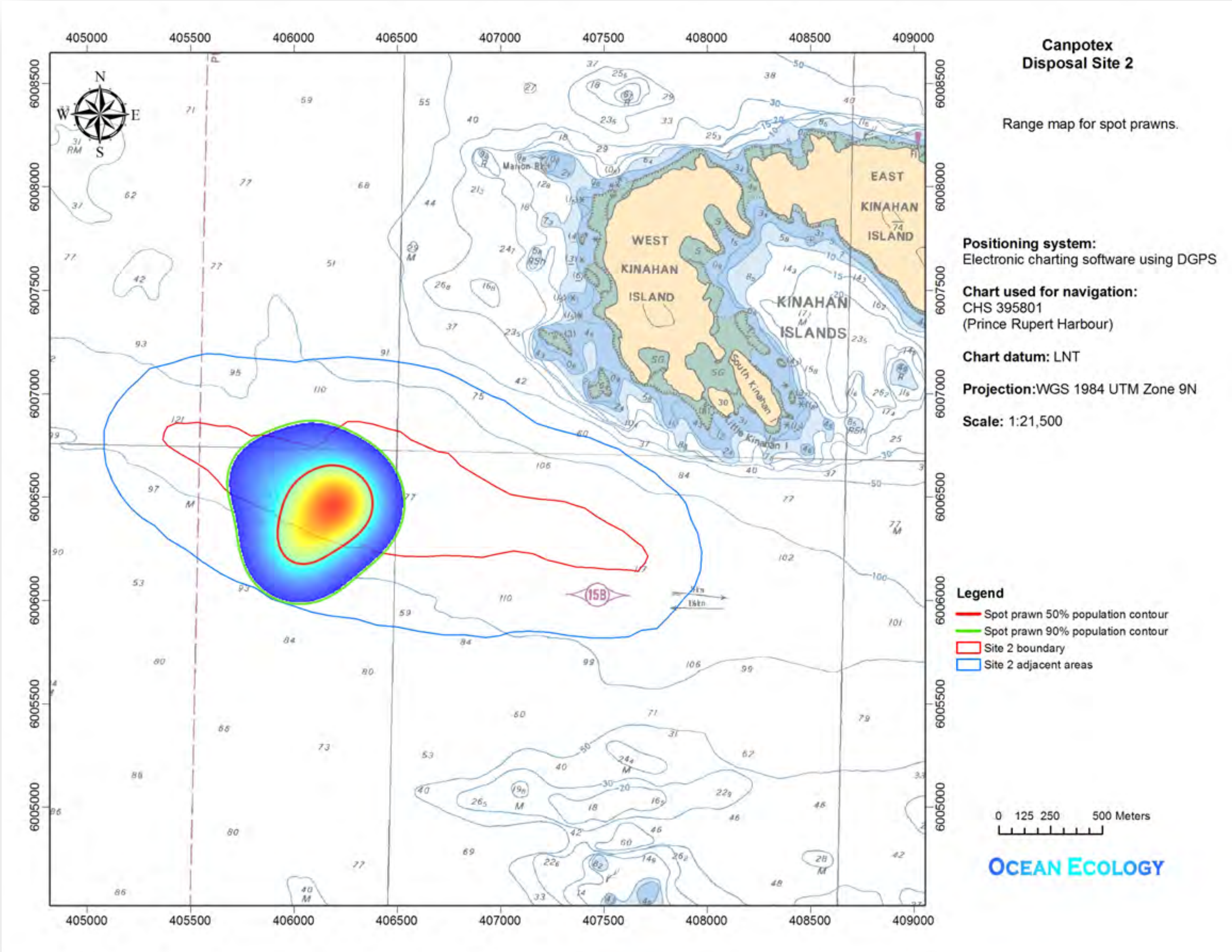

Figure 18. Range map for spot prawns.

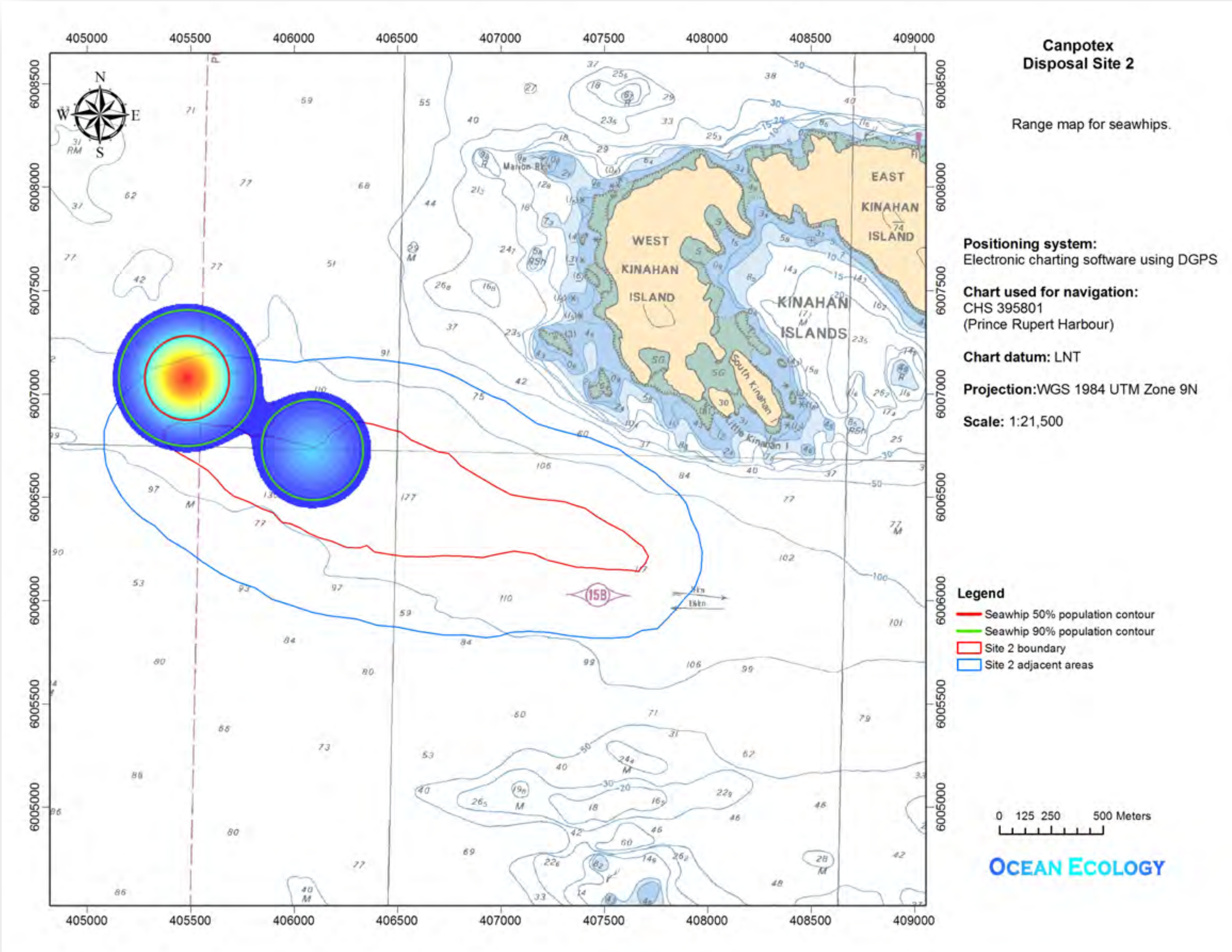

Figure 19. Range map for sea whips.

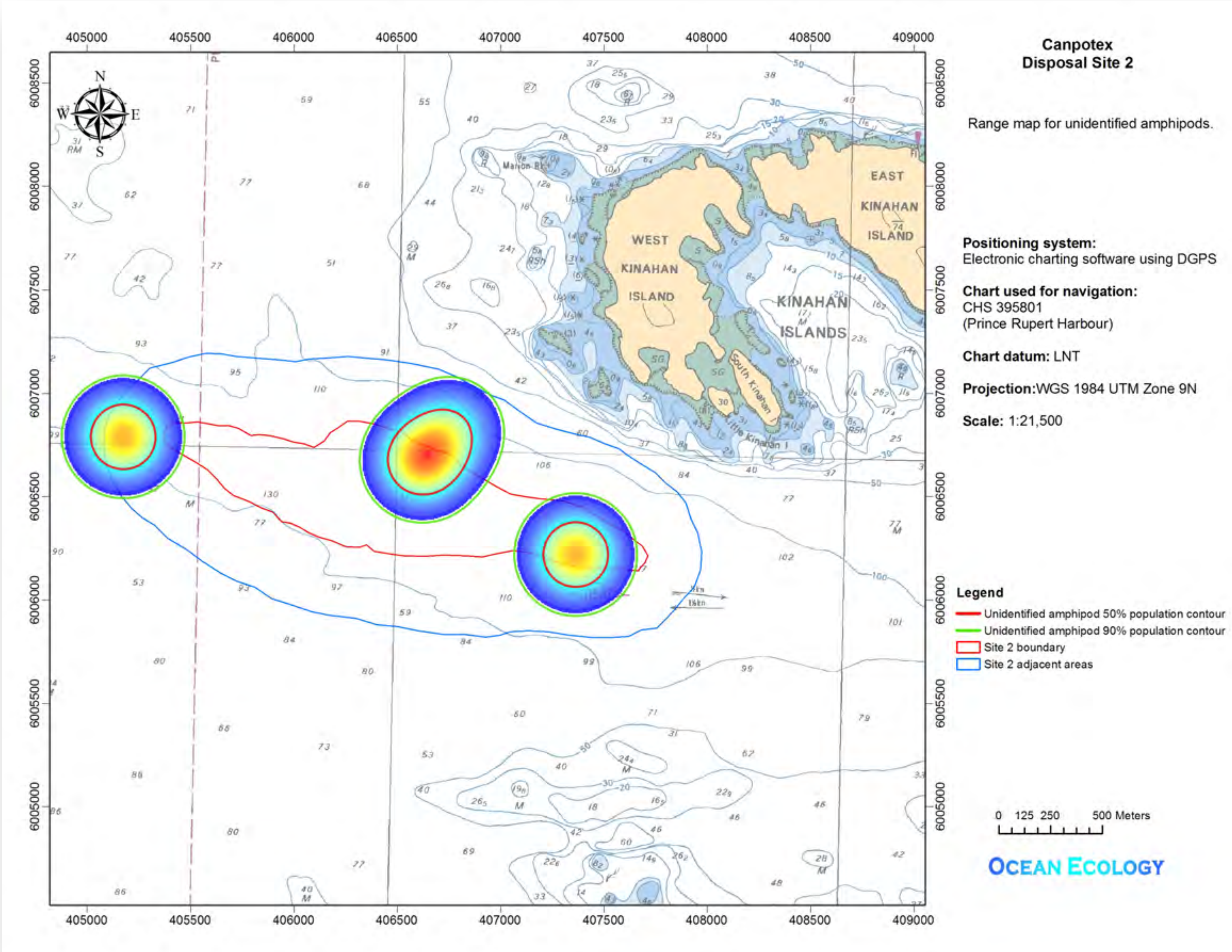

Figure 20. Range map for unidentified amphipods.

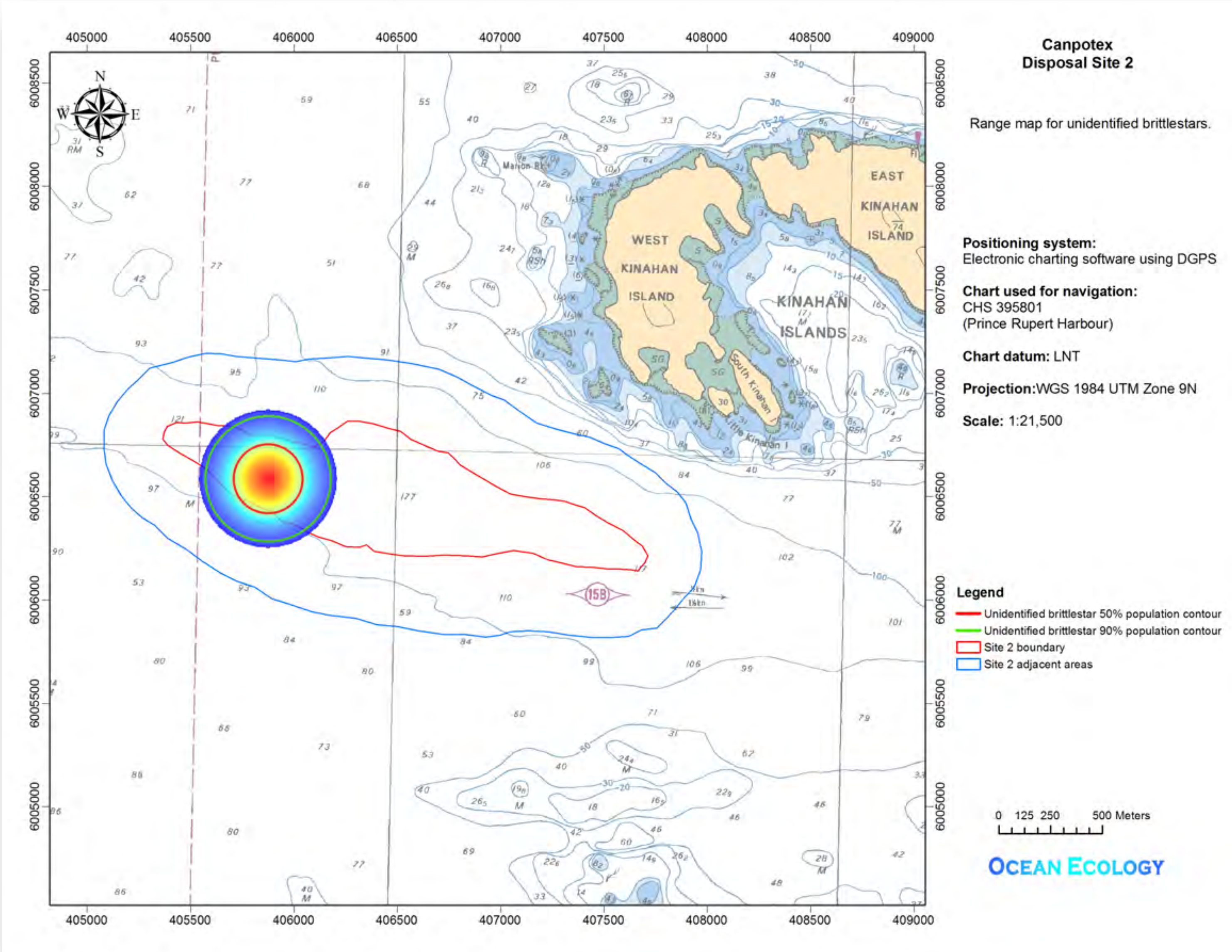

Figure 21. Range map for unidentified brittlestars.

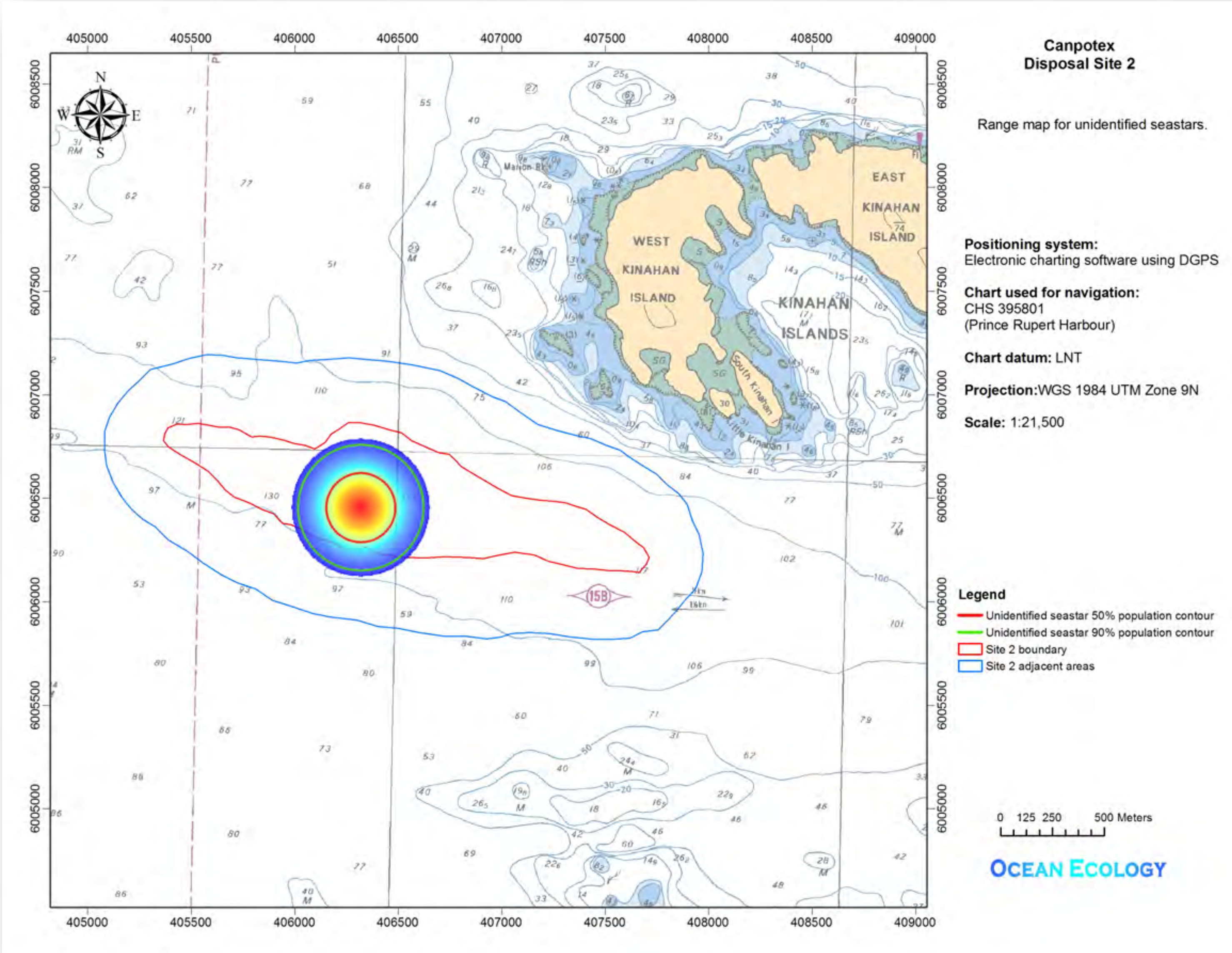

Figure 22. Range map for unidentified seastars.

3. The only commercial species observed at the site was spot prawns. Statistical data can be obtained from DFO regarding the aggregated prawn catch and effort for the years 2001 to 2004 in the region around Site 2. In order to prevent disclosure to a third party of confidential information that may prejudice the competitive position of a fisher, DFO used a 4 km x 4 km grid to protect exact fishing locations. The data for each grid cell was derived from a count of 3 or more vessels that were fishing within the same grid cell and within the same fishing season (DFO, 2011). The grid cells which are located in the vicinity of Site 2 are shown in Figure 23. The aggregated catch and effort values for these cells are given in Table 2.

   Table 2. Aggregated prawn catch and effort data in the vicinity of Site 2.

Grid Cell	Aggregated Prawn Catch (kg)	Aggregated Prawn Effort (hours soak time)
1	7674	6078
2	3786	2512
3	5440	4160
4	6330	3751

   The aggregated prawn catch and effort values in grid cell 1 are the highest values north of Banks Island.

3.3 Diversity Analyses

3.3.1 Diversity Indices

Due to the very large difference in areal coverage between the drop camera methodology (e.g., 9 m^2 at Site 2) and towed benthic video camera methodology (e.g., 3,950 m^2 at Site 1), the diversity indices from these two methodologies are not comparable. As a result of the reduced areal coverage of the drop camera system, fewer species will be observed, and diversity indices calculated from the data produced by this methodology will tend to be much lower than those calculated from data produced by the towed video system.

The overall Shannon’s diversity index for the site was 1.979, and the species richness was 10. If all organisms at Site 2 were completely evenly distributed (which would generate a maximum value for Shannon’s diversity index), the maximum possible diversity for the site would be 2.303. This suggests that the particular complement of species at this site is fairly close to reaching their maximum diversity. The Shannon’s evenness value of 0.860 also indicates that the species are relatively evenly distributed throughout the site (a value of 1.0 would indicate a completely even distribution).

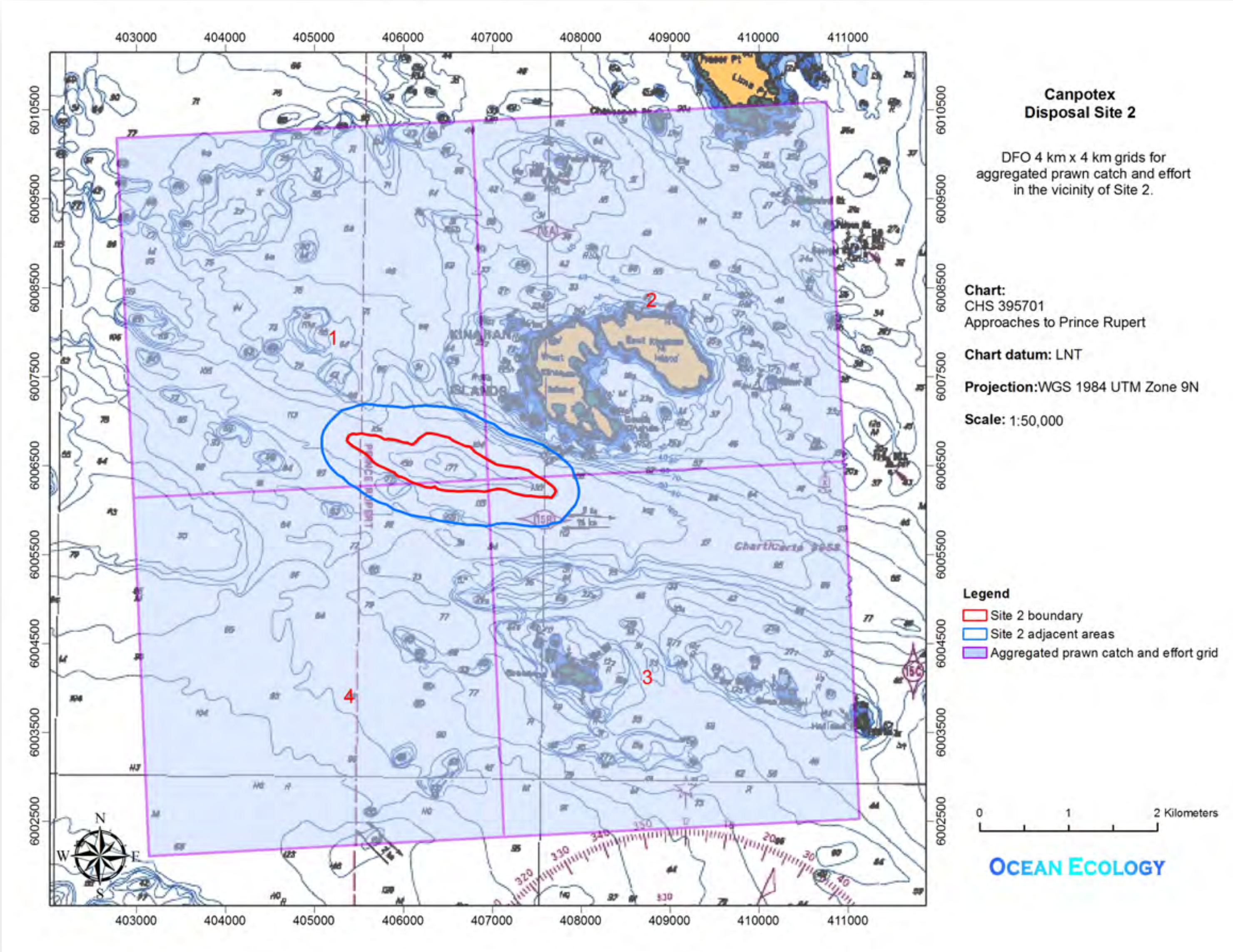

Figure 23. DFO 4 km x 4 km grids for aggregated prawn catch and effort in the vicinity of Site 2.

The site has a Simpson's dominance index of 0.323. The Simpson's dominance index approaches 1.0 as one particular species dominates the site. A value of 0.323 suggests that there is relatively little dominance by any species at the site.

Figure 24 shows the species richness map for the site. Species richness in each hexagonal polygon ranges from 0 to 7. Maximum species richness for the site occurred towards the northwest end of the site, and in the deeper regions of the site. Most likely these are the areas where the current flow is strongest and plankton abundance is greatest.

Figure 25 shows the overall organism abundance at the site. The greatest number of organisms occurred near the center of the site, just to the south of the central deep region.

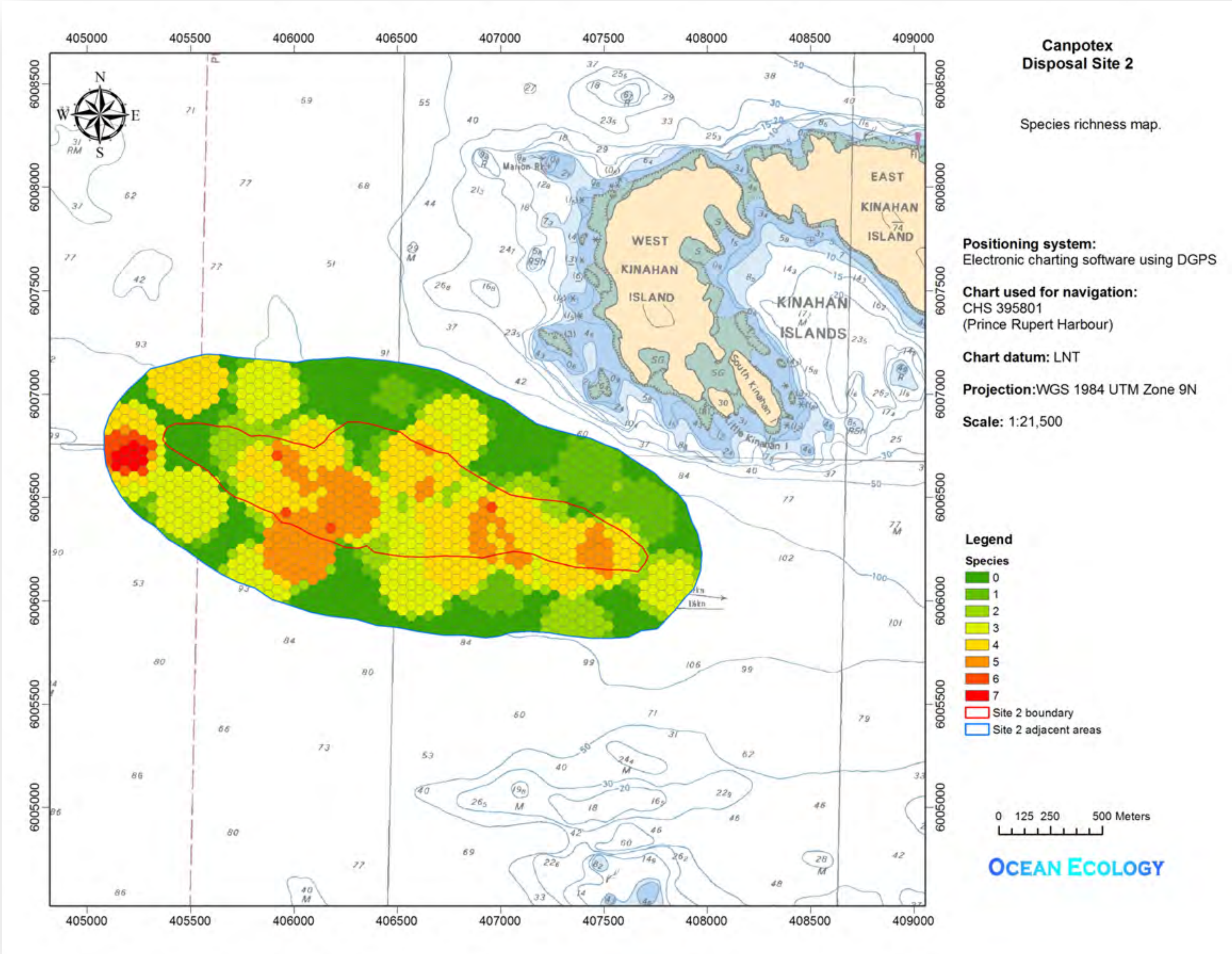

Figure 24. Species richness map.

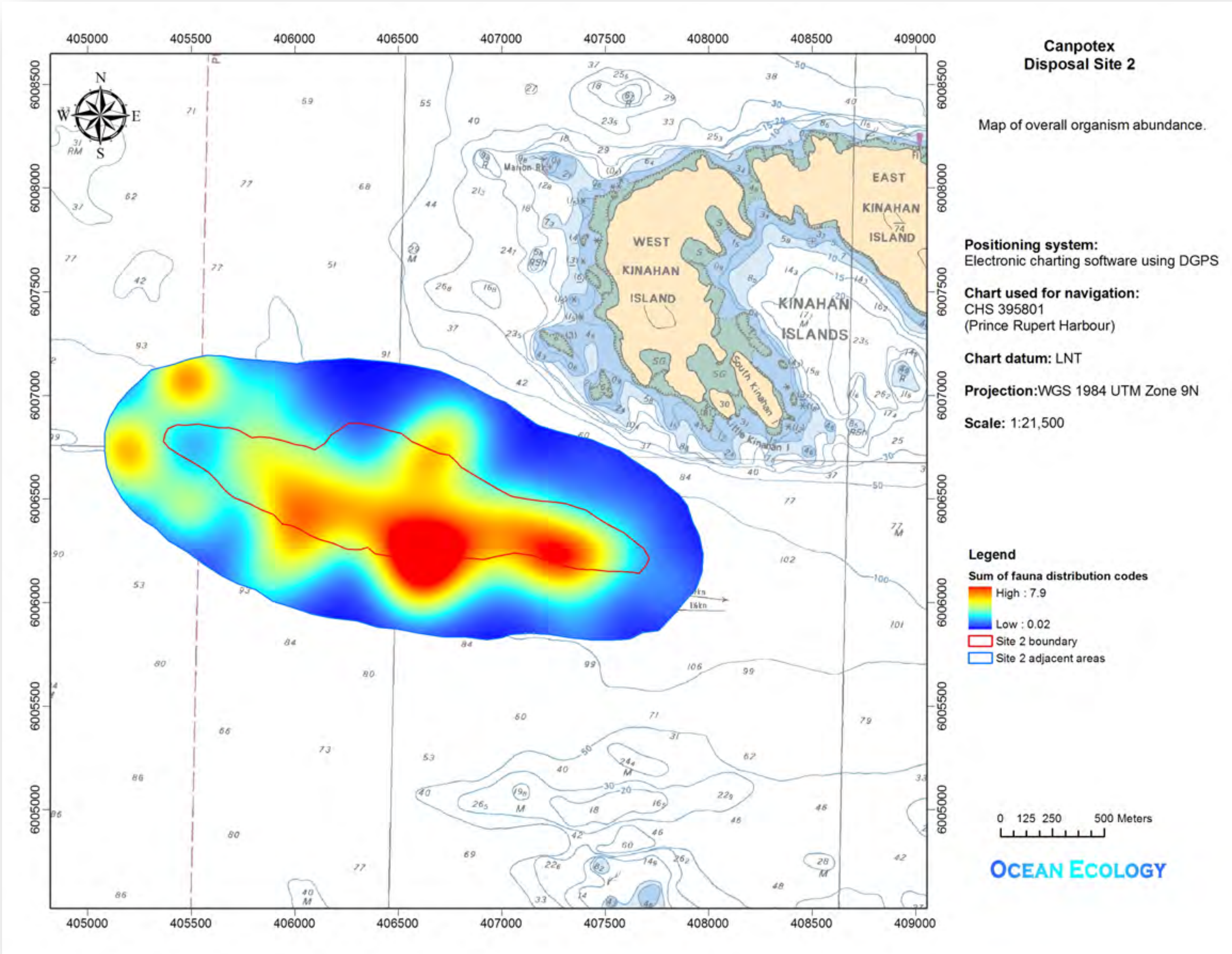

Figure 25. Map of overall organism abundance.

4 Project Deliverables

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

1. One DVD containing:.
    a. raw seabed video imagery* (overlaid with date and time) of the survey site.
    b. 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.
    c. a library of video* annotations
    d. a georeferenced, classified Access database* for biological and physical features of the seabed.
    e. an electronic ArcGIS project* containing maps of analyzed video data.
    f. a report describing and explaining the results of the video survey.

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

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6 Appendix

Table 3. Substrate type codes.

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

Table 4. Average particle size values.

Substrate Class/Subclass	Average Size (mm)
Rock	10000
Veneer over bedrock	10000
Boulder	512
Cobble	256
Pebble	64
Granules	4
Sand	2
Silt-mud	0.62
Shell	--
Organic debris	--
Wood debris	--
Anthropogenic	--

Table 5. Percentage substrate cover codes.

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

Table 6. Vegetation codes.

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

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

Table 7. Vegetation coverage codes.

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

Table 8. Fauna codes.

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

Species or Species Complex	Code	Description
Crabs	CRB	Unidentified crab.
	CAN	*Cancer* sp.
	DUN	Dungeness crab (*Cancer magister*).
	TAN	Tanner crab (*Chionoecetes* sp.).
	KCR	Kelp crab (*Pugettia* sp.).
	BXC	Box crab (*Lopholithodes foraminatus*).
	BXC	Box crab (*Lopholithodes foraminatus*).
	HEC	Helmet crab (*Telmessus cheiragonus*).
	SQT	Squat lobster (*Munida quadraspina*).
Shrimps (Pandalid)	PAN	Unidentified pandalid.
	PRN	Spot prawn (*Pandalus platyceros*).
	PNB	Spiny pink shrimp (*Pandalus borealis*).
	PNH	Humpback shrimp (*Pandulus hypsinotus*).
Ghost and mud shrimps	GHS	Ghost shrimp (*Callianassa californiensis*).
	MDS	Mud shrimp (*Upogebia pugettensis*).
Other crustaceans	EUP	Krill (*Euphasia pacifica*).
	AMP	Unidentified amphipod.
Gastropods	WHK	Unidentified whelk.
	ELI	Eelgrass limpet (*Lottia alveus paralella*).
	NUC	Dogwinkle (*Nucella* sp.).
	CDV	Carinate dovesnail (*Alia carinata*)
	TBI	Threaded bittium (*Bittium eschrichtii*)
	MOO	Moon snail (*Euspira lewisii*).
	WLN	White-lined nudibranch (*Dirona albolineata*).
	TOT	Orange-peel nudibranch (*Tochuina tetraquetra*).
	SNU	Striped nudibranch (*Armina californica*).
Bivalves	MUS	Mussel bed (*Mytilus trossulus*).
	GCL	Geoduck clam (*Panopea abrupta*).
	HCL	Horseclam (*Tresus* sp.).
	PCL	Piddock clam.
	BCL	Butter clam (*Saxidomas gigantea*).
	COC	Nuttall's cockle (*Clinocardium nuttallii*).
	SFC	Softshell clam (*Mya* sp.).
	OYS	Oyster.
	OCL	Other clam species.
	SCA	Scallop (*Chlamys* sp.)
	TER	Teredo worm (*Bankia setacea*).
	BIV	Unidentified bivalve.
Octopus	OCT	Pacific octopus (*Octopus*).

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

Species or Species Complex	**Code**	**Description**
Chaetognath	CGN	Chaetognath (*Sagitta* sp.).
Larvacean	LVN	Larvacean (*Oikopleura* sp.).
Fish	FSH	Unidentified fish.
	SAL	Unidentified salmonid.
	ELP	Unidentified eelpout (Zoarcidae).
	POA	Unidentified poacher.
	PSP	Pacific snake prickleback (*Lumpenus sagitta*).
	TUS	Tubesnout (*Aulorhynchus flavidus*).
	GBE	Black-eyed goby (*Coryphoterus nicholsi*).
	PLP	Pile perch (*Rhacochilus vacca*).
	PST	Striped perch (*Embiotica lateralis*).
	SHP	Shiner perch (*Cymatogaster aggregata*).
	FTF	Unidentified flatfish.
	STF	Starry flounder (*Platichthys stellatus*).
	RKS	Rock sole (*Lepidopsetta bilineata*).
	RFS	Unidentified rockfish.
	BRF	Black rockfish (*Sebastes melanops*).
	NRK	China rockfish (*Sebastes nebulosus*).
	CRK	Copper rockfish (*Sebastes caurinus*).
	QRF	Quillback rockfish (*Sebastes maliger*).
	TRF	Tiger rockfish (*Sebastes nigrocinctus*).
	YRF	Yelloweye rockfish (*Sebastes ruberrimus*).
	GLG	Unidentified greenling (Hexagrammid).
	KGR	Kelp greenling (*Hexagrammos decagrammus*).
	LNG	Lingcod (*Ophiodon elongatus*).
	SCU	Unidentified sculpin (Cottidae).
	NRN	Northern ronquil (*Ronquilus jordani*).
	RAT	Ratfish (*Hydrolagus colliei*).
	BSK	Big skate (*Raja binoculata*).
	LSK	Longnose skate (*Raja rhina*)
Unknown	UNK	Macro fauna visible but cannot be identified.
No Fauna	NOF	No fauna observed.

Table 9. Faunal distribution classes.

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

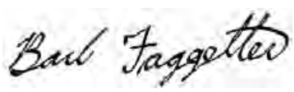
7 Disclaimer

The findings presented in this report are based upon data collected during the days July 6^{th} and July 7^{th}, 2011 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 Stantec, pursuant to the agreement between Ocean Ecology and Stantec. 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.

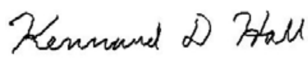
Any questions concerning the information or its interpretation should be directed to the undersigned.

Prepared By:



Barb Faggetter, Ph.D
Oceanographer, R.P.Bio.

Reviewed By:



Kennard Hall, Captain
Partner, Ocean Ecology