Characterization of the Corals and Sponges of the Eastern Scotian Slope from a Benthic Imagery Survey

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A benthic imagery survey was conducted along the Eastern Scotian Slope in June 2018 to collect data in support of a Strategic Program for Ecosystem-Based Research and Advice project to evaluate the effectiveness of the *Lophelia* Coral Conservation Area and identify new areas of importance for benthic species that may qualify for protection under Fisheries and Oceans Canada's 2009 Policy for Managing the Impact of Fishing on Sensitive Benthic Areas. Linear video and photographic transects from ~200 to 1000 m depth were collected at 10 stations between the Gully Marine Protected Area and the *Lophelia* Coral Conservation Area using the video and photographic camera system Campod and the '4K Camera' drop camera system. Here we present a quantitative assessment of the corals and sponges observed at each of these 10 stations. Patterns in distribution by transect and depth are presented, as well as the relationship between coral distribution and groundfish fishing effort. We highlight the importance of the slope outside the canyons for the distribution of corals and sponges, where nearly 25 taxa were recorded between 167 – 970 m depth. Diversity and abundance appeared to show a west-to-east gradient across the study area, being highest on those stations adjacent to the *Lophelia* Coral Conservation Area. Groundfish fishing activity overlapped the distribution of corals and sponges in some parts of the study area, particularly between 200 and 500 m where the large branching corals *Paragorgia arborea* and *Primnoa resedaeformis* were observed, and also suggested that fishing may have taken place within the boundaries of the *Lophelia* Coral Conservation Area since its implementation in 2004. An extension of the boundaries of this closure may ensure its continued effectiveness and provide protection for the diverse and abundant coral and sponge communities that reside beyond its boundaries.

RÉSUMÉ

Beazley, L., Lirette, C., and Guijarro, J. 2019. Characterization of the corals and sponges of the Eastern Scotian Slope from a benthic imagery survey. Can. Tech. Rep. Fish. Aquat. Sci. 3302: vi + 83 p.

Un relevé photographique benthique a été effectué le long de l’est du talus néo-écossais en juin 2018 afin de recueillir des données pour appuyer un projet du Programme stratégique de recherche et d’avis fondés sur l’écosystème visant à évaluer l’efficacité de la zone de conservation des coraux *Lophelia* et à déterminer de nouvelles zones importantes pour les espèces benthiques qui pourraient être protégées en vertu de la Politique de gestion de l’impact de la pêche sur les zones benthiques vulnérables adoptée par Pêches et Océans Canada en 2009. Des transects vidéo et photographiques linéaires d’une profondeur d’environ 200 à 1 000 m ont été recueillis à 10 stations entre la zone de protection marine du Gully et la zone de conservation des coraux *Lophelia* à l’aide du système de caméras vidéo et photographiques Campod et du système de caméra lestée « caméra 4K ». Nous présentons ici une évaluation quantitative des coraux et des éponges observés à chacune de ces 10 stations. Nous présentons les modèles de distribution par transect et par profondeur, ainsi que la relation entre la répartition des coraux et l’effort de pêche du poisson de fond. Nous soulignons l’importance du talus à l’extérieur des canyons pour la répartition des coraux et des éponges, où presque de 25 taxons ont été enregistrés entre 167 et 970 m de profondeur. La diversité et l’abondance semblaient montrer un gradient d’ouest en est à travers la zone d’étude, les stations adjacentes à la zone de conservation des coraux *Lophelia* étant les plus élevées. L’activité de pêche du poisson de fond a chevauché la répartition des coraux et des éponges dans certaines parties de la zone d’étude, en particulier entre 200 et 500 m, où les grands coraux arborescents *Paragorgia arborea* et *Primnoa resedaeformis* ont été observés, et suggère également que de la pêche a pu avoir lieu dans les limites de la zone de conservation des coraux *Lophelia* depuis son implantation en 2004. Un prolongement des limites de cette fermeture pourrait assurer son efficacité continue et assurer la protection des communautés diversifiées et abondantes de coraux et d’éponges qui résident au-delà de ses limites.

INTRODUCTION

In 2009, Fisheries and Oceans Canada (DFO) published the Policy for Managing the Impact of Fishing on Sensitive Benthic Areas (http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/benthi-eng.htm), with the purpose of aiding DFO to "mitigate impacts of fishing on sensitive benthic areas or avoid impacts of fishing that are likely to cause serious or irreversible harm to sensitive marine habitat, communities and species". The Policy (herein referred to as the SeBA Policy, *sensu* DFO (2017a)) outlines a series of guidelines for which historically fished and frontier areas be assessed to address the impacts of fishing on sensitive benthic areas:

1. Assemble and map existing data and information that would help determine the extent and location of benthic habitat types, features, communities and species; including whether the benthic features (communities, species and habitat) situated in areas where fishing activities are occurring or being proposed are important from an ecological and biological perspective;

2. Assemble and map existing information and data on the fishing activity;

3. Based on all available information, and using the Ecological Risk Analysis Framework, assess the risk that the activity is likely to cause harm to the benthic habitat, communities and species, and particularly if such harm is likely to be serious or irreversible;

4. Determine whether management measures are needed, and implement such management measures; and,

5. Monitor and evaluate the effectiveness of the management measure and determine whether changes are required to the management measures following this evaluation.

Although the SeBA Policy could be applied to various benthic species and habitats, it is currently focused on communities dominated by deep-water corals and sponges as they are recognized as key habitat-forming species vulnerable to fishing impacts (FAO 2009), and are relatively well understood from a management perspective due to international efforts to protect these species (DFO 2013).

In March 2016, a Canadian Science Advisory Secretariat (CSAS) national peer review meeting was held in Halifax, Nova Scotia, on the "Delineation of Significant Areas of Coldwater Corals and Sponge-Dominated Communities in Canada's Atlantic and Eastern Arctic Marine Waters and their Overlap with Fishing Activity" (see DFO 2017b). During this process, Significant Benthic Areas (SBAs) of deep-water corals and sponges were defined using both kernel density estimation (KDE) and species distribution modelling (SDM) techniques in support of the SeBA Policy (Kenchington et al. 2016a). While the percent overlap between the SBAs and fishing activity was calculated, a risk assessment of the impacts of fishing was not conducted (Step 2 and 3 of the SeBA Policy's guidelines). Such an assessment would allow for identification and prioritization of SBAs for which mitigation measures could be applied.

Consideration of these SBAs in conservation planning came shortly thereafter during an initiative to identify a draft network of marine protected areas (MPAs) in domestic waters. In order to meet Canada's commitments under the Aichi Biodiversity Targets to protect 10% of coastal and marine areas by 2020, DFO, with consultation from other government departments, First Nations, Indigenous organizations, and stakeholders, is currently leading the development of a network of MPAs, to be implemented independently in five priority bioregions across the country. One of these is the Scotian Shelf Bioregion, which generally coincides with the DFO Maritimes Region administrative boundary. Development of the draft MPA network design for this region is being led by the Ocean and Coastal Management Division (OCMD). The data layers considered for use in the draft MPA network design were presented during a CSAS meeting held in Halifax, N.S. in 2016 (DFO 2018). Here, the 2016 coral and sponge SBAs were identified as important conservation priorities for the network. Subsequently, these data layers were assigned conservation targets and used in the conservation planning software MARXAN to identify a draft network of areas for further refinement.

On March 22, 2018, the Minister of Fisheries and Oceans Canada announced three new potential marine conservation measures off Nova Scotia selected from the draft MPA network design for the Maritimes Region: the Eastern Shore Islands Area of Interest (AOI), the Fundian Channel-Browns Bank AOI, and the Eastern Canyons Proposed Conservation Area (http://www.dfo-mpo.gc.ca/oceans/conservation/news-nouvelles/2018-03-21/index-eng.html). The Eastern Shore Islands and Fundian Channel-Browns Bank AOIs represent areas of future MPA designation under the *Oceans Act*, while the Eastern Canyons Proposed Conservation Area is considered an Other Effective Area-Based Conservation Measure (OECM) to be designated under the *Fisheries Act*. Located approximately 60 km southeast of Sable Island, the Eastern Canyons Proposed Conservation Area is situated along the shelf break and slope off Banquereau Bank between the Gully MPA and the Stone Fence, and extends south over the abyssal plain to meet Canada's Exclusive Economic Zone (EEZ). In its current proposed extent the area encompasses approximately 36,000 km^2 (https://www.canada.ca/en/fisheries-oceans/news/2018/03/three-new-potential-marine-conservation-measures-announced-off-the-coast-of-nova-scotia.html). This area was selected from the broader draft MPA network to represent various biological features and geomorphic habitats typically found in slope and abyssal environments. Most notably, this proposed conservation area encompasses both Shortland and Haldimand canyons, as well as the *Lophelia* Coral Conservation Area (LCCA), for which aggregations of deep-water corals have been previously identified (Cogswell et al. 2009), therefore qualifying it for protection under the SeBA policy. These canyons have collectively been identified as an Ecologically and Biologically Significant Area (EBSA) referred to as the 'Eastern Scotian Shelf Canyons' for its significant coral habitat, northern bottlenose whale occurrences, and important habitat for commercially harvested fish species (King et al. 2016). The proposed closure also represents several geomorphic features, including the Eastern Scotian Slope, Scotian Rise, Gully Fan, Laurentian Fan, and the Scotian Rise Debris Flow (Stortini 2015).

On the slope between these canyons, and particularly between Haldimand Canyon and the LCCA, little data exists on the distribution of deep-water corals and sponges. During the 2016 CSAS process to identify coral and sponge SBAs, a SBA for large gorgonian corals was delimited along the slope between Haldimand Canyon and the LCCA using kernel density estimation (KDE) analysis on large gorgonian coral catch data from DFO's multispecies trawl survey. This KDE-derived area was assessed against a species distribution model developed to model the probability of occurrence of large gorgonian corals, which unlike KDE, incorporates information on environmental correlates. However, little to no *in situ* data has been collected within this SBA, which would be useful in identifying finer-scale depth distributions, biodiversity, and species associations within its boundaries.

As part of a current Strategic Program for Ecosystem-Based Research and Advice (SPERA) project to evaluate the 'Effectiveness of a Coral Conservation Area after a Decade of Closure to Bottom-Contact Fishing Gears and Exploration of Coral Community Distribution for Significant Benthic Area Planning', an optical camera survey was conducted along the Eastern Scotian Slope and within the Eastern Canyons Proposed Conservation Area using the newly refurbished video camera system Campod and the 4K Camera. Ten stations along the slope to the east of the Gully MPA and over to and including the LCCA (see Figure 1) were surveyed to A) evaluate the effectiveness of the LCCA management measure through documentation of recruitment and recovery of the reef-building coral *Lophelia pertusa*, B) validate the large gorgonian coral Significant Benthic Area that encompasses the LCCA and the slope to the west of the closure (Figure 1), and identify new areas along the slope that may qualify for protection under the SeBA Policy. Here we present a quantitative assessment of the coral and sponge taxa observed at these 10 stations in support of objective B) to validate the large gorgonian coral SBA and identify new areas that would qualify for protection under the SeBA Policy. A secondary objective of this SPERA project to assess whether fishing activity has potentially occurred inside the LCCA through observable damage to the benthos was also assessed herein. The video and photographic data collected at each station were analyzed for the abundance of large and small gorgonian corals, sea pens, and large-sized sponges. Habitats formed by significant concentrations of these taxa are considered SBAs in the context of DFO's SeBA Policy (DFO 2017b), and formed the coral and sponge functional group units for which KDE analyses were applied to identify SBAs (Kenchington et al. 2016a, DFO 2017b). The large gorgonian coral SBA was evaluated in terms of its species composition, and the spatial and depth distribution of observations. This information will serve to identify important areas for deep-water corals and sponges along the Eastern Scotian Slope, particularly outside the canyons in areas not previously surveyed, and may provide useful information for delimiting boundaries of any future management measure for the area.

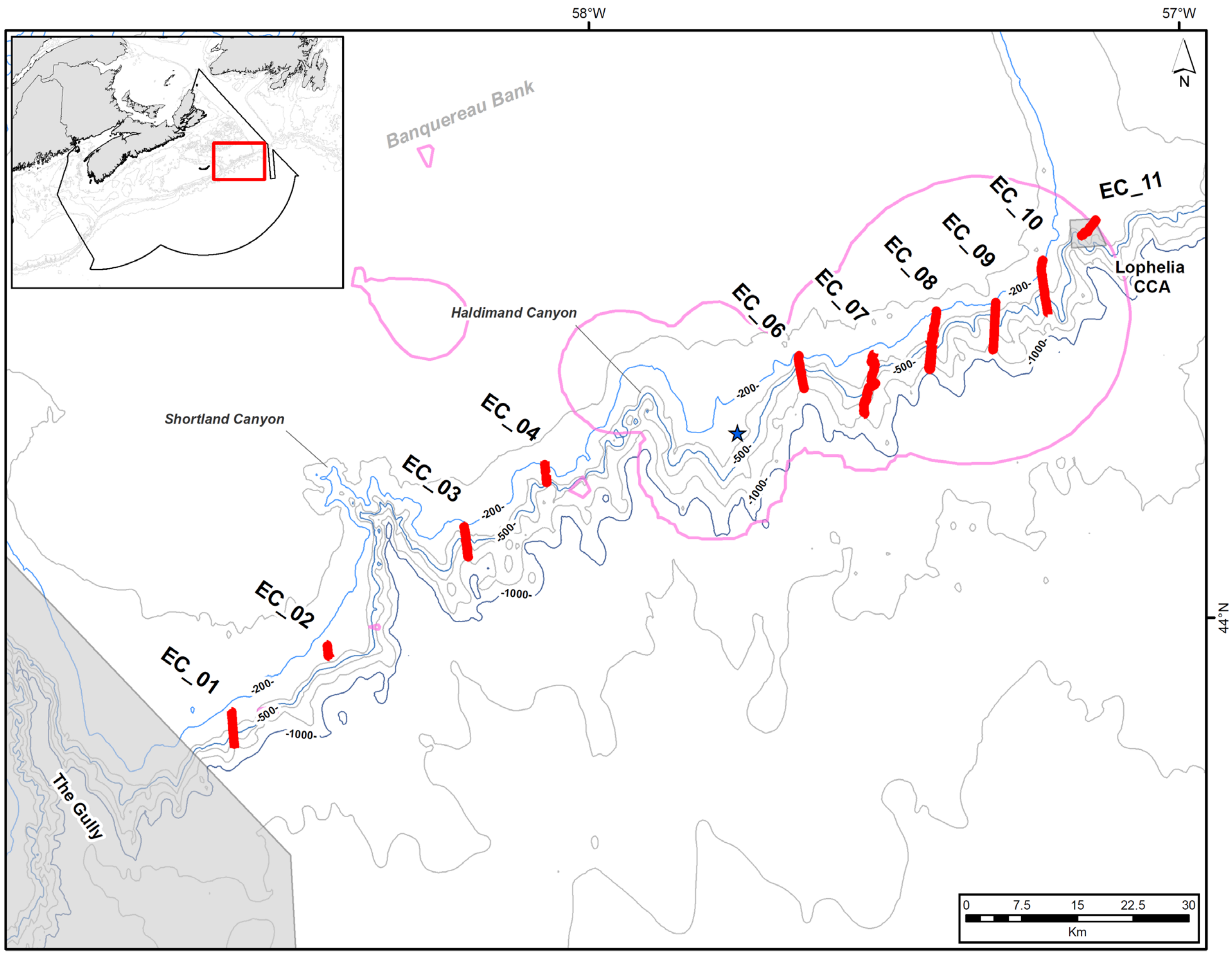

Figure 1. Map showing the location of stations where video and/or photographic data were collected using the Campod and 4K Camera systems. Red lines represent transects at each station. Also shown is the large gorgonian coral Significant Benthic Area polygons (in pink) identified during the 2016 CSAS process (see DFO 2017b). Blue star represents the approximate location of station EC_05, which was planned but not completed due to inclement weather. Table 1 shows the properties of each of the 10 stations.

METHODOLOGY

Data Collection

Benthic video and photographic transects were collected at 10 different stations along the Eastern Scotian Slope between June 25 and 29, 2018 onboard the Canadian Coast Guard Ship *Hudson*. The video and photographic camera system Campod was planned for use at all stations, but due to equipment failures the ‘4K Camera’ drop camera system was deployed on sections of some stations. Campod is a tripod camera system that is controlled on deck via a winch, and drifts along the seabed collecting continuous forward- and downward-facing video and digital still images. Campod’s forward-facing video camera is a DeepSea Power and Light HD Multi SeaCam with Dome Port (HDMSC-3145), the downward-facing camera a Sony HDC-P1, and the downward digital still camera a Nikon D810. Digital still images were collected at ~1-minute intervals when the Campod system was landed on the seabed. Campod has a pair of 10-cm scaling lasers for taking measurements, an altitude package to record the altitude of the system, and an attached SeaBird 39 pumping CTD (SBE 39), which allowed for the collection of depth and temperature at the vehicle’s location. Video feed, digital still images, altitude, and the SBE data are fed in real time to the operating system on deck via a fibre optical cable. The maximum depth capacity of Campod is ~1000 m.

The 4K Camera is capable of photographic acquisition only, and is operable to 4000 m (4 kilometres, hence its name ‘4K’) depth. The system houses a high-resolution EOS Rebel SL1 digital still camera and two flashes inside an aluminum roll cage, and drifts over the seabed until it is lowered via a winch until a trigger weight touches the seabed and triggers the flash and camera to take a picture. There is no live feed to the surface, and the images are downloaded upon recovery. This blind capture technique reduces bias in image acquisition which may be desirable for some applications.

The location of both Campod and the 4K Camera were tracked using a Nexus 2 Console Model 2692 USBL tracking system and attached beacon, rented from Romor Ocean Solutions in Mount Uniacke, Nova Scotia.

Data collection was planned at a total of 11 stations in the study area, with 10 located along the slope between the Gully MPA and the LCCA and one inside the LCCA. Due to inclement weather, one station along the slope (EC_05; Figure 1) was not sampled, resulting in data collection at only 10 stations. Linear transects were designed to sample across contours, starting at the ~200 m contour and surveying to ~1000 m depth or until coral and sponge observations diminished. Contours derived from 500-m bathymetry from the Canadian Hydrographic Service (CHS) Atlantic Bathymetry Compilation (ABC) were used for planning purposes. Vessel drift and inaccurate contour depths resulted in a variable, sometimes deeper than intended start depth on some transects, and so deployment of the camera systems was started at slightly shallower depths for subsequent transects. Table 1 shows the gear, overall depth range, objectives and comments for each station. The minimum and maximum depth, instead of start and end depth of each transect are shown due to the highly variable topography of the area. Stations were named with a unique number and the 'EC' prefix (e.g. EC_01), an abbreviation of 'Eastern Canyons'. A detailed description of the data collected at each station, including start/end coordinates, on bottom time, etc., are given in Appendix 1.

Video Analysis

Deep-water corals and sponges were enumerated from the downward-facing Campod video using the in-house software ClassAct Mapper, version 3.24, designed by Robert Benjamin of the Bedford Institute of Oceanography in Dartmouth, NS. ClassAct Mapper decodes navigational data embedded in the video as audio signals into GMT (time), latitude, and longitude. Customized buttons allow for entry of the taxonomic identity of fauna as they are observed in the video. Once a taxon button is selected, the species identification, GMT, and coordinates are entered into a Microsoft Access database linked to ClassAct Mapper.

Although the forward-facing video gives a greater view of the seabed due to the wide-angle lens of its camera, the ability to detect smaller organisms in the forward-facing video was considered more difficult compared to the downward video due to the inconsistent lighting and poorer resolution of the former. Therefore only the downward-facing video was analyzed for this study. Video footage was viewed in VLC version 3.0.3. Identification of taxa was aided by examination of high-resolution digital still images that were collected at approximately 1-minute intervals throughout the transects.

Only those large and small gorgonian corals, sea pens, and sponges that are considered vulnerable marine ecosystem (VME) indicators by the Northwest Atlantic Fisheries Organization (NAFO) (see Annex 1.E. of the 2018 NAFO Conservation and Enforcement Measures (CEM); NAFO 2018) were recorded from the video. These taxa formed the coral and sponge functional group units for which the SBAs were designated (Kenchington et al. 2016b, DFO 2017b). The tube-dwelling anemone *Pachycerianthus borealis*, which is also considered a VME indicator and abundant in the study area, was also enumerated. Other taxa not found in the NAFO CEM but thought to be indicative of VMEs and sensitive benthic areas (e.g. other or unknown sea pen species) were also recorded. These taxa often could not be identified beyond the order level. Other unidentified sponge species thought to be indicative of VME (defined here as erect sponges with a growth form that is more vertical than lateral, with an estimated height above bottom > 10 cm) were also recorded as 'large-sized sponges'. The World Register

Table 1. Gear, depth range (minimum and maximum depth sampled), and the objective of the Campod and 4K Camera transects collected at 10 stations on the Eastern Scotian Slope. CON = Consecutive Operation Number, a unique identifier for each gear deployment. Multiple gear deployments occurred at some stations. EC_05 was not completed due to inclement weather. LCCA = *Lophelia* Coral Conservation Area, SBA = Significant Benthic Area.

Station	Gear	Min - Max Depth (m)	Objective	Comments
EC_01	4K Cam (CON 026) Campod (CON 027)	236 - 345 (CON 026) 320 - 828 (CON 027)	Collect data on the distribution of corals between Shortland Canyon and the Gully where no data has been previously collected.	Failure of Campod before launch; Station partially sampled using the 4K Cam.
EC_02	Campod (CON 028)	220 - 410	Collect data on the distribution of corals between Shortland Canyon and the Gully. Targets large gorgonian coral records from the NOAA Deep-Sea Coral Data Portal.	Campod recovered early due to deteriorating weather conditions, resulting in 26 hours lost.
EC_03	Campod (CON 029)	265 - 916	Collect data on the distribution of corals between Shortland and Haldimand Canyons. Targets a *Keratoisis* record from the commercial fishery.	
EC_04	Campod (CONs 30 & 31)	140 - 313 (CON 030) 363 - 511 (CON 031)	Collect data on the distribution of corals between Shortland and Haldimand Canyons where no has been previously collected.	Entanglement of Campod in discarded fishing gear. Campod recovered and redeployed to complete the transect.
EC_05			Collect data on the distribution of corals within the large gorgonian SBA. Targets a significant catch of *Keratoisis* and other coral records.	Station not sampled due to lost time from inclement weather.
EC_06	Campod (CON 032)	332 - 881	Collect data on the distribution of corals within the large gorgonian SBA. Targets an area that potentially represents a small canyon or channel (tight contours).	
EC_07	Campod (CON 033)	293 - 860	Collect data on the distribution of corals within the large gorgonian SBA. Targets significant catches of *Paragorgia* and *Keratoisis* from DFO's multispecies trawl survey.	

EC_08	Campod (CON 034) 4K Cam (CON 035) Campod (CON 036)	185 - 419 (CON 034) 154 - 927 (CON 035) 369 - 468 (CON 036)	Collect data on the distribution of corals within the large gorgonian SBA. Targets significant catches of *Paragorgia*, *Primnoa*, and *Keratoisis* from DFO's multispecies trawl survey.	Recovery of Campod due to power failure part way through transect. Transect completed using the 4K Cam. Campod re-deployed at location of suspected *Paragorgia*.
EC_09	Campod (CON 037)	187 - 971	Collect data on the distribution of corals within the large gorgonian SBA. Targets significant catches of *Paragorgia*, *Primnoa*, and *Keratoisis* from DFO's multispecies trawl survey.	
EC_10	Campod (CON 038)	163 - 835	Collect data on the distribution of corals within the large gorgonian SBA. Targets a significant catch of *Primnoa* from DFO's multispecies trawl survey.	
EC_11	Campod (CON 039)	255 - 435	Explore area for fishing disturbance, collect video/photo data of the *Lophelia pertusa* reef for documentation of recovery.	

of Marine Species (WoRMS, http://www.marinespecies.org/) was used as the taxonomic authority.

The reef-building coral *Lophelia pertusa* was encountered and enumerated from video data collected in the LCCA. Although *L. pertusa* is considered a VME indicator species, data on its distribution were not presented here and will be summarized in a later study aimed at documenting the recovery of the reef complex.

Data Analysis & Display

It is important to note that the coral and sponge abundances presented in this report represent counts across linear transects not standardized by area covered. The field of view and thus area of sea bed sampled was variable throughout the Campod transects due to sea state. This may give the appearance of greater abundances in certain portions of the transect compared to others. Thus, emphasis should be placed on the presence, rather than abundance, of the corals and sponges observed. Similarly, as the 4K Camera collected only still images and not continuous video footage of the seabed, the resulting abundance data between the two camera systems are not directly comparable.

Georeferenced coral and sponge records were plotted in ArcMap version 10.6.1. Due to poor USBL tracking of the Campod and 4K Camera systems in this area, the position of the vessel was used instead of actual vehicle position. Patterns within and between transects and by depth were examined. The minimum, maximum and mean temperature associated with observations of each taxon is given in Appendix 2. Note that the temperature here represents the ambient temperature in June 2018 only and therefore does not reflect seasonality or inter-annual variability in water mass characteristics experienced along the shelf break off Nova Scotia (Brickman et al. 2018).

Ridgeline plots were used to display the overall vertical (depth) distribution of taxa across all 10 stations. Here, densities of each taxon were estimated and plotted along the gradient in depth. Trailing tails were trimmed prior to final display. Ridgeline plots were generated in the R statistical software program version 3.5.2 (R Core Team 2018).

Validation of Coral and Sponge Significant Benthic Areas & Predictive Models

Maps were generated showing all available occurrence data for each functional group. Data sources included previous scientific surveys conducted by DFO and NRCan using various camera systems, coral and sponge bycatch records from the Fishery Observer Program (FOP; 2000 to 2017 for corals, 1985 to 1999 for sponges), coral and sponge observations from the NOAA Deep-Sea Coral Data Portal (downloaded in 2016), and records from the Gass (2002) and Breeze et al. (1997) reports on the distribution of corals from scientific literature, museum records, and bycatch reports. Presence and absences derived from catch data collected from DFO's multispecies trawl surveys conducted between 1999 to 2018 were also extracted (see Beazley et al. (2016) for explanation on how absence records were calculated). Note that the SBAs were generated on data collected up to and including the winter trawl survey of 2015 (March 2015).

For each functional group all available occurrence data was shown in relation to the Significant Benthic Area polygons (see DFO (2017b)). For large gorgonian corals, sea pens, and sponges, kernel density estimation (KDE) analyses based on catch data collected from DFO's multispecies trawl survey were used to delineate SBAs (referred to as KDE-SBAs in subsequent maps). The lower slope and deep-water areas off the Scotian Shelf where corals tend to aggregate are not fully surveyed in the multispecies trawl survey, and consequently, the KDE approach was not able to adequately delineate SBAs in those areas (Kenchington et al. 2016b). As a result, additional SBAs were generated from areas predicted as suitable habitat along the slope by random forest modelling (see Kenchington et al. 2016a). These SBAs (referred to as SDM-SBAs where SDM is species distribution modelling) encompassed coral occurrence data from science surveys used in the SDM models and are meant to highlight areas of significant presence over aggregations based on biomass. Furthermore, the number of catch records for small gorgonian corals was considered too low to apply KDE, and so its SBA was identified from random forest outputs only. For sponges the random forest SDM was generated based on the multispecies catch data only and so SDM-SBAs were not created.

The coral and sponge records from the Campod and 4K Camera transects were used to validate the random forest presence probability surfaces from Beazley et al. (2016). The 'Extract Values to Points' tool in ArcMap 10.6.1. was used to extract the SDM raster presence probability values to the coral and sponge locations from the 10 stations, and the data were summarized by presence probability percentiles.

We recommend that caution be exercised when validating SDM outputs using data collected from different gear types than those used to train the model. This is particularly true for the sponge SDM, which was trained only on data from the RV trawl survey which collates catches over relatively long distances (~3 km). Thus poor congruence between fine-scale camera observations and modelled outputs may result. Similarly, the random forest models generated for large and small gorgonian corals and sea pens were trained on highly imbalanced response data, with a greater proportion of absences than presences. Classification accuracy in random forest is prone to bias towards the majority class (i.e., absence class) when the response data are highly imbalanced (Chen et al. 2004). Thus predicted probabilities may be lower than if the model was trained on balanced data, which could possibly translate into lower probabilities at the location of the occurrence data used for validation purposes.

Congruence between Fishing Effort and the Distribution of Corals

The overlap between fishing effort and the distribution of corals was ascertained by plotting both mobile- and fixed-gear groundfish fishing effort from the period of 2005 to 2014 in relation to the location of large gorgonian corals observed across the 10 stations. These fishing layers were compiled from a combination of vessel monitoring system (VMS) and logbook data, and were created for the analysis of overlap between fishing effort and the coral and sponge Significant Benthic Areas created across eastern Canada (DFO 2017b, Koen-Alonso et al. 2017). The data were collated over 1 x 1 km grid cells and are represented by percentiles where increasing values represent decreasing effort. The highest effort concentration is therefore represented by the top 20%. The groundfish mobile-gear effort represents those fisheries that employ trawls and bottom seines whereas the groundfish fixed-gear effort includes fisheries that use gillnets, longlines, handlines and pots (Koen-Alonso et al. 2017).

The ‘Extract Values to Points’ tool in ArcMap was used to extract the percent effort values from each fishing effort raster at the location of large gorgonian colonies. The number of coral colonies per effort percentile, and the depth range of observations within each effort percentile were summarized.

Catch weight landings maps for the two most active commercial fisheries in the area (redfish otter trawl and halibut longline; Butler and Coffen-Smout 2017) were also shown against the location of large gorgonian corals at each station. These fisheries are encompassed by the groundfish mobile-gear and fixed-gear effort layers, respectively. Landings data were collected from 2008 to 2017 (time period different from effort layers due to availability of data) and were aggregated into 2 x 2 minute grid cells.

The groundfish mobile-gears fishing effort data described above was also plotted in relation to the LCCA in order to ascertain whether potential compliance issues exist with its boundaries. As the LCCA does not restrict fixed-gear fishing activities (e.g. groundfish longlining), only the mobile-gears effort was examined.

Data Availability

The data summarized in this report are available for download through Mendeley Data (https://data.mendeley.com/) using the following DOI: http://dx.doi.org/10.17632/z87pcc5vfz.1. Included are shapefiles of the taxonomic observations by functional group and transect track lines.

RESULTS

Large Gorgonian Corals

A total of 8338 large gorgonian coral colonies from five different taxa were recorded across all 10 stations. The minimum, maximum, and average depth of each are listed in Table 2. All were identified to the species level except for the single colony of *Paramuricea*, which, following the designation of Murillo et al. (2018) to account for multiple and possibly cryptic species in the region, was designated to the genus level only. The most abundant species encountered was *Acanthogorgia armata* (68% of all large gorgonians observed), followed by *Keratoisis grayi* (28%) *Primnoa resedaeformis* (3%), and *Paragorgia arborea* (1%).

The overall depth range of all large gorgonian observations was 232 – 914 m (Table 2), with the shallowest record belonging to *P. resedaeformis* and the deepest *A. armata*, the latter of which had the widest depth distribution of all five taxa (Figure 2). *Paragorgia arborea* was found between 245 and 499 m depth. Most taxa had similar and overlapping depth distributions with the exception of *K. grayi*, which was first encountered at ~350 m and was more abundant at deeper depths of ~600 m (Figure 2). The depth range of all taxa is within that previously recorded for the North Atlantic (*A. armata*: 100-2000 m, *P. arborea*: 200-1200 m, and *P. resedaeformis*: 150-900 m (Buhl-Mortensen et al. 2015); *K. grayi*: 274-3235, southeast US (Hourigan et al. 2017); *Paramuricea*, Grand Banks of Newfoundland: 150-1500 m (Radice et al. 2016)). Most taxa occurred between 4.2 and ~6°C (ambient temperature in June 2018; see Table A2.1 in Appendix 2), however *P. arborea* and *P. resedaeformis* were found at temperatures up to 8.7°C.

Table 2. Total number of colonies, and minimum (Min.), maximum (Max.), and average (Avg.) depth of large gorgonian corals recorded from the 10 video/photo stations on the Eastern Scotian Slope. Depth is from the SBE 39 attached to Campod/4K Camera. Average depth is ± standard deviation.

Large gorgonian corals				
	Total Observed	Min. Depth (m)	Max. Depth (m)	Avg. Depth (m)
Acanthogorgia armata	5658	264	914	323 ± 109
Keratoisis grayi	2294	349	900	593 ± 116
Paragorgia arborea	96	245	499	302 ± 44
***Paramuricea* sp.**	1	492	492	
Primnoa resedaeformis	289	232	491	287 ± 32

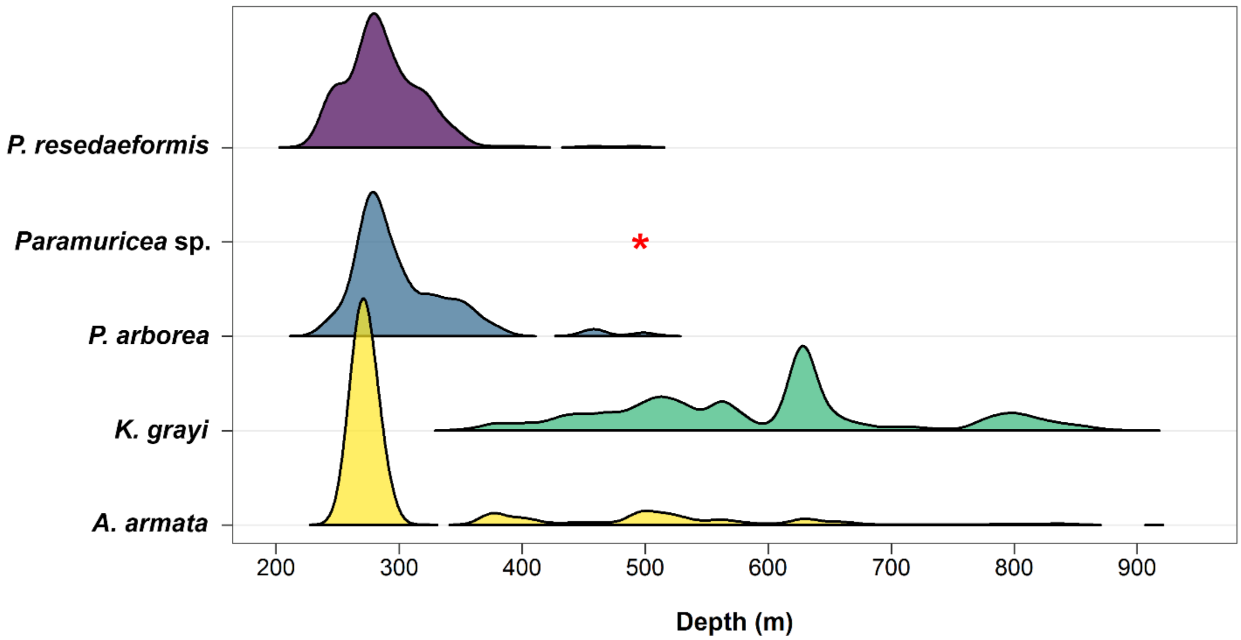

Figure 2. Density ridgeline plot showing the vertical (depth) density distribution of the five large gorgonian coral taxa observed across all 10 stations on the Eastern Scotian Slope. The red asterisk indicates a single observation of *Paramuricea* at 492 m depth.

The occurrence of taxa across all stations is presented in Figures 3 and 4 (map not shown for the single *Paramuricea* colony observed on Transect EC_07 at 492 m depth). Detailed transect-level distributions of large gorgonian corals can be found in Figure 5. Of the 8338 colonies recorded, over half (4807, 57%) were recorded from the single Campod transect collected within the LCCA (Station EC_11). *Acanthogorgia armata* and *K. grayi* had the widest spatial distribution across the region, and were found at all stations except EC_02 for *A. armata*, and EC_02 and EC_06 for *K. grayi*. *Paragorgia arborea* and *P. resedaeformis* were restricted to stations in the eastern portion of the region and were first encountered on EC_08 for *P. resedaeformis* and EC_09 for *P. arborea*. At Station EC_08 Campod was redeployed between ~350 and 500 m depth (see CON 036, Table 1) to survey for a potential *P. arborea* colony that was observed in the forward-facing camera of CON 034, just before Campod's power system failed and it was recovered. The colony was not encountered again, but during this survey a single colony of *P. resedaeformis* was observed, suggesting the habitat is suitable for both species.

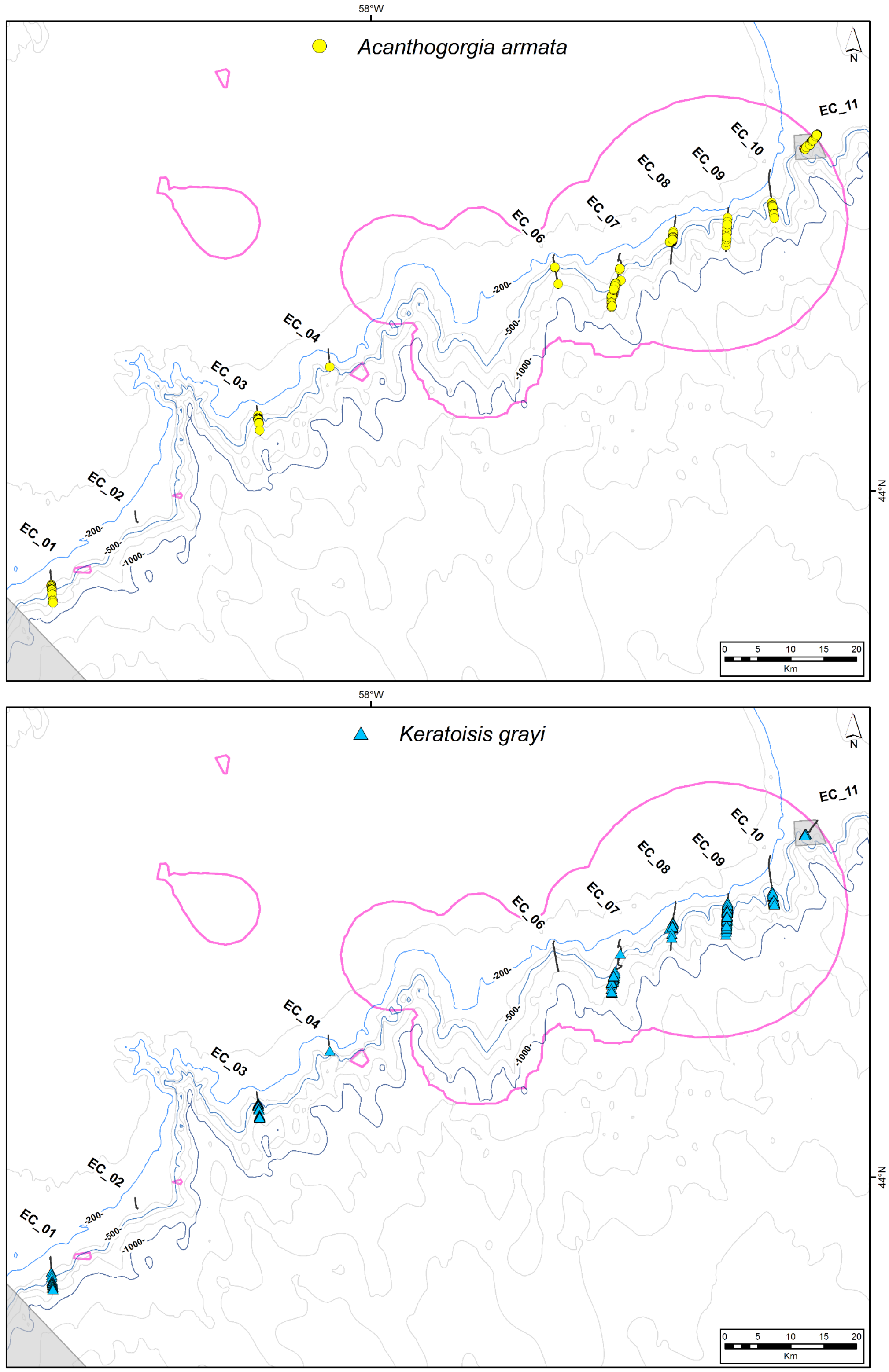

Figure 3. Distribution of large gorgonian corals *Acanthogorgia armata* (top panel) and *Keratoisis grayi* (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the large gorgonian coral Significant Benthic Areas (pink polygons) based on kernel density analysis (see DFO 2017b).

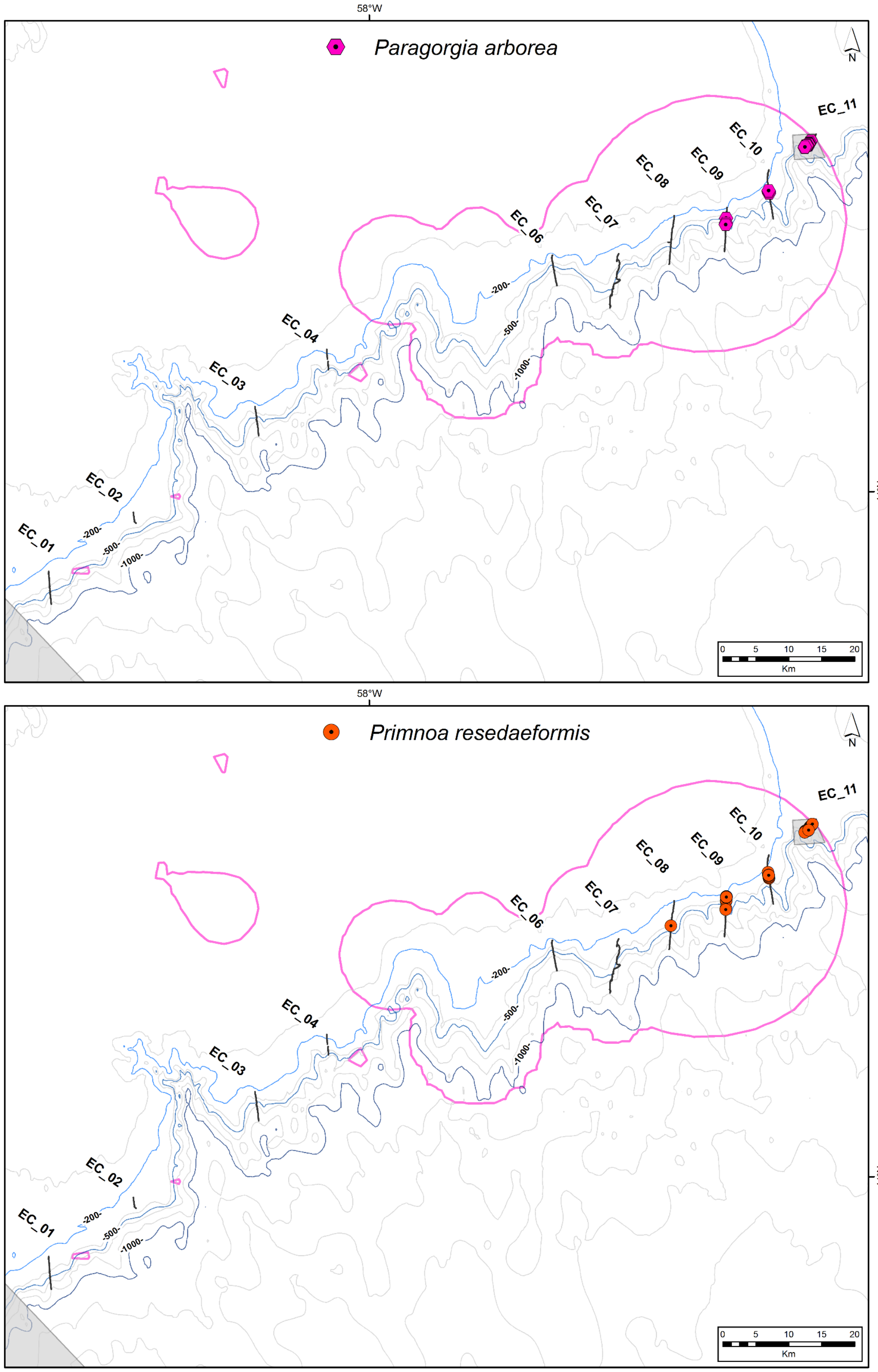

Figure 4. Distribution of large gorgonian corals *Paragorgia arborea* (top panel) and *Primnoa resedaeformis* (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the large gorgonian coral Significant Benthic Areas (pink polygons) based on kernel density analysis (see DFO 2017b).

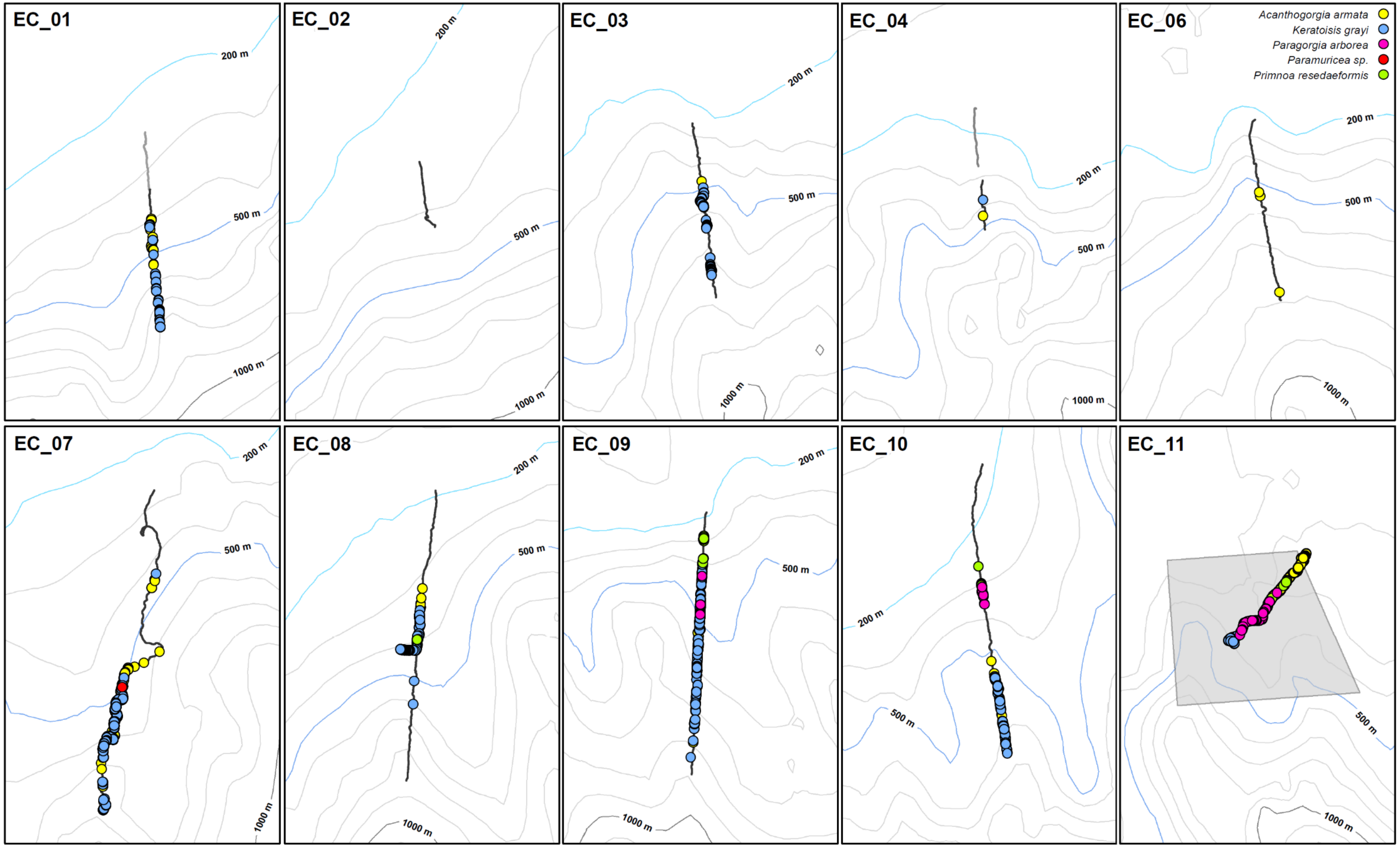

Figure 5. Transect-level distribution of large gorgonian corals at 10 video/photo stations. 100-m contours are displayed. The 200, 500, and 1000-m contours are in blue and labelled. The *Lophelia* Coral Conservation Area is indicated by the grey polygon in EC_11. All maps are scaled equally (1:100,000).

Validation of Large Gorgonian Coral Significant Benthic Areas and Predictive Models

Figure 6 shows the location of all large gorgonian coral records accessible for the region against the large gorgonian KDE-SBAs. Data sources were the Campod video and 4K photographic transects analyzed for this study, DFO scientific surveys conducted between 2002 and 2008, records from the Gass (2002) and Breeze et al. (1997) reports on coral occurrences from bycatch records, museum collections, and scientific literature, the NOAA Deep-Sea Coral Data Portal (downloaded in 2016), coral bycatch records from the Fisheries Observer Program (FOP) from 2000-2017, and trawl catch data (presences and absences; see Beazley et al. (2016) for description of how absence records are calculated) from DFO's multispecies trawl survey, collected between 2002 to 2017.

Data collected at Stations EC_01, EC_04, and EC_06 provided new records of large gorgonian corals for portions of the slope where little to no data on coral distributions had been previously collected. The shallower portions of Stations EC_07 to EC_10 were within the vicinity of previously collection data from DFO science surveys, the Gass (2002) & Breeze et al. (1997) reports, and the multispecies trawl survey, but extended the known distribution of large gorgonian coral records to the south into deeper waters not previously sampled.

All five species were recorded on transects located inside the large gorgonian coral KDE-SBA (EC_06 to EC_11), while on only *A. armata* and *K. grayi* were recorded on transects outside the KDE-SBA (EC_01 to EC_04). The overall depth range of large gorgonian coral observations inside and outside the KDE-SBA was comparable, with large gorgonians observed between 232 to 914 m inside the SBA from an overall depth range surveyed of 154 to 927 m, while outside the SBA *A. armata* and *K. grayi* were observed between 265 – 871 from a depth range surveyed of 140 to 916 m. The absence of large gorgonian corals above 230 m from our data supports the uncertainty discussed by Murillo et al. (2018) in the large gorgonian coral records from the RV trawl survey, particularly *P. arborea*, on the shallow banks of the eastern Scotian Shelf. It's possible that both mis-identification and contamination from deeper sets were responsible. These shallower records were included in both the KDE and SDM analyses to identify SBAs. Future modelling applications should consider the removal of those records shallower than 200 m depth.

Figure 7 shows the predicted presence probability of large gorgonian corals from the random forest SDM model of Beazley et al. (2016) overlaid by large gorgonian occurrences from all data sources. There was good congruence between the large gorgonian coral locations recorded in this study and areas of high predicted presence probability from the model. Of the 8338 large gorgonian corals observed, 96% fell into

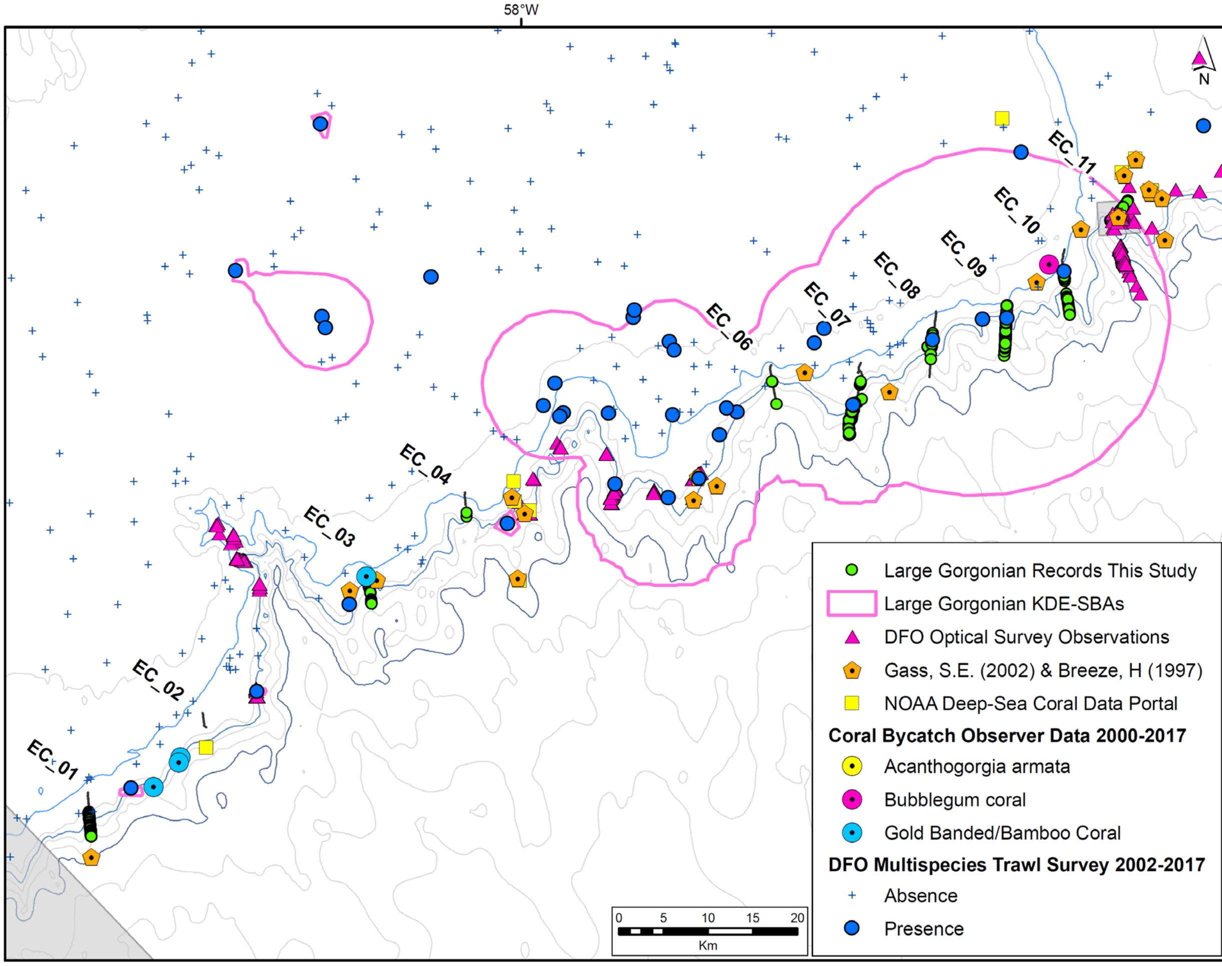

Figure 6. Distribution of available large gorgonian coral records on the Eastern Scotian Slope. Data sources are described above.

areas with the highest predicted probability of presence (75 to 96%). Those records predicted with lower probability of occurrence (27%) were isolated to a single station, EC_03. Large gorgonian records from the Gass (2002) and Breeze et al. (1997) reports lie within the vicinity of Station EC_03, as do records from the commercial fishery and DFO's multispecies trawl survey. However, the former were not included in the species distribution model, and the record from the RV survey was made in 2016 after the SDM analysis was conducted. This record was of a single colony of *P. arborea* weighing 30 kg that was collected on the slope immediately adjacent to the eastern flank of Haldimand Canyon at 464 m depth.

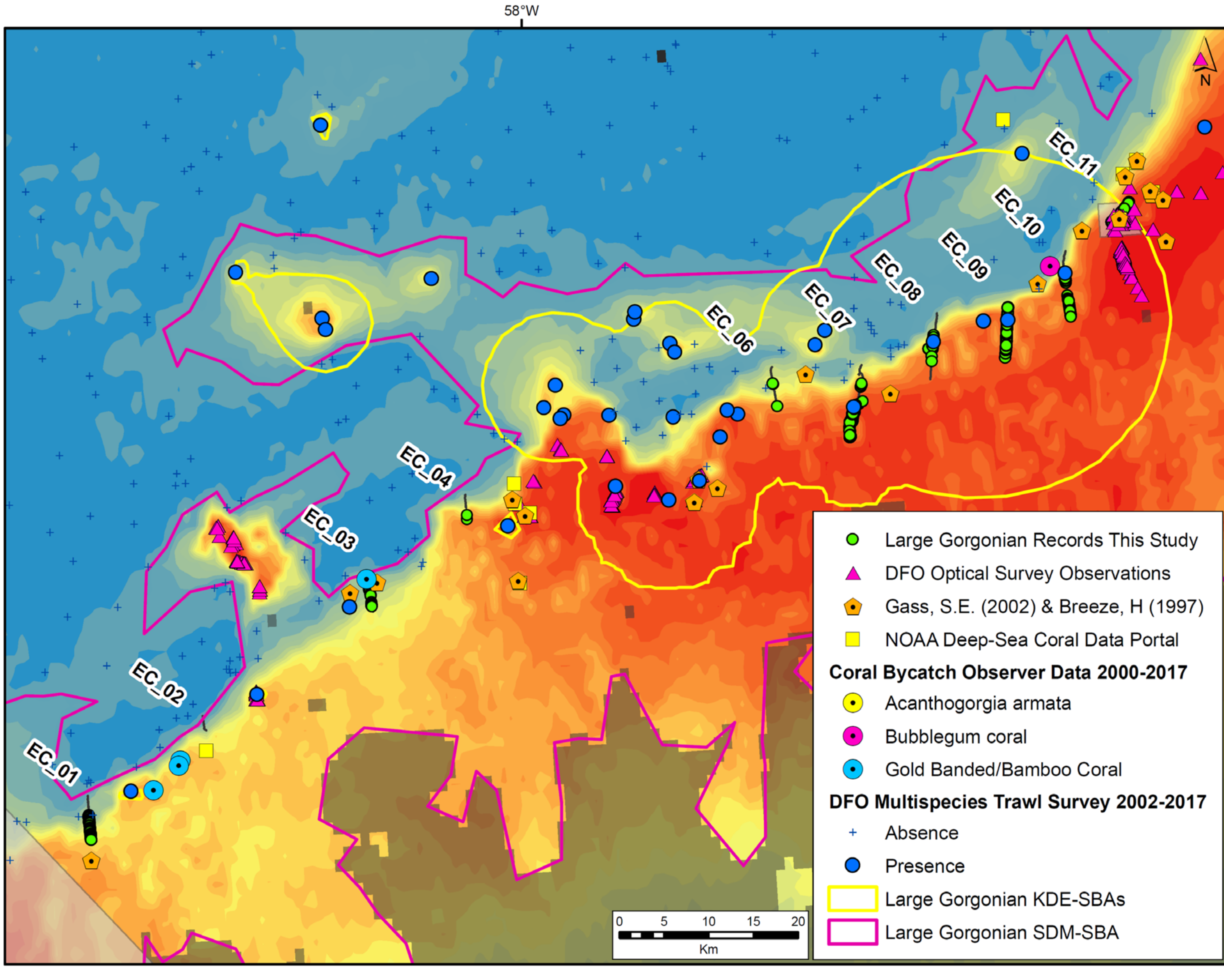

Figure 7. Location of large gorgonian coral records from all data sources against the large gorgonian coral presence probability model from Beazley et al. (2016). Presence probability values at the location of identified large gorgonian corals from the 10 video/photo stations were extracted and are summarized in Table 3.

Table 3. Predictions of presence probability at the location of large gorgonian corals recorded across the 10 video/photo stations. Species distribution model was a random forest model based on presence-absence data of large gorgonian corals (see Beazley et al. 2016). Also shown is the minimum, maximum, and average depth ± standard deviation (SD) of observations per presence probability class.

Presence Probability (%)	Number of Colonies & Percentage of Total	Min – Max Depth (m)	Average Depth ± SD (m)
27 – 50	185 (2%)	382 – 872	644 ± 138
50 – 75	128 (2%)	446 – 831	577 ± 143
75 - 96	8025 (96%)	232 - 914	387 ± 158

Small Gorgonian Corals

Three small gorgonian coral taxa were recorded across the 10 stations: *Acanella arbuscula*, cf. *Anthothela grandiflora*, and *Radicipes* sp. The minimum, maximum, and average depth of each are listed in Table 4. The single colony suspected to be *A. grandiflora* (denoted by the 'cf.', or '*confer*' designation) was observed on Transect EC_11 in the LCCA. A small purple soft coral likely of the family Clavulariidae recorded from video imagery collected in both the Gully and the LCCA (see Cogswell et al. (2009)) was historically mis-identified as *A. grandiflora* (Dr. Javier Murillo, DFO, pers. comm.). Thus the single colony observed here potentially represents the first valid (although unconfirmed by the lack of collected specimens) record of this species reported from the region. It was assigned the 'cf.' designation as no collections exist from the LCCA to corroborate its identification. To date the only species in the genus *Radicipes* reported to occur in Canadian waters is *Radicipes gracilis* (Cordeiro et al. 2017). However, Cordeiro et al. (2017) suggested based on molecular analysis that *R. gracilis* could be a cryptic species, hence our designation to the genus level only.

Table 4. Total number of colonies, and minimum (Min.), maximum (Max.), and average (Avg.) depth of small gorgonian corals recorded from the 10 video/photo stations on the Eastern Scotian Slope. Depth is from the SBE 39 attached to Campod/4K Camera. Average depth is ± standard deviation.

Small gorgonian corals				
	Total Observed	Min. Depth (m)	Max. Depth (m)	Avg. Depth (m)
Acanella arbuscula	1181	377	895	585 ± 94
cf. *Anthothela grandiflora*	1	266	266	
***Radicipes* sp.**	181	414	913	597 ± 163

The overall depth range of the three taxa across all stations was 266 – 913 m (Table 4 and Figure 8), with the shallowest record belonging to cf. *Anthothela grandiflora* (266 m) and the deepest *Radicipes* sp. (913 m). The depth range of both *A. arbuscula* and *Radicipes* sp. was similar and within that previously reported for the North Atlantic (*A. arbuscula*: 350-2035 m (Saucier et al. 2017), *Radicipes* sp. (*gracilis*): 500-3259 m (Cordeiro et al. 2017). However, *Anthothela grandiflora* has typically been reported at depths > 400 m elsewhere in the North Atlantic (528-918 m off Newfoundland, Canada; (Wareham and Edinger 2007); 416-679 m off eastern US; (Lawler et al. 2016)), deeper than that observed in this study (266 m). The temperature range of occurrences was 4.6 to 6°C (Table A21, Appendix 2).

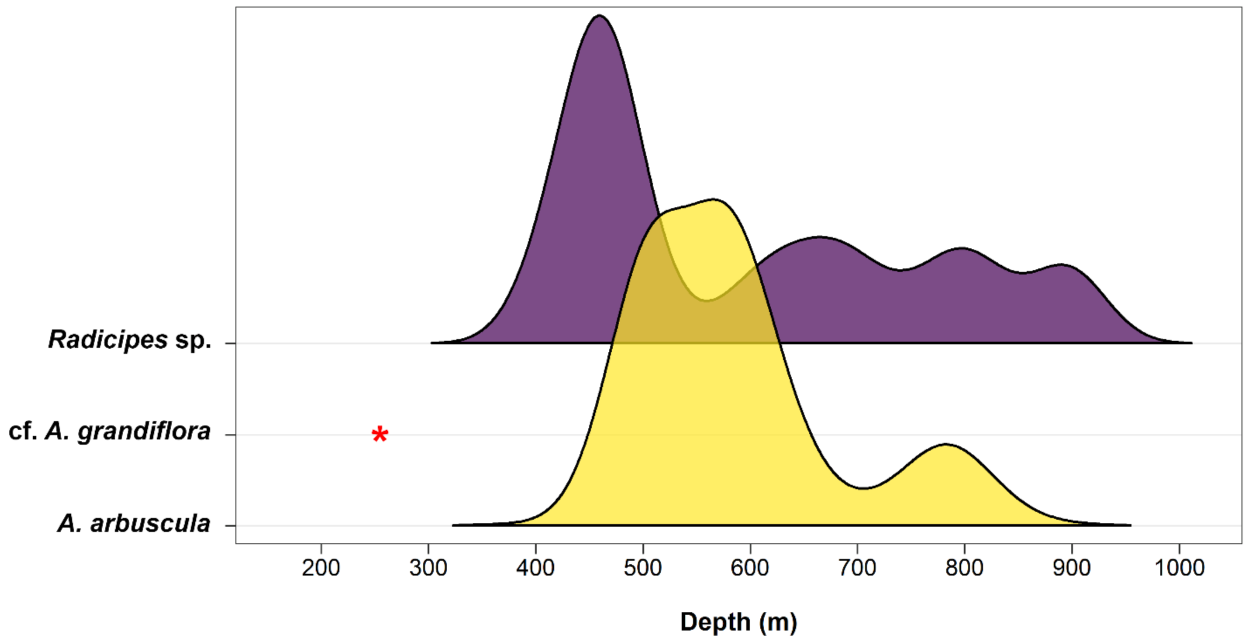

Figure 8. Density ridgeline plot showing the vertical (depth) density distribution of the small gorgonian coral taxa observed across all 10 stations on the Eastern Scotian Slope. The red asterisk indicates a single observation of *Paramuricea* at 492 m depth.

The distribution of *A. arbuscula* and *Radicipes* sp. across the region is presented in Figure 9 (map not shown for the single colony of cf. *Anthothela grandiflora* on Transect EC_11). Detailed transect-level distributions of small gorgonian corals can be found in Figure 10 Also shown is the small gorgonian coral SDM-SBA along the slope. Note that the shallow boundary of this SBA was delimited by the 200 m depth contour due to the importance of depth as a predictor variable in this model. All small gorgonian coral observations fall completely within this SBA.

The only small gorgonian recorded inside the LCCA was cf. *A. grandiflora*, which was observed attached to a large boulder. *Acanella arbuscula* and *Radicipes* sp. anchor in soft substrate and so their absence in the LCCA is likely due to the predominance of hard substrate there. Both *A. arbuscula* and *Radicipes* sp. had a similar spatial distribution across the region, and were both most abundant on Transect EC_07.

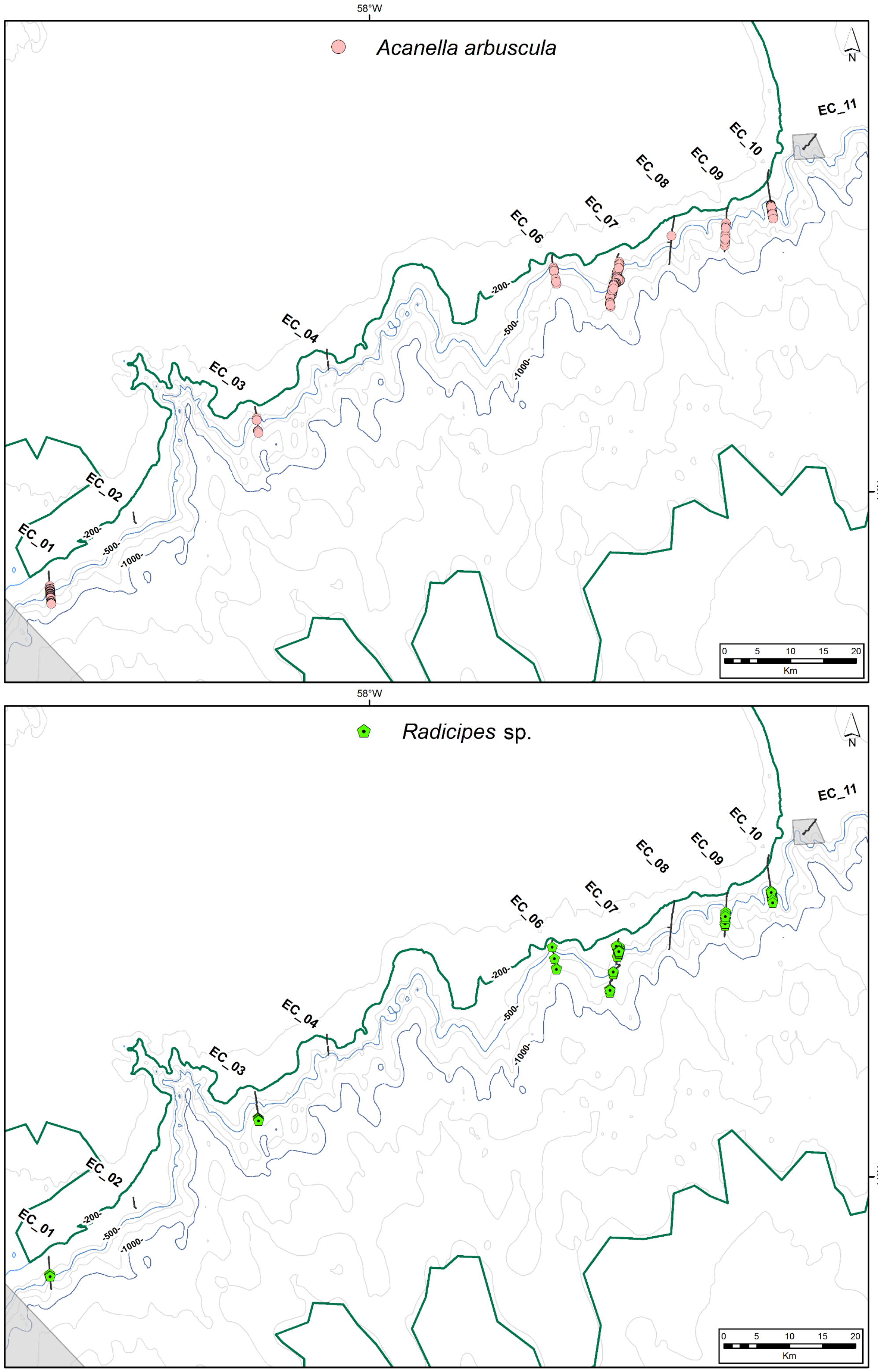

Figure 9. Distribution of small gorgonian corals *Acanella arbuscula* (top panel) and *Radicipes* sp. (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown is the small gorgonian coral Significant Benthic Area polygon (green) based on areas of suitable habitat from species distribution modelling (see DFO 2017b).

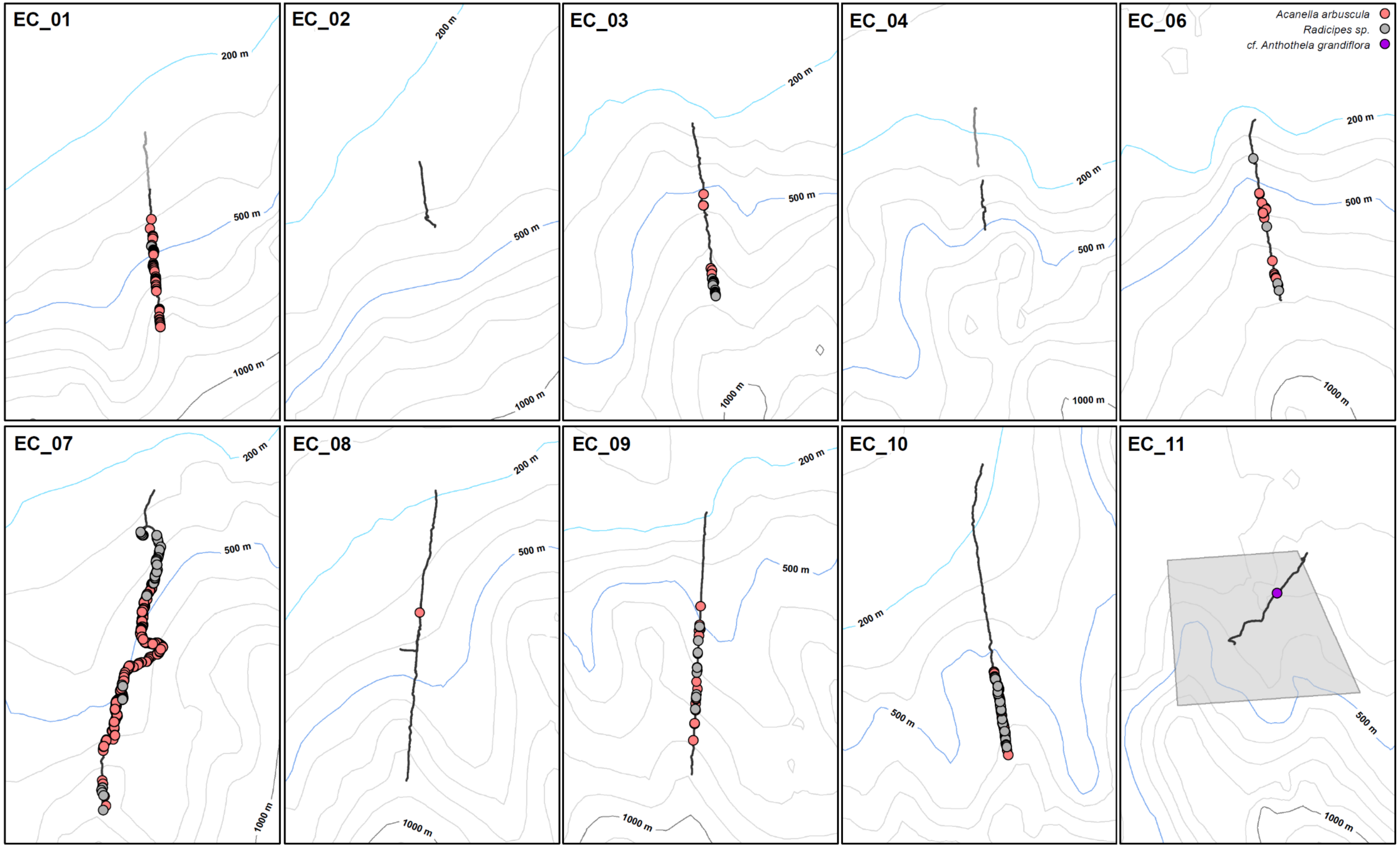

Figure 10. Transect-level distribution of small gorgonian corals at 10 video/photo stations. 100-m contours are displayed. The 200, 500, and 1000-m contours are in blue and labelled. The *Lophelia* Coral Conservation Area is indicated by the grey polygon in EC_11. All maps are scaled equally (1:100,000).

Validation of Small Gorgonian Coral Significant Benthic Areas and Predictive Models

Figure 11 shows the location of all small gorgonian coral records accessible for the region against the small gorgonian SDM-SBA. Data sources include the Campod video and 4K photo transects analyzed for this study, previous DFO science surveys conducted in 2001 and between 2007 and 2008, records from the NOAA Deep-Sea Coral Data Portal (downloaded 2016), and trawl catch data (presences and absences) from DFO's multispecies trawl survey collected between 2002 to 2016. Note that two records of the bottle-brush gorgonian *Chrysogorgia* were included in the DFO science survey data, which was not observed on our video/photo transects. This taxon was observed on a deep transect conducted with the ROV ROPOS in 2007 in the southeast portion of the study area.

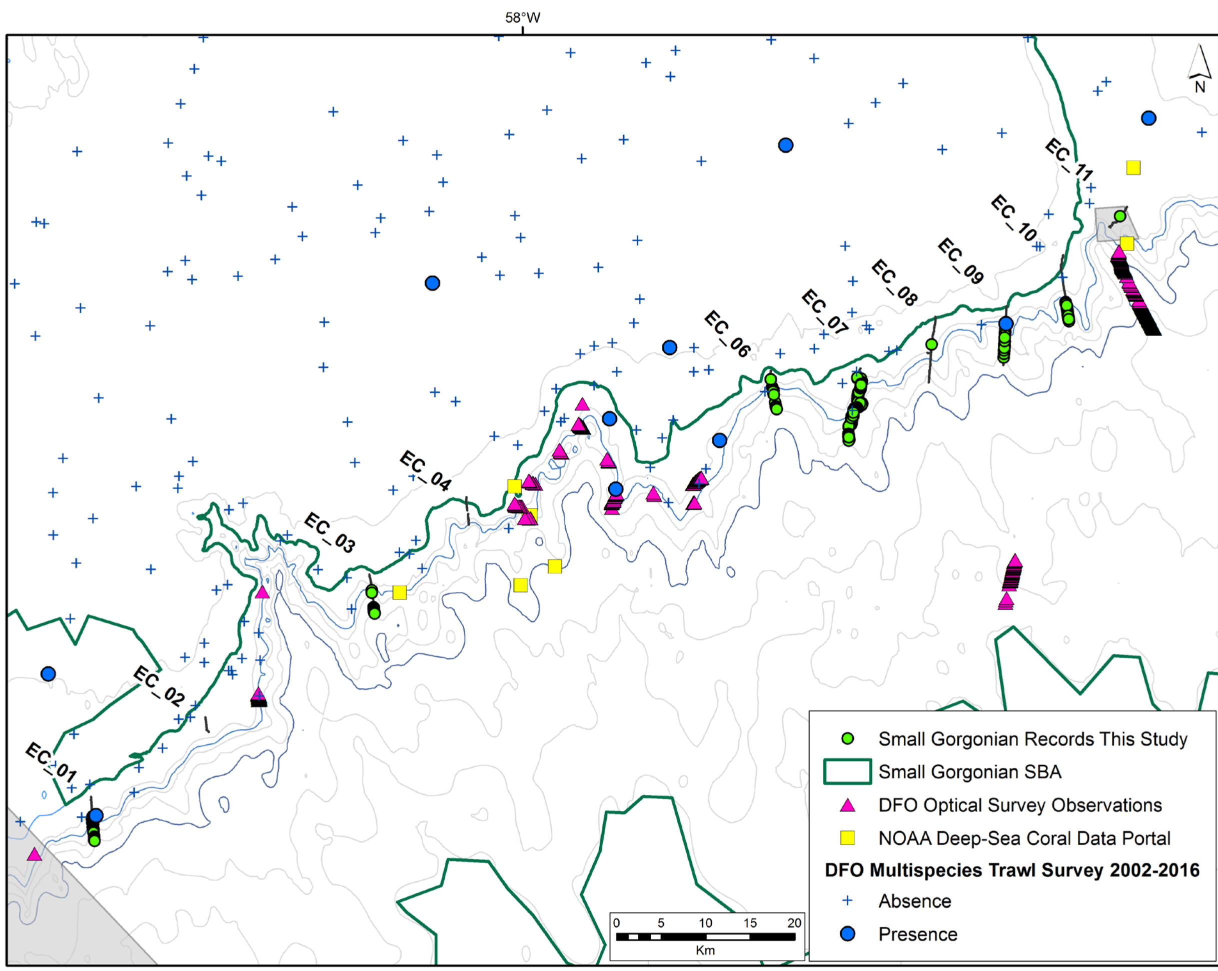

Figure 11. Distribution of available small gorgonian coral records on the Eastern Scotian Slope. Data sources are described above.

Our study has increased the number of small gorgonian coral observations for the Eastern Scotian Slope, particularly on the slope between Stations EC_06 to EC_10 where only a single small gorgonian observation from DFO's multispecies trawl survey was previously made. When considering all the available data, all but three records were located inside the small gorgonian SDM-SBA. The records above this boundary are from the multispecies trawl survey and consist of two *A. arbuscula* and one *R. gracilis*.

Figure 12 shows the predicted presence probability of small gorgonian corals from Beazley et al. (2016) overlaid by small gorgonian occurrences from all data sources. The majority of small gorgonian records from this study fell into locations predicted with moderate presence probabilities from the model, indicating fair congruence between the two. Lower probabilities were associated with shallower records on average (416 ± 0.93

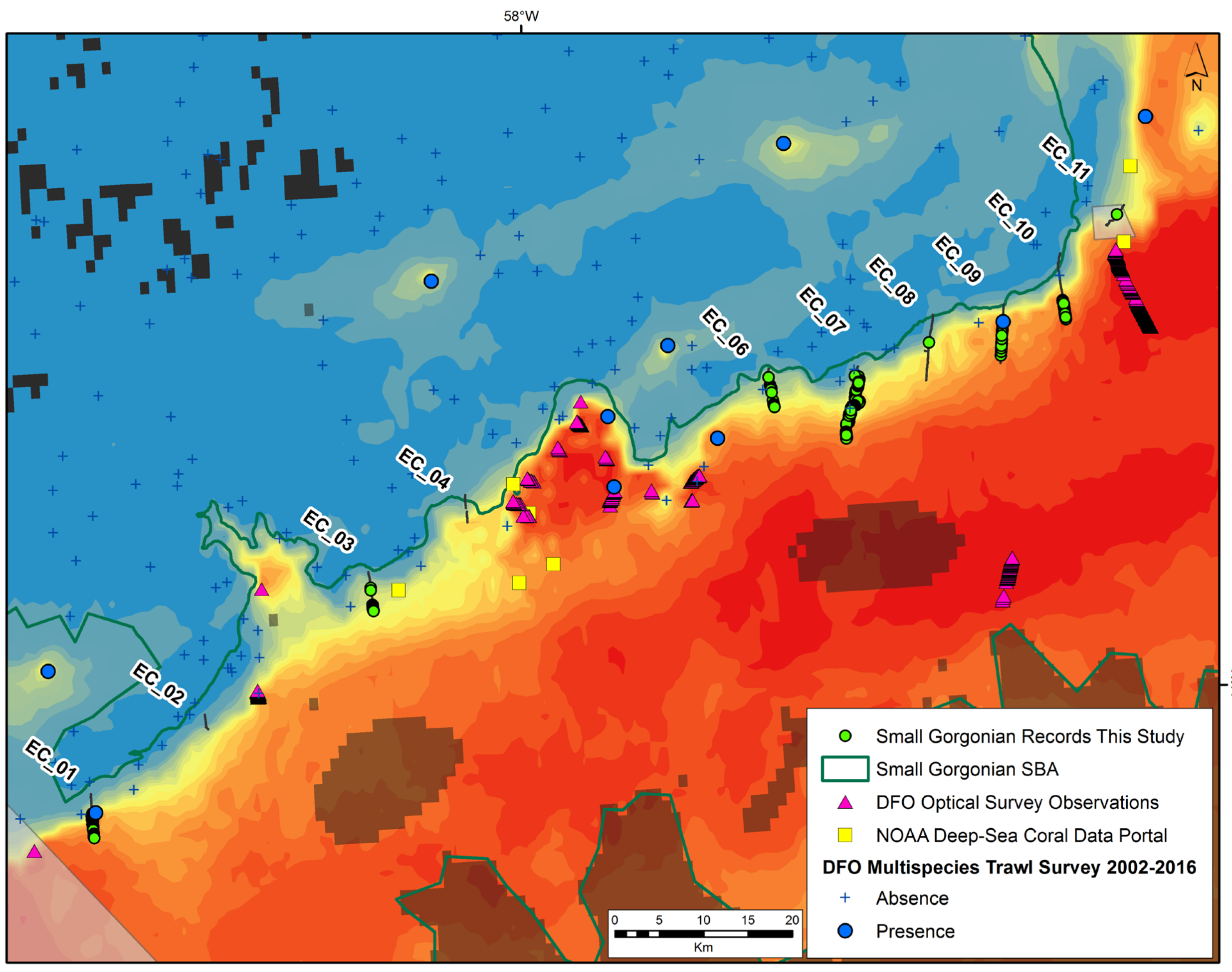

Figure 12. Location of small gorgonian coral records from all data sources against the small gorgonian coral presence probability model from Beazley et al. (2016). Presence probability values at the location of identified small gorgonian corals from the 10 video/photo stations were extracted and are summarized in Table 5.

m), while the highest probabilities (75 to 84%) were associated with the deepest records (777 ± 50 m; Table 5). Thus, the additional small gorgonian records observed in this study may increase the predictive capacity of any future models in shallower waters.

Table 5. Prediction of presence probability at the location of small gorgonian corals recorded across the 10 video/photo stations. Species distribution model was a random forest model based on presence-absence data of small gorgonian corals (see Beazley et al. 2016). Also shown is the minimum and maximum depth and average ± standard deviation (SD) of observations per presence probability class.

Presence Probability (%)	Number of Colonies & Percentage of Total	Min – Max Depth (m)	Average Depth ± SD (m)
10 – 25	17 (1%)	414 - 417	416 ± 0.9
25 – 50	558 (41%)	266 - 913	537 ± 92
50 – 75	639 (47%)	455 - 828	590 ± 69
75 - 84	149 (11%)	464 - 895	777 ± 50

Sea Pens

A total of 6661 sea pens were recorded across 11 different taxa (Table 6). Three were identified to the species level (*Anthoptilum grandiflorum*, *Pennatula aculeata* and *P. grandis*), three to genus (*Pennatula* sp., *Umbellula* sp., and *Kophobelemnon* spp.), and five to the order level. To date only one species from the genus *Kophobelemnon* has been positively identified from the Maritimes Region (*K. stelliferum*, Murillo et al. (2018)), however the 'spp.' designation was given here to represent the wide range in morphologies encountered in the video and photographs. Two order-level morphotype groups (Pennatulacea Type 1 and Type 2) were created to encompass what are likely several different sea pen taxa that could not be consistently distinguished from one another. Pennatulacea Type 1 includes *Halipteris finmarchica*, and a sea pen with a similar morphology to *H. finmarchica*. Pennatulacea Type 2 likely includes two different species, one resembling *Protoptilum carpenteri*. Pennatulacea sp. 3 was an unknown sea pen that resembled *Funiculina quadrangularis*, while Pennatulacea_juvenile represented a single juvenile specimen observed on the 4K Camera transect collected at station EC_08, and is likely *A. grandiflorum* or Pennatulacea Type 1. Six specimens were identified as cf. Pennatulacea. These are small white specimens observed at Stations EC_07 and EC_11 that resembled the genus *Virgularia*. However collections of these specimens have not yet been made and so the 'cf.' designation was assigned.

The most numerous taxon was *P. aculeata* (41% of total), followed by *Kophobelemnon* spp. (21%), and Pennatulacea Type 1 (16%). The overall depth range of sea pens was 240 – 970 m (Table 6 and Figure 13), with the shallowest record belonging to *P. aculeata* (240 m) and the deepest *Kophobelemnon* spp. and Pennatulacea Type 2 (970 m). Both *Pennatula* species overlapped in their distribution (see Figure 13) but *P. aculeata* was more abundant at shallower depths than *P. grandis* and also experienced a peak in abundance at deeper depths where *P. grandis* was largely absent. Pennatulacea sp. 3 and Pennatulacea Type 2 were both restricted to deeper depths. The temperature range of occurrences was 4.2 to 8.4°C (Table A2.1, Appendix 2).

The distribution of the six most common sea pen taxa across all 10 stations are presented in Figures 14 through 16. Detailed transect-level distributions of sea pens can be found in Figure 17. Most sea pen taxa were observed across the study area with the exception of *A. grandiflorum*, which was observed mainly on those transects in the eastern portion of the study area (EC_06 to EC_10). Only *P. grandis* and Pennatulacea Type 1 were found inside the LCCA, likely due to the predominance of hard substrate (pebbles, cobbles, and boulders) there. No sea pen observations were within the sea pen Significant Benthic Area polygons based on KDE analysis, but Stations EC_01 and EC_03 and EC_04 were in close proximity.

Table 6. Total number, and minimum (Min.), maximum (Max.), and average (Avg.) depth of sea pens recorded from the 10 video/photo stations on the Eastern Scotian Slope. Depth is from the SBE 39 attached to Campod/4K Camera. Average depth is ± standard deviation.

Sea pens				
	Total Observed	Min. Depth (m)	Max. Depth (m)	Avg. Depth (m)
Anthoptilum grandiflorum	224	372	912	522 ± 107
***Kophobelemnon* spp.**	1411	383	970	663 ± 140
Pennatula aculeata	2703	240	894	449 ± 192
Pennatula grandis	308	242	820	391 ± 88
***Pennatula* sp.**	1	255	255	
***Umbellula* sp.**	1	505	505	
Pennatulacea Type 1	1080	251	964	468 ± 152
Pennatulacea Type 2	915	376	970	734 ± 116
Pennatulacea sp. 3	11	708	966	813 ± 91
Pennatulacea_juvenile	1	813	813	
cf. Pennatulacea	6	263	272	270 ± 3.3

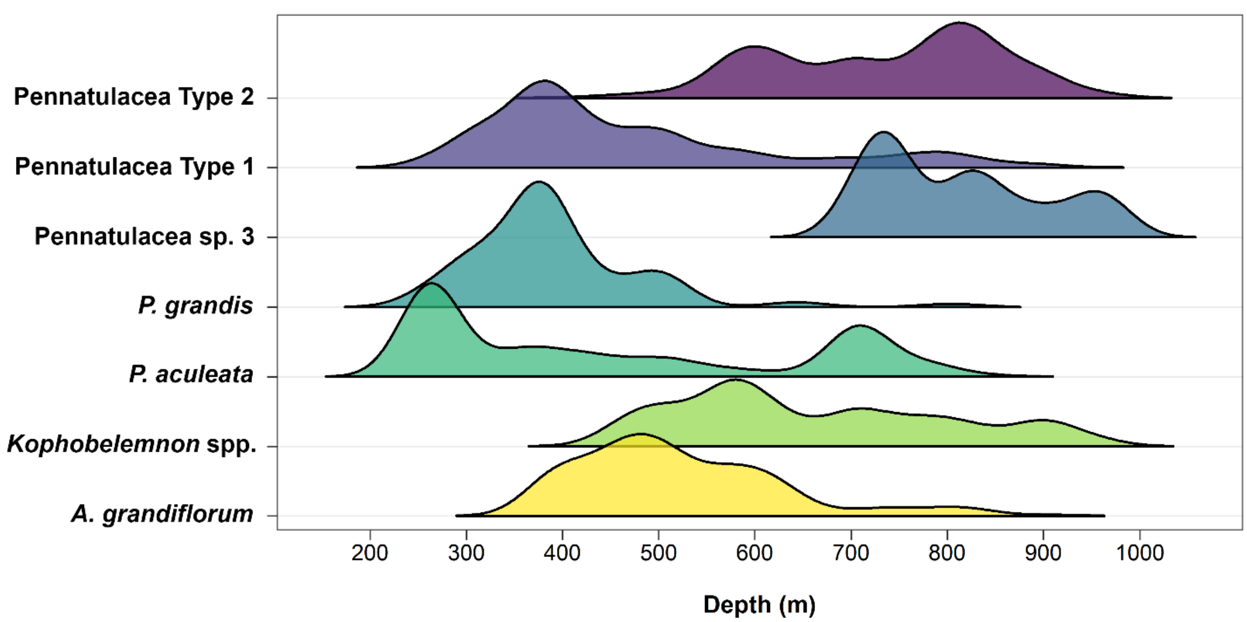

Figure 13. Density ridgeline plot showing the vertical (depth) density distribution of the most common sea pen taxa observed across all 10 stations on the Eastern Scotian Slope.

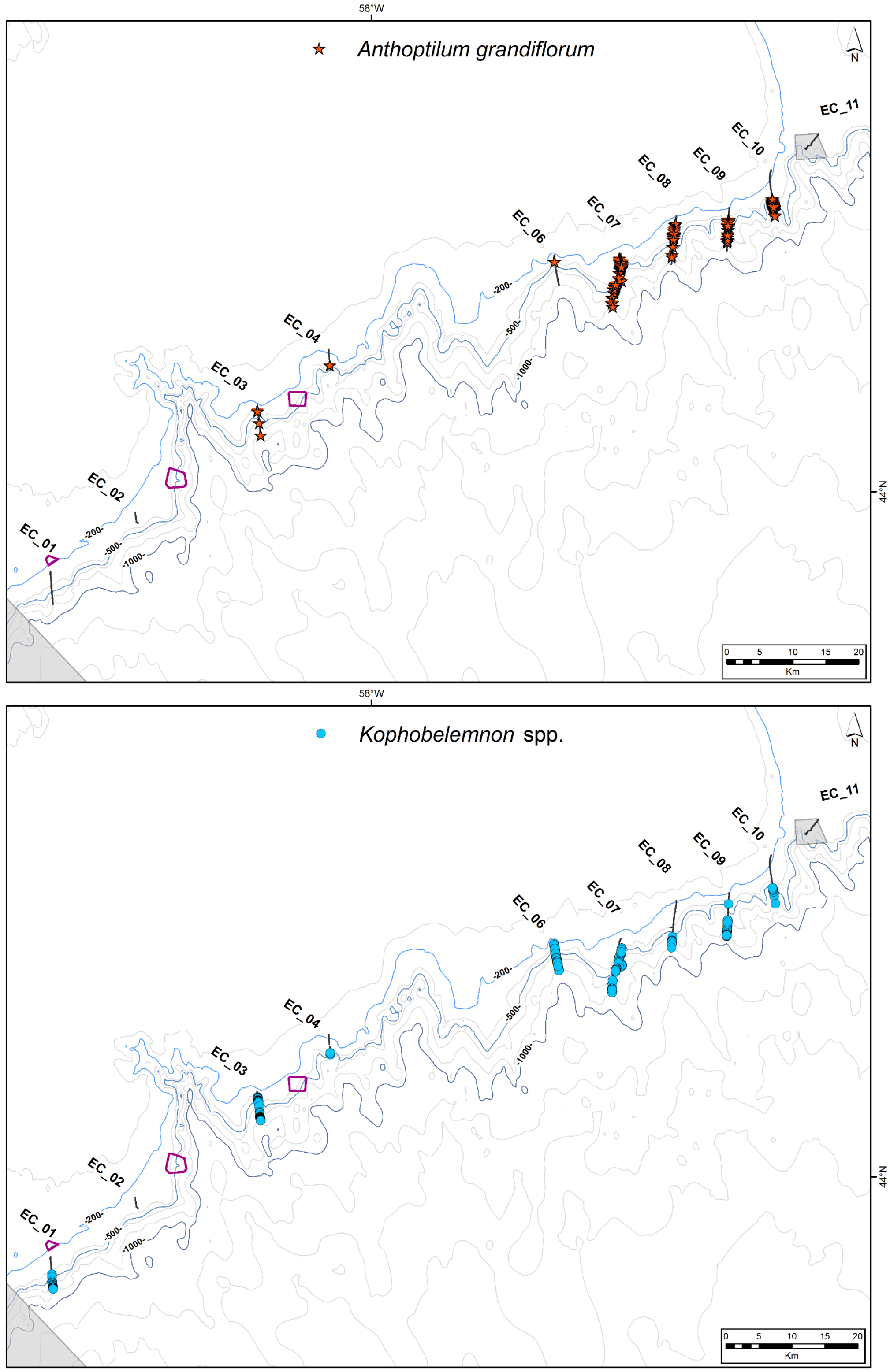

Figure 14. Distribution of sea pens *Anthoptilum grandiflorum* (top panel) and *Kophobelemnon* spp. (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the sea pen Significant Benthic Areas (purple polygons) based on kernel density analysis (see DFO 2017b).

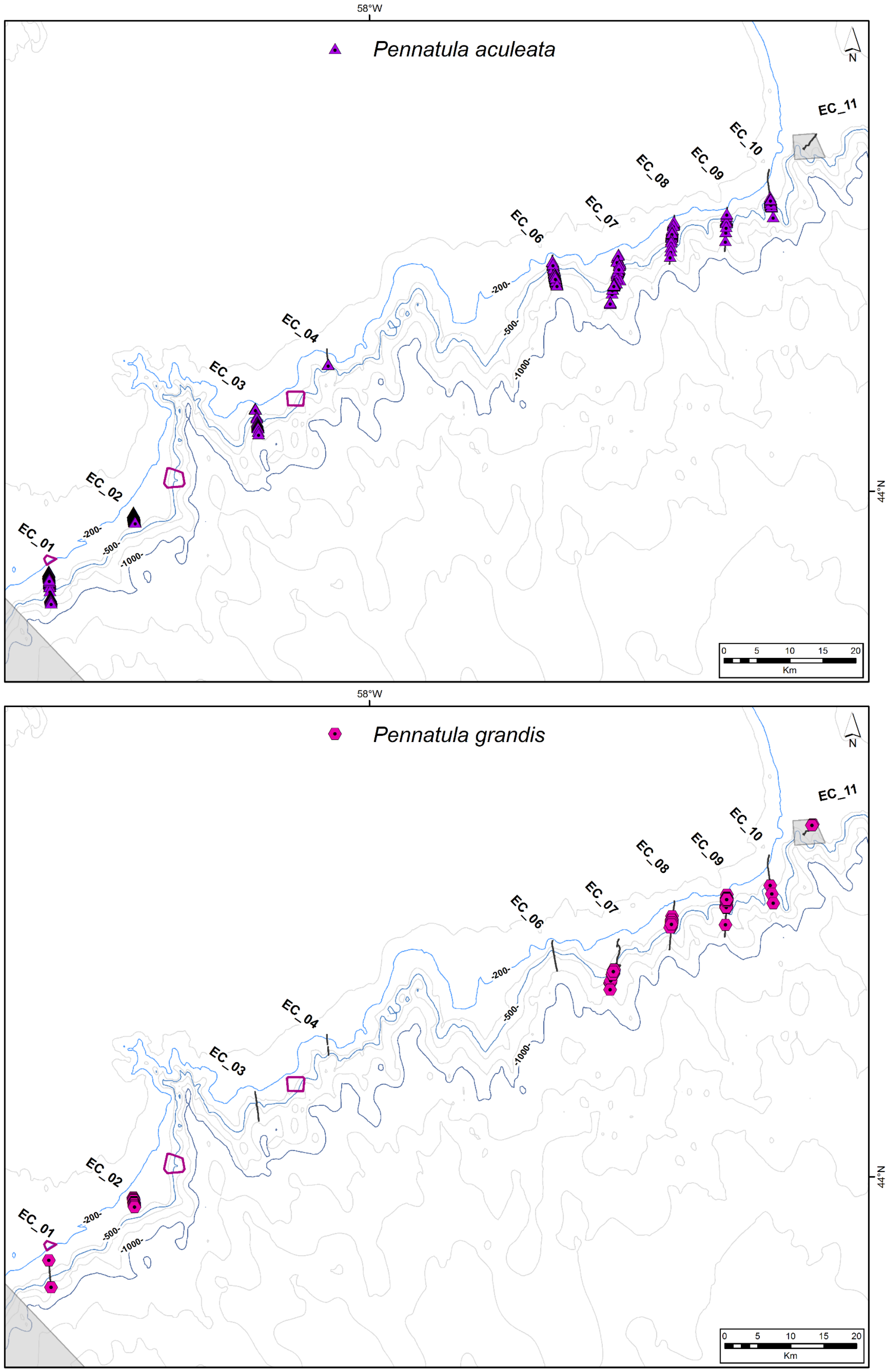

Figure 15. Distribution of sea pens *Pennatula aculeata* (top panel) and *Pennatula grandis* (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the sea pen Significant Benthic Areas (purple polygons) based on kernel density analysis (see DFO 2017b).

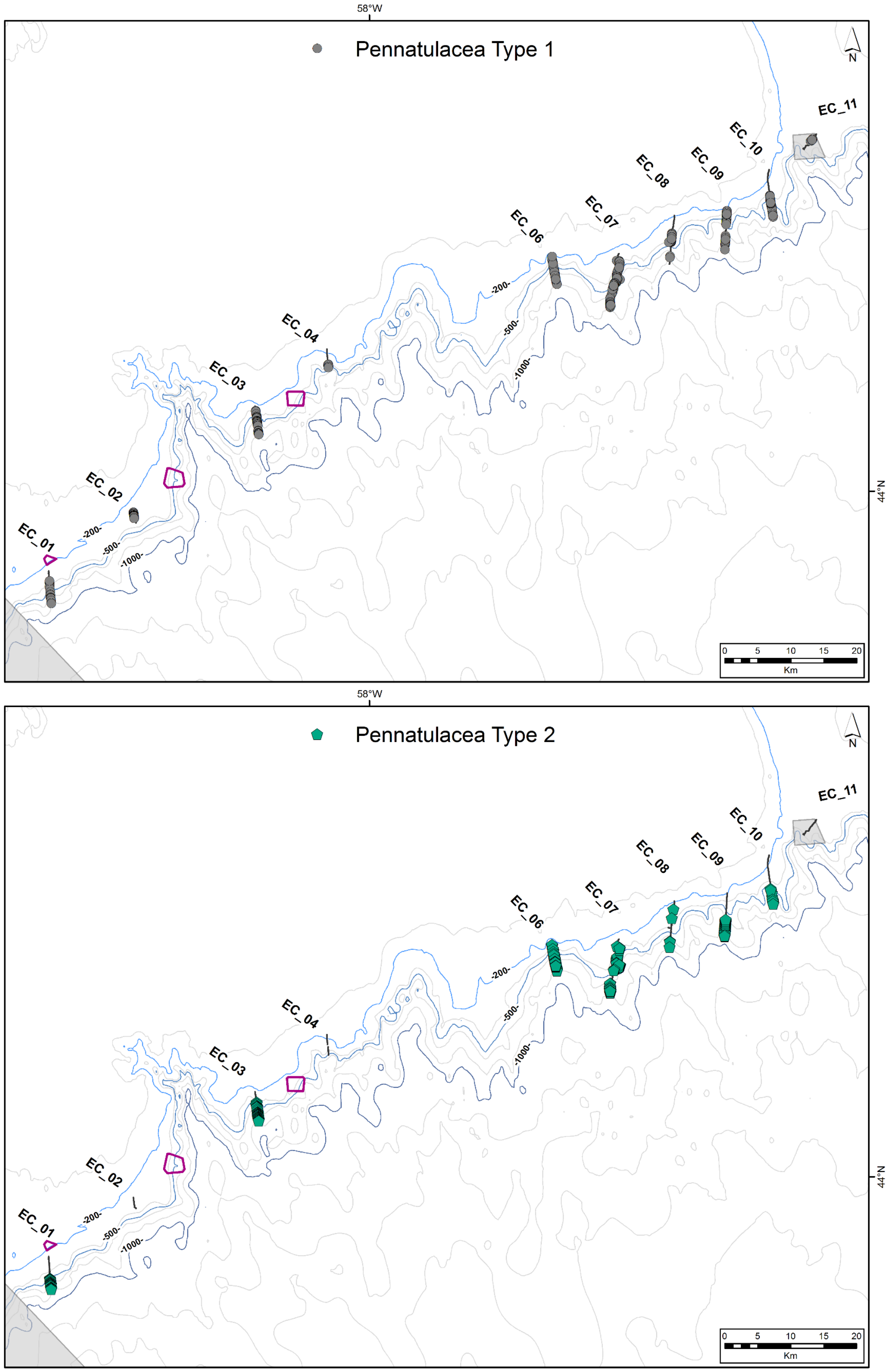

Figure 16. Distribution of sea pen morphotype groups Pennatulacea Type 1 (top panel) and Pennatulacea Type 2 (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the sea pen Significant Benthic Areas (purple polygons) based on kernel density analysis (see DFO 2017b).

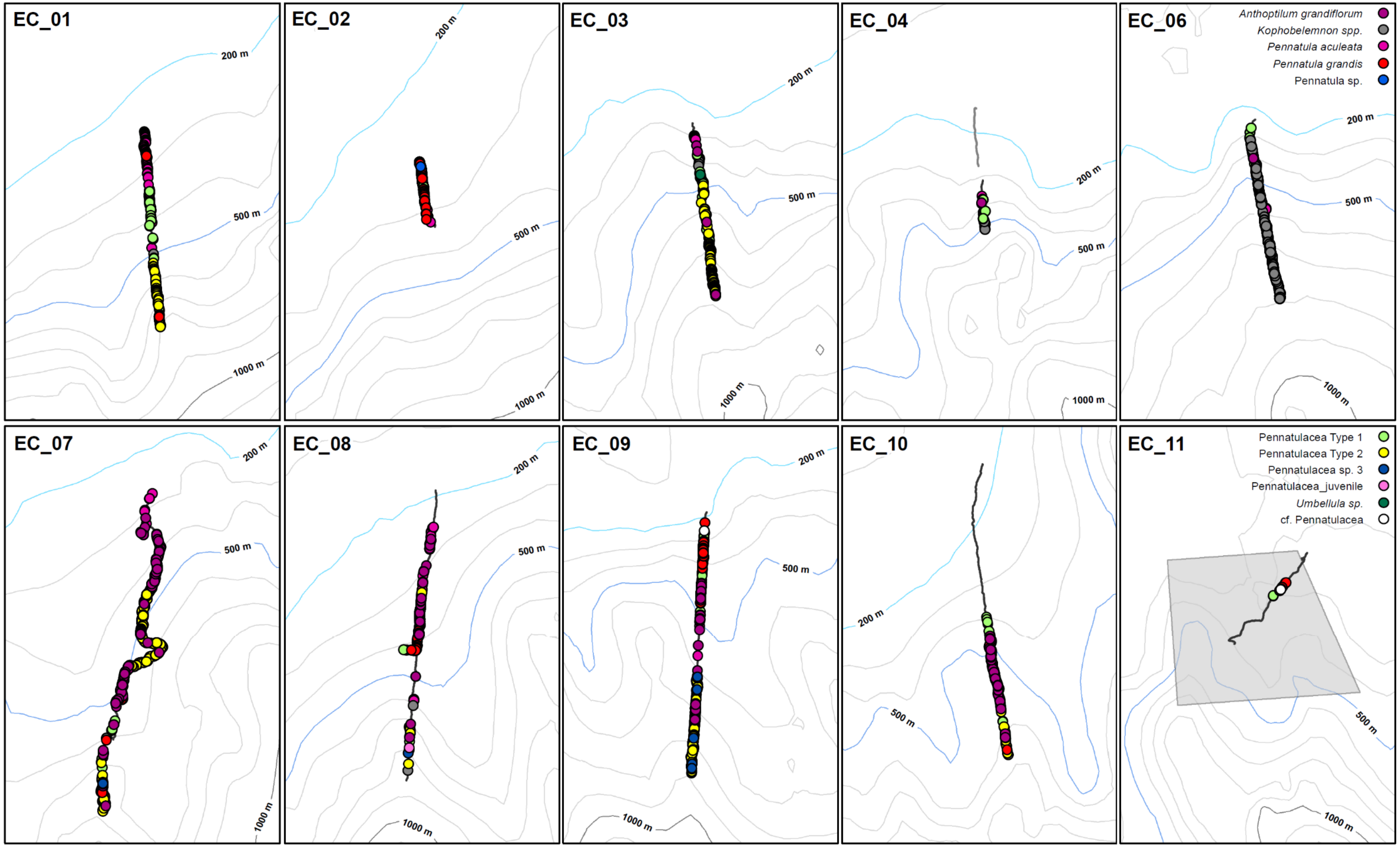

Figure 17. Transect-level distribution of sea pens at 10 video/photo stations. 100-m contours are displayed. The 200, 500, and 1000-m contours are in blue and labelled. The *Lophelia* Coral Conservation Area is indicated by the grey polygon in EC_11. All maps are scaled equally (1:100,000).

Validation of Sea Pen Significant Benthic Areas and Predictive Models

Figure 18 shows all the available sea pen records for the Eastern Scotian Slope against the sea pen KDE-SBAs. Data sources include the Campod video and 4K photo transects analyzed from this study, previous optical (camera) surveys conducted by DFO in 2007 and 2008, records from the NOAA Deep-Sea Coral Data Portal, and trawl catch data (presences and absences) from DFO's multispecies trawl survey, collected between 2003 to 2017. Our study has increased the number of sea pen observations significantly for the eastern portion of the study area (Stations EC_06 to EC_10) where only a single sea pen observation was previously noted from DFO's trawl survey. The majority of records fell below the 200 m depth contour except several DFO science survey records on the trough of Shortland Canyon. Here, *Pennatula grandis* was recorded between 100 and 200 m depth from a Campod survey of the area in 2008.

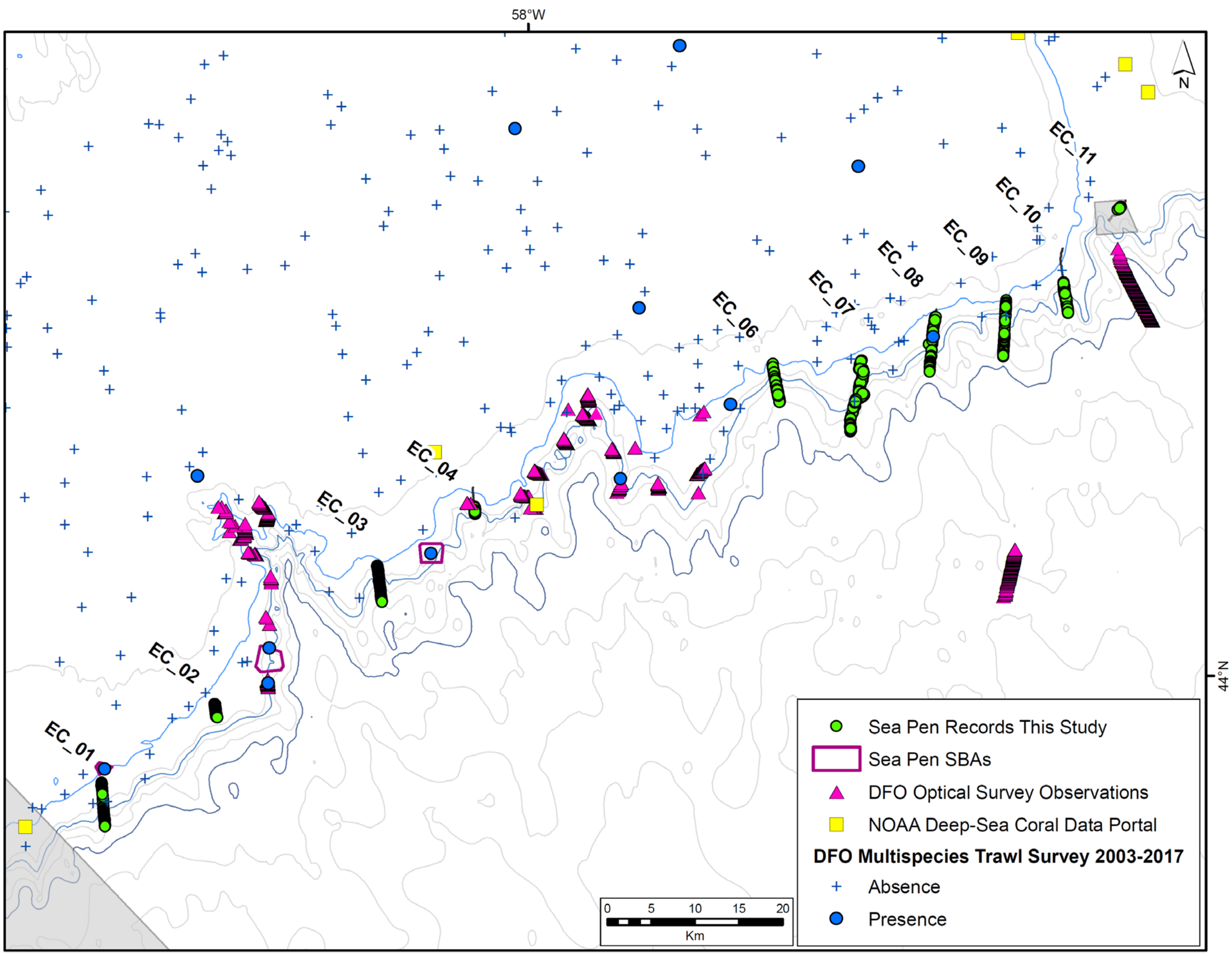

Figure 18. Distribution of available sea pen records on the Eastern Scotian Slope. Data sources are described above.

Figure 19 shows the predicted presence probability of sea pens from Beazley et al. (2016) overlaid by sea pen occurrences from all data sources. Also shown are the KDE- and SDM-SBA polygons. Of the 6661 sea pens observed across all 10 stations, only 11% were predicted with a high probability of occurrence by the model (75 – 84%; Table 7). Most records (88%) were predicted with moderate probabilities (25 to 75%). On average the shallowest sea pen records (343 ± 84 m) were associated with the lowest probabilities. Most sea pen records were encompassed by the sea pen SDM-SBA with the exception of those on the shallower portion of Station EC_08. Any future SDM applications with the inclusion of these new sea pen records may increase the probability of occurrence in shallower waters.

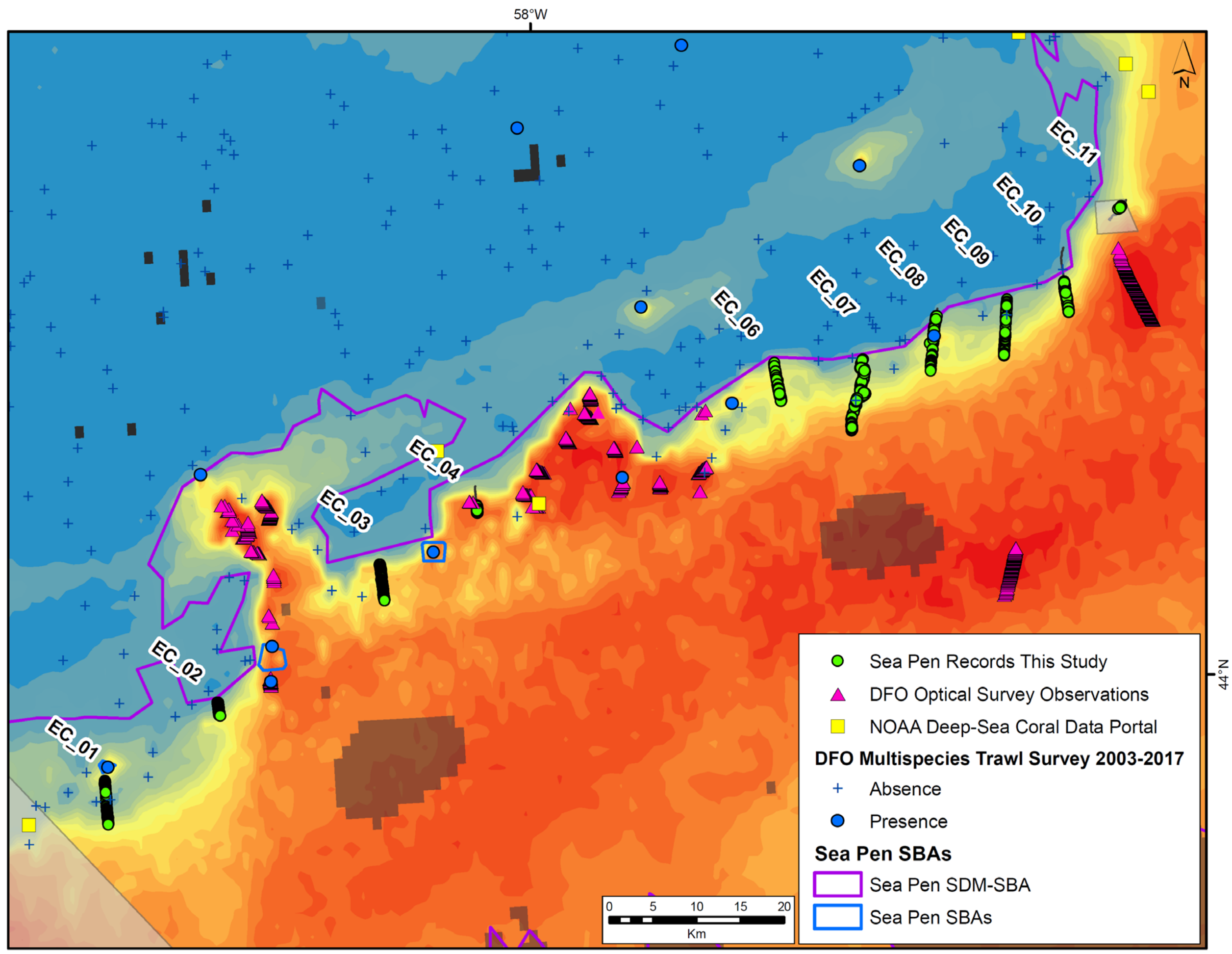

Figure 19. Location of sea pen records from all data sources against the sea pen presence probability model from Beazley et al. (2016). Presence probability values at the location of identified sea pens from the 10 video/photo stations were extracted and are summarized in Table 7.

Table 7. Predictions of presence probability at the location of sea pens recorded across the 10 video/photo stations. Species distribution model was a random forest model based on presence-absence data of sea pens (see Beazley et al. 2016). Also shown is the minimum and maximum depth and average ± standard deviation (SD) of observations per presence probability class.

Presence Probability (%)	Number of Colonies & Percentage of Total	Min – Max Depth (m)	Average Depth ± SD (m)
3 – 25	827 (1%)	242 - 613	343 ± 84
25 – 50	4492 (41%)	240 - 895	551 ± 183
50 – 75	1284 (47%)	273 – 970	614 ± 226
75 - 84	58 (11%)	387 - 505	476 ± 36

Tube-Dwelling Anemones

The tube-dwelling anemone *Pachycerianthus borealis* was observed in high densities in localized patches along the Eastern Scotian Slope. This species is considered a VME indicator by NAFO (NAFO 2018) and a benthic Ecologically and Biologically Significant Area (EBSA) indicator (Kenchington 2014) due to its large size (over 40 cm in height) and ability to form dense aggregations on otherwise featureless soft-sediment habitats. Other, unknown tube-dwelling cerianthids were observed on the Campod and 4K camera transects in this study, sometimes in dense concentrations. However they were not considered here as their height above the seabed was less than 10 cm and therefore their ability to modify their surroundings was considered negligible compared to *P. borealis*. Table 8 shows the minimum, maximum, and average depth of *P. borealis*. The depth range of observations was 167 to 635 m with most occurring between 200 and 300 m depth (Figure 20). The temperature range of observations was 4.5 to 10.2°C (Table A2.1, Appendix 2).

Table 8. Total number, and minimum (Min.), maximum (Max.), and average (Avg.) depth of the tube-dwelling cerianthid anemone *Pachycerianthus borealis* recorded from the 10 video/photo stations on the Eastern Scotian Slope. Depth is from the SBE 39 attached to Campod/4K Camera. Average depth is ± standard deviation.

Tube-dwelling anemones				
	Total Observed	Min. Depth (m)	Max. Depth (m)	Avg. Depth (m)
Pachycerianthus borealis	10656	167	635	218 ± 32

The distribution of *P. borealis* across the 10 stations is shown in Figure 21. Of the 10,656 records, 10,241 (96%) were recorded from CON 030 on Station EC_04. Here, *P. borealis* formed a dense, monospecific aggregation between 167 and 313 m depth (see Figure 22). It was the only taxon observed on CON 030. The species was observed almost consistently along the shallow portion of the transects (see Figure 23).

Models to predict the distribution of this species have not yet been developed due to the sparsity of presence observations. To date, only 1 trawl set from DFO's multispecies trawl survey in the Maritimes Region has recorded *P. borealis* (Murillo et al. 2018). Tube-dwelling anemones have the ability to retract into their tubes in the sediment upon mechanical stimuli, likely resulting in low catchability from trawl gears. Three observations of *P. borealis* were made from the western flank of Shortland Canyon during a previous Campod mission in 2008 (Figure 21). Observations of tube-dwelling cerianthids listed as

'Cerianthidae' exist for the region and may represent *P. borealis*, but were not considered here due to their taxonomic uncertainty.

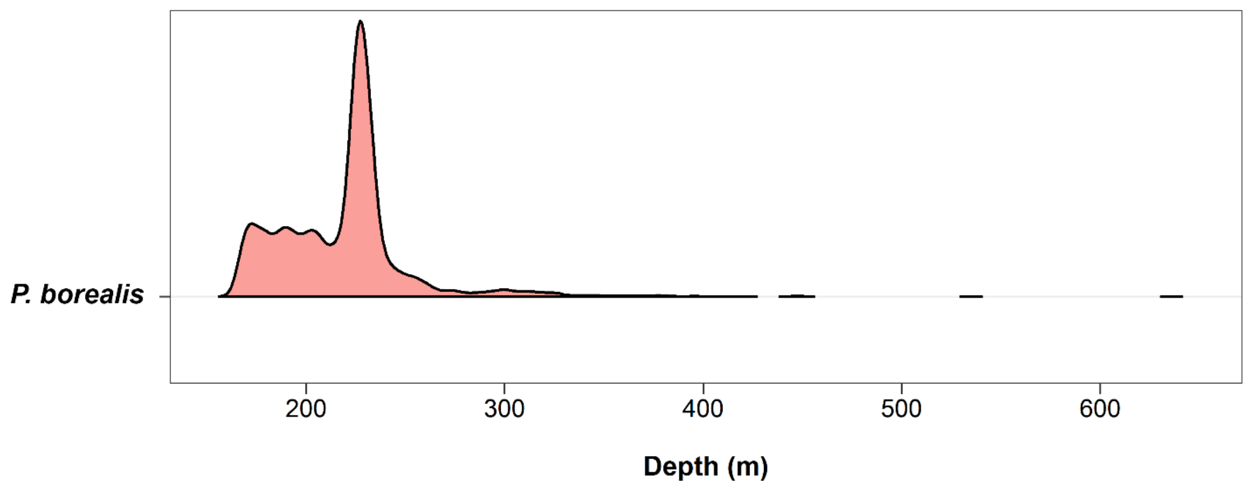

Figure 20. Density ridgeline plot showing the vertical (depth) density distribution of the tube-dwelling anemone *Pachycerianthus borealis* observed across all 10 stations on the Eastern Scotian Slope.

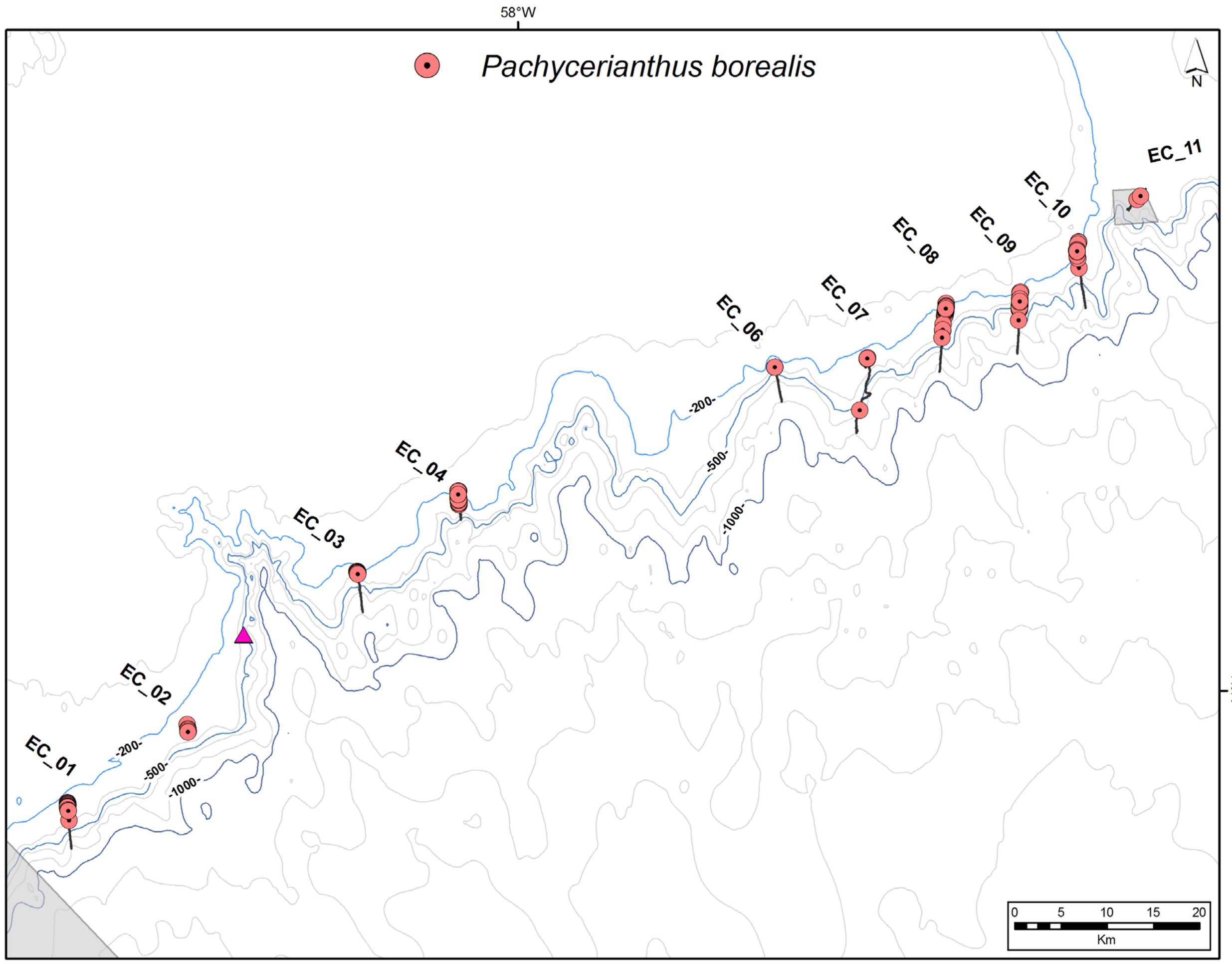

Figure 21. Distribution of tube-dwelling cerianthid anemone *Pachycerianthus borealis* across all 10 video/photo stations on the Eastern Scotian Slope. Pink triangle represents the location of several *P. borealis* records from a 2008 DFO Campod survey of the area.

Figure 22. Aggregation of the tube-dwelling anemone *Pachycerianthus borealis* observed on Campod transect Con 030, Station EC_04. Depth is 189 m.

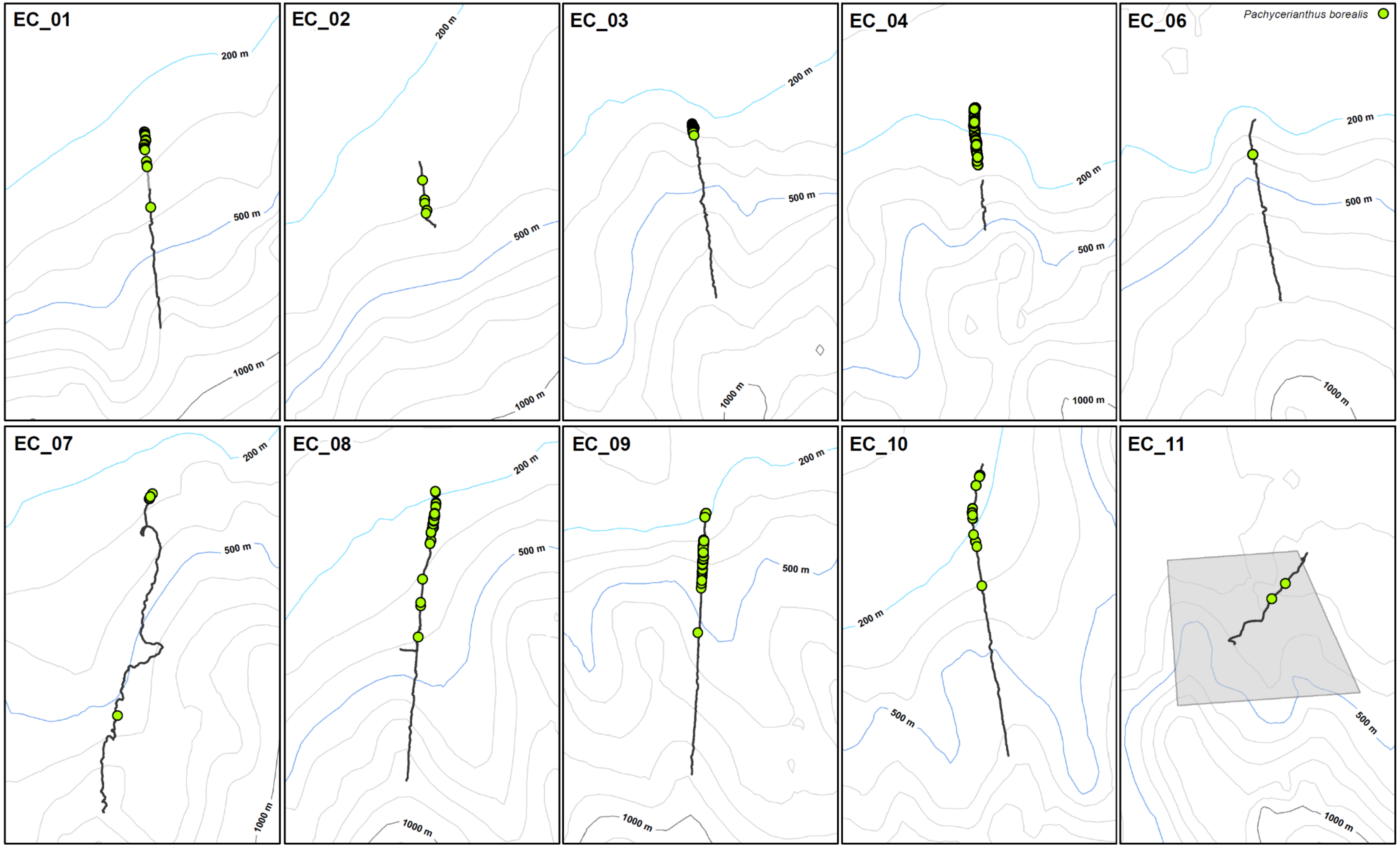

Figure 23. Transect-level distribution of tube-dwelling anemone *Pachycerianthus borealis* at 10 video/photo stations. 100-m contours are displayed. The 200, 500, and 1000-m contours are in blue and labelled. The *Lophelia* Coral Conservation Area is indicated by the grey polygon in EC_11. All maps are scaled equally (1:100,000).

Large-Sized Sponges

Five large-sized sponge taxa that are considered indicators of VME (NAFO 2018) were recorded across the 10 stations. The minimum, maximum, and average depth of each are listed in Table 9. Two taxa were identified to the species level (*Asconema foliatum* and *Chondrocladia grandis*), one to the family level (Polymastiidae), and one to the suborder level (Astrophorina spp.). The polymastid sponges observed here are likely a combination of *Weberella bursa* and *Polymastia,* both of which are considered VME indicators. The taxa designated as Astrophorina spp. are possibly from the genera *Geodia* or *Stryphnus*. These taxa are not frequently encountered in the Maritimes Region but are important constituents of the structure-forming tetractinellid sponge grounds of the Flemish Cap (Murillo et al. 2012) and the slope off Newfoundland and Labrador (Knudby et al. 2013). The 'Large-Sized Porifera spp.' group encompassed multiple species of sponge not found on the list of VME indicator taxa, but whose size and morphology (erect with growth more vertical than lateral, with a height above the sea bed > 10 cm) may fit the FAO criteria for VME designation (FAO 2009).

Chondrocladia grandis is a large (exceeding 50 cm in height), erect carnivorous sponge that anchors in soft sediments in the boreo-Arctic between 240 and 1600 m depth (Hestetun et al. 2017). Although it is not listed in NAFO's current Annex V.I. List of VME Indicator Species (NAFO 2018), this species was recently assessed against the FAO VME criteria during the 11th Meeting of the NAFO Scientific Council Working Group on Ecosystem Science and Assessment (WG-ESA) held in Dartmouth, Nova Scotia in November 2018. Its large size, fragility, presumed slow growth, and ability to provide structure on soft substrates deemed it suitable for future inclusion as a VME indicator species. It was previously observed in the Gully Marine Protected Area during a survey conducted with the remotely operated vehicle ROPOS in 2007 (Hestetun et al. 2017).

The most numerous sponge taxon was Polymastiidae spp. (75% of total), followed by Large-Sized Porifera spp. (24%), and the glass sponge *A. foliatum* (16%). The overall depth range of sponges was 189 – 915 m (Table 9), with the shallowest record belonging to Polymastiidae (189 m) and the deepest an unknown sponge in the Large-Sized Porifera spp. category (915 m depth). Figure 24 shows the ridgeline plot for all five sponge taxa. The polymastiids, Astrophorina spp., and *A. foliatum* overlapped in their depth distribution in shallow waters. Astrophorina spp. showed a second peak in abundance at deeper depths, suggesting the possible inclusion of multiple species. The carnivorous sponge *C. grandis* had a deeper depth distribution, peaking in abundance between 600 and 700 m depth.

Table 9. Total number, and minimum (Min.), maximum (Max.), and average (Avg.) depth of large-sized sponges recorded from the 10 video/photo stations on the Eastern Scotian Slope. Depth is from the SBE 39 attached to Campod/4K Camera. Average depth is ± standard deviation.

Large-sized sponges	Total Observed	Min. Depth (m)	Max. Depth (m)	Avg. Depth (m)
Asconema foliatum	55	264	827	395 ± 175
Astrophorina spp.	5	224	806	578 ± 303
Chondrocladia grandis	19	552	817	681 ± 89
Polymastiidae spp.	12502	189	845	292 ± 114
Large-Sized Porifera spp.	4100	190	915	296 ± 118

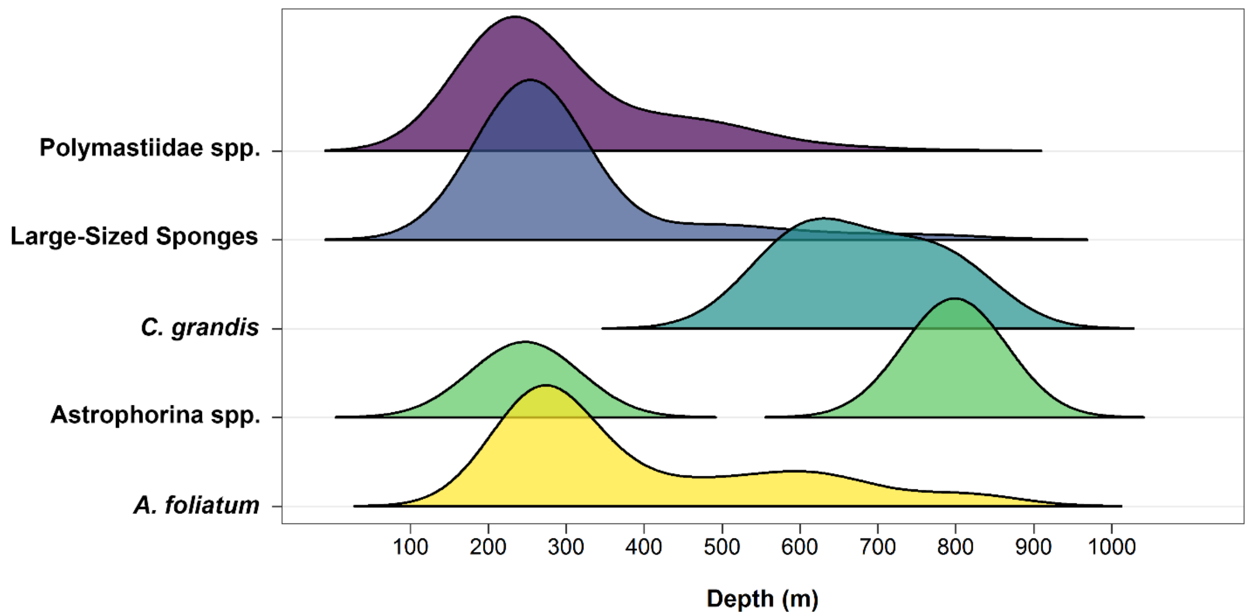

Figure 24. Density ridgeline plot showing the vertical (depth) density distribution of large-sized sponges observed across all 10 stations on the Eastern Scotian Slope.

Distribution maps of the observed sponges are presented in Figures 25 through 27. Detailed transect-level sponge distributions can be found in Figure 28. Glass sponge *Asconema foliatum* was found on most transects in the eastern portion of the study area and Station EC_01 immediately adjacent to the Gully. Of the 55 occurrences, over 50% (32) were found on the single transect in the LCCA. Here this species was observed between 264 and 294 m depth, shallower than its depth distribution on stations to the west of the closure (range 374 to 827 m). Tetractinellid sponges from the suborder Astrophorina and carnivorous sponge *C. grandis* were restricted to stations in the eastern portion of the study area, while polymastiids and Large-Sized Porifera spp. were found on all stations.

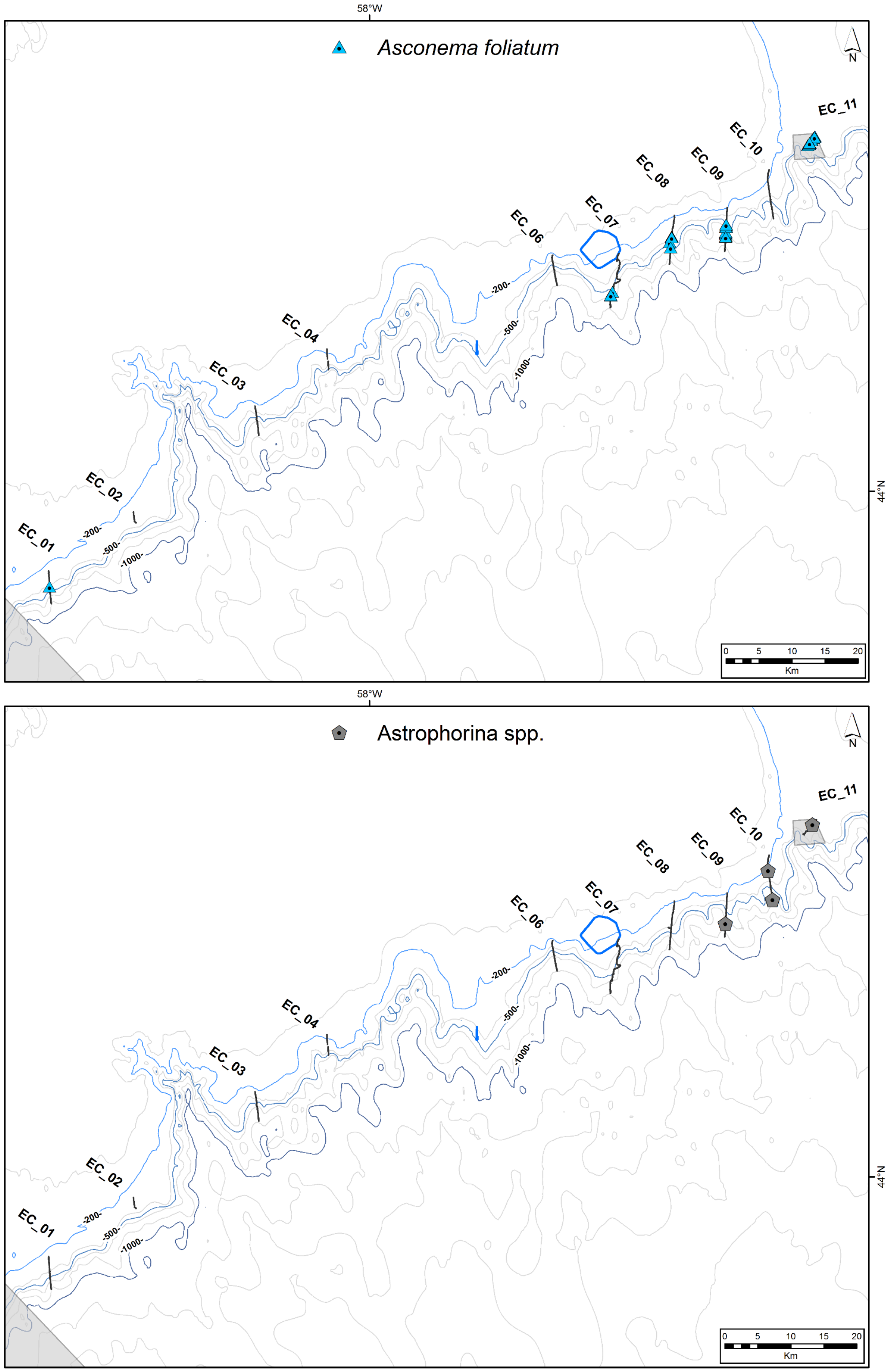

Figure 25. Distribution of *Asconema foliatum* (top panel) and sponges from the suborder Astrophorina (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the sponge Significant Benthic Areas (blue polygon) based on kernel density analysis (see DFO 2017b).

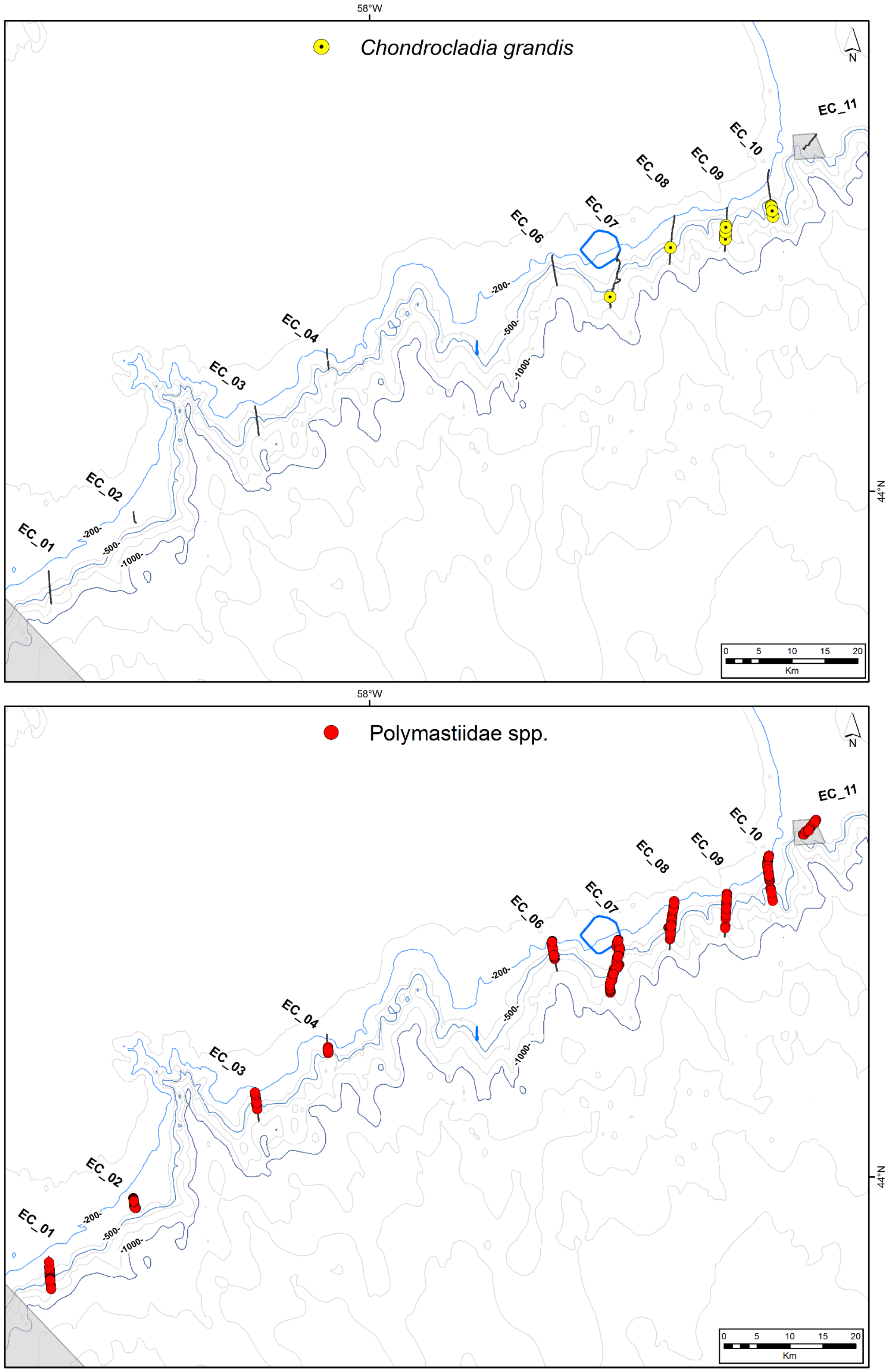

Figure 26. Distribution of *Chondrocladia grandis* (top panel) and polymastiid sponges (bottom panel) across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the sponge Significant Benthic Areas (blue polygon) based on kernel density analysis (see DFO 2017b).

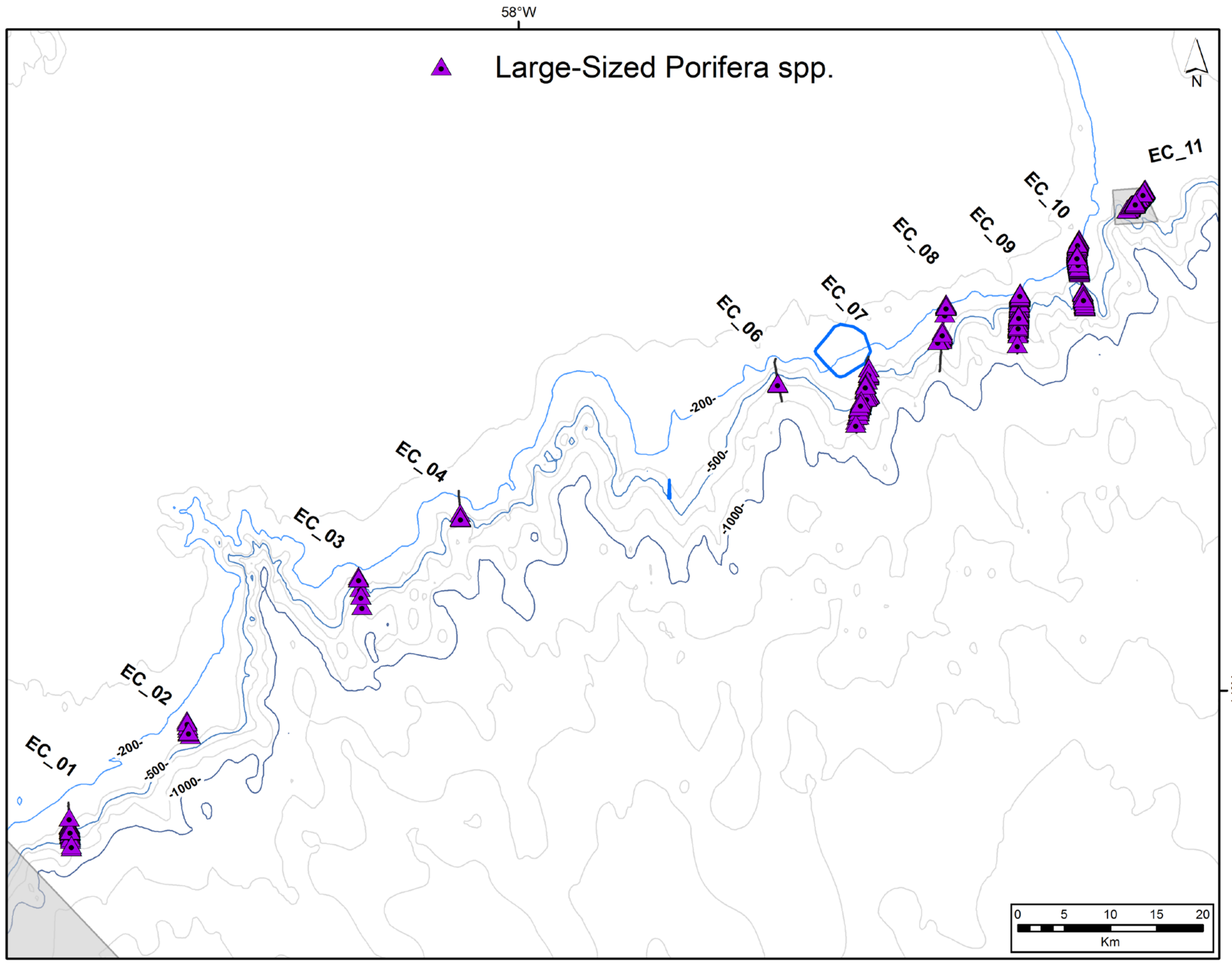

Figure 27. Distribution of unidentified large-sized sponges across all 10 video/photo stations on the Eastern Scotian Slope. Also shown are the sponge Significant Benthic Areas (blue polygon) based on kernel density analysis (see DFO 2017b).

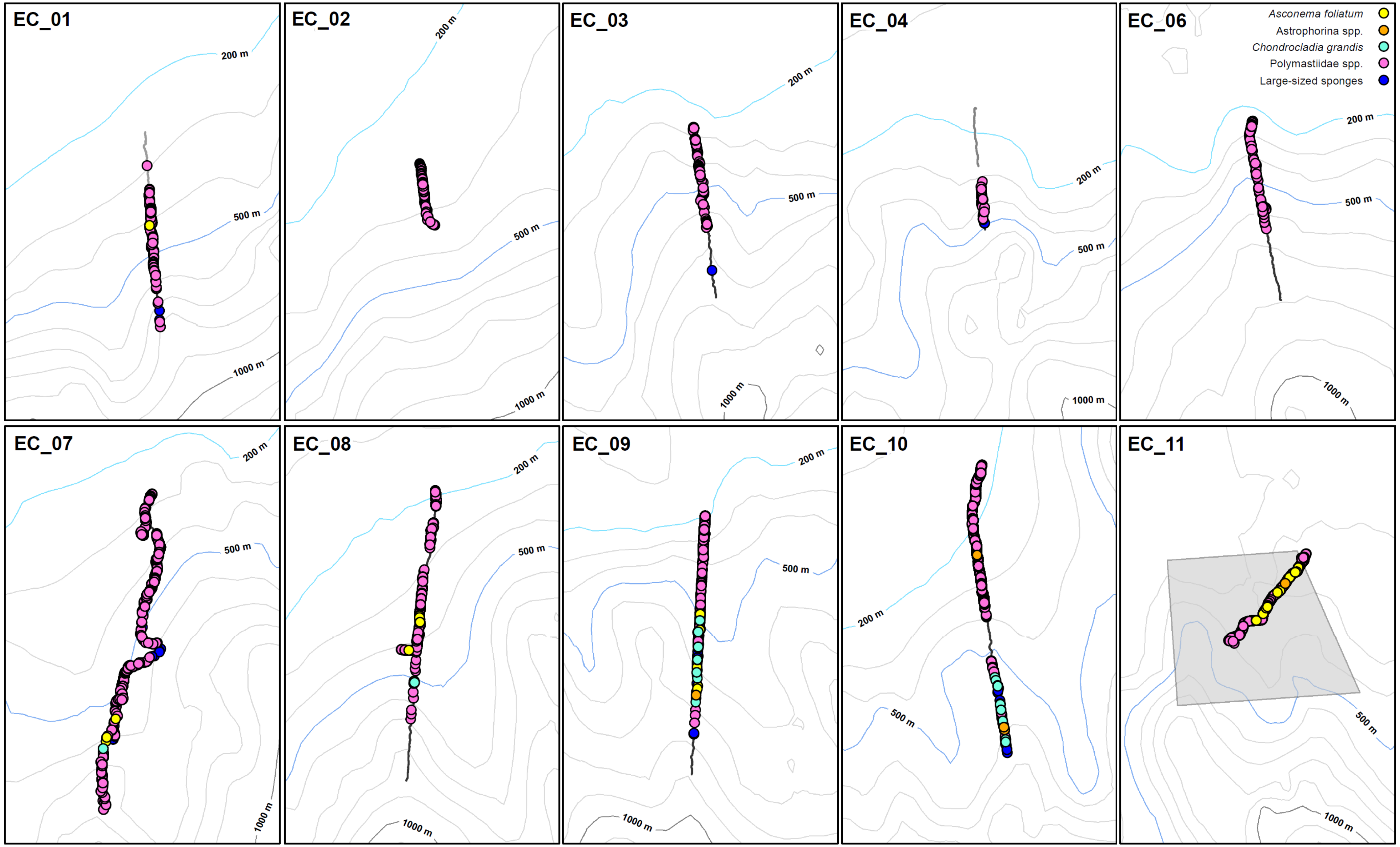

Figure 28. Transect-level distribution of large-sized sponges at 10 video/photo stations. 100-m contours are displayed. The 200, 500, and 1000-m contours are in blue and labelled. The *Lophelia* Coral Conservation Area is indicated by the grey polygon in EC_11. All maps are scaled equally (1:100,000)

Validation of Sponge Significant Benthic Areas and Predictive Models

Figure 29 shows all the available sponge records for the Eastern Scotian Slope. Data sources include the Campod video and 4K photo transects from this study, previous optical (camera) surveys conducted by DFO in 2007 and 2008 and NRCan in 2003 and 2004, sponge bycatch records from the Fisheries Observer Program (FOP) collected between 1985 and 1999, and trawl catch data (presences and absences) from DFO's multispecies trawl survey, collected between 2002 to 2017. A large number of sponge occurrences are present in the study area relative to the coral groups. Occurrences are concentrated between 100 and 500 m depth and within Shortland and Haldimand Canyons where significant scientific effort has been focused.

Our study has significantly increased the number of sponge observations outside the canyons, particularly in the eastern portion of the study area between Stations EC_06 and EC_10 where only a few sponge observations were previously available from DFO's multispecies trawl survey and commercial records from the FOP program.

Figure 30 shows the predicted presence probability of sponges from Beazley et al. (2016) overlaid by sponge occurrences from all data sources. Of the 16,681 sponges observed across all 10 stations, most (73%) were predicted with a high probability (75 - 91%; Table 10). Unlike the gorgonian and sea pen SDMs, which also included records from targeted science surveys along the slope, the sponge SDM was built using records from DFO's multispecies trawl survey and scallop dredge surveys in the Bay of Fundy, the former of which does not fully encompass the lower slopes off Nova Scotia. This may explain the lower probabilities associated with those deeper sponge occurrences. Nonetheless, the sponge observations from all 10 video/photo transects fell within the slope area predicted as suitable habitat for sponges based on the prevalence threshold (0.43, see Beazley et al. (2016) and Figure 31).

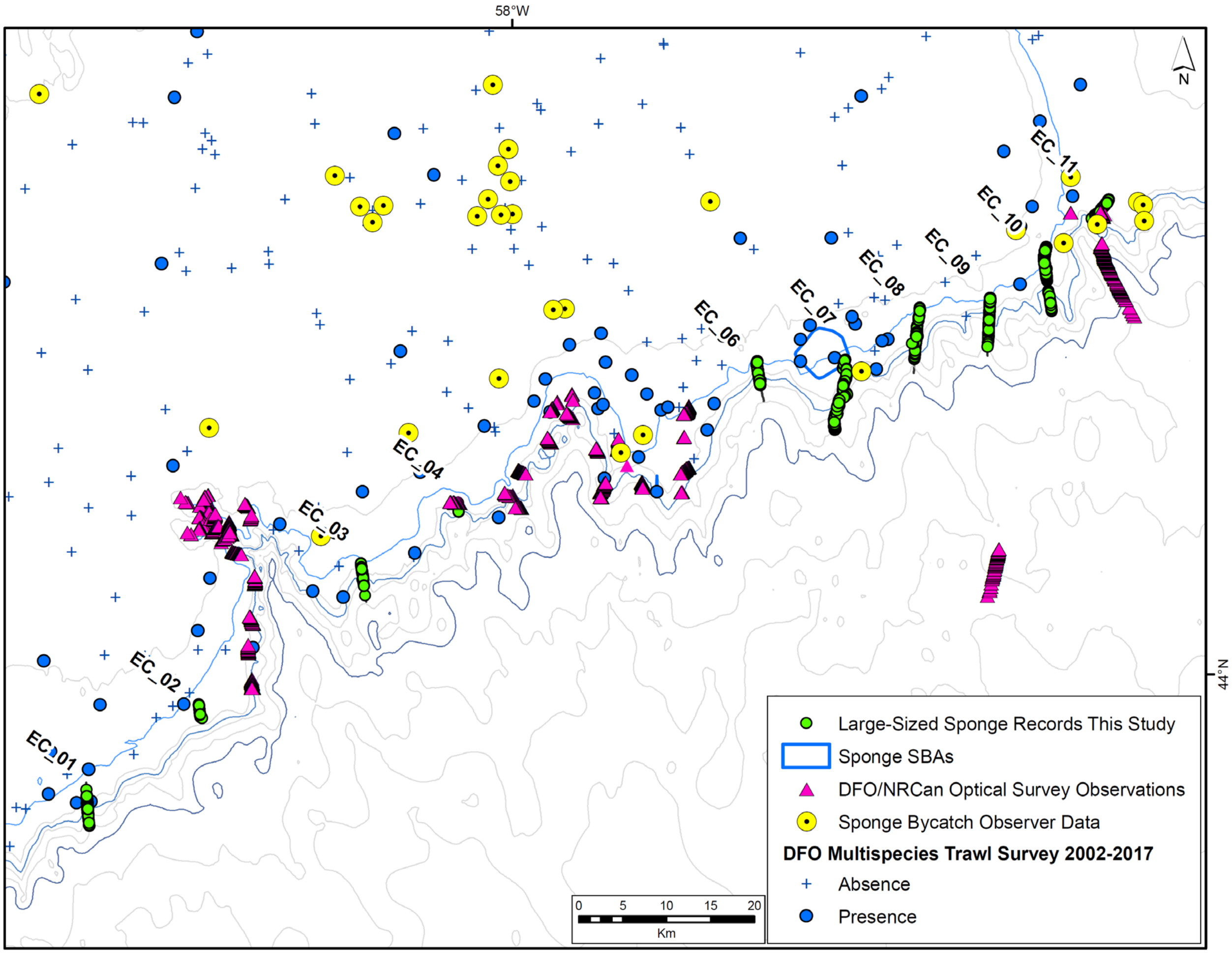

Figure 29. Distribution of available sponge records on the Eastern Scotian Slope. Data sources are described above.

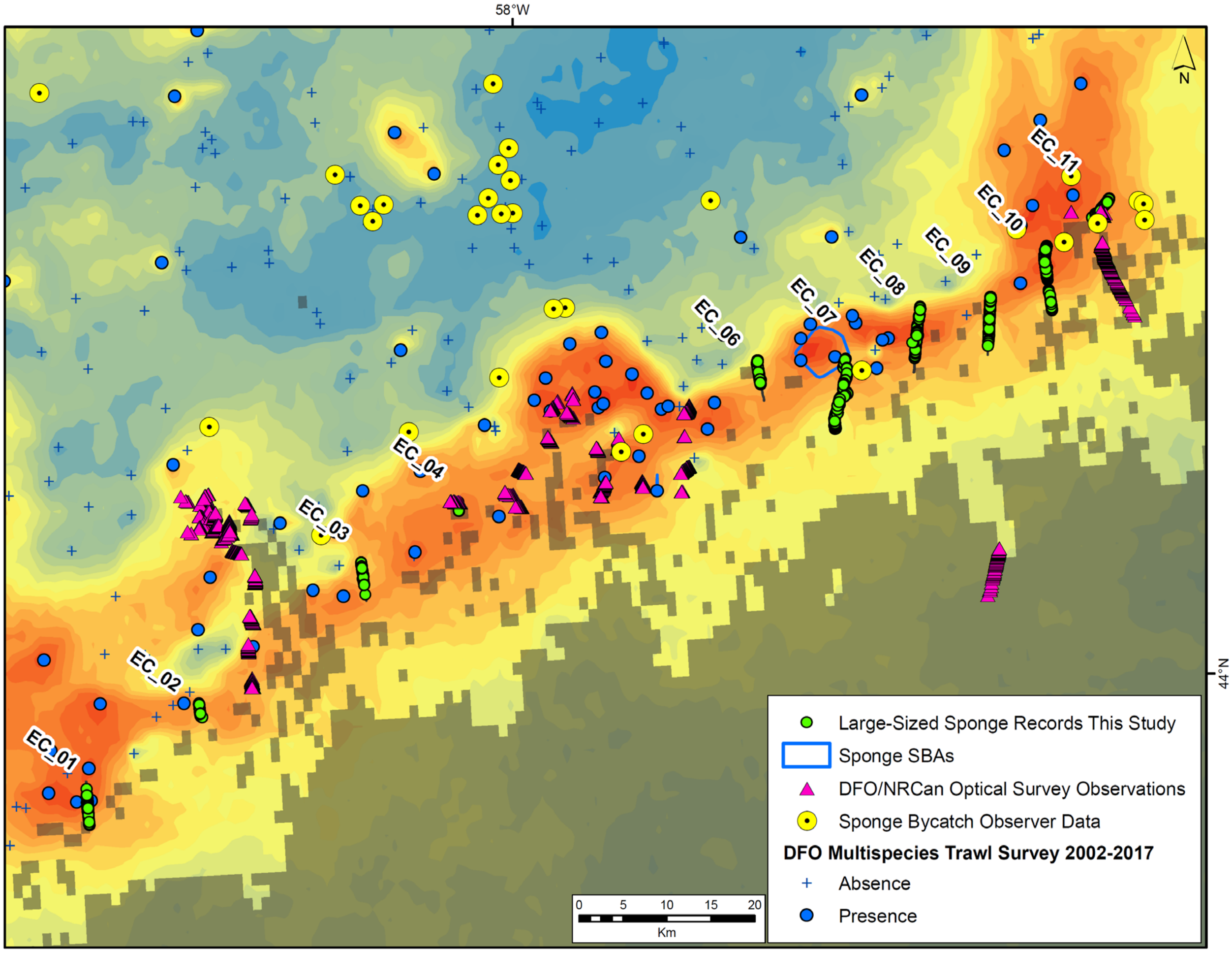

Figure 30. Location of sponge records from all data sources against the sponge presence probability model from Beazley et al. (2016). Presence probability values at the location of identified sponges from the 10 video/photo stations were extracted and are summarized in Table 10.

Table 10. Predictions of presence probability at the location of sponges recorded across the 10 video/photo stations. Species distribution model was a random forest model based on presence-absence data of sponges (see Beazley et al. 2016). Also shown is the minimum and maximum depth and average ± standard deviation (SD) of observations per presence probability class.

Presence Probability (%)	Number of Colonies & Percentage of Total	Min – Max Depth (m)	Average Depth ± SD (m)
47 – 50	153 (1%)	562 – 845	677 ± 68
50 – 75	4416 (26%)	208 – 915	392 ± 144
75 - 91	12112 (73%)	189 - 776	253 ± 64

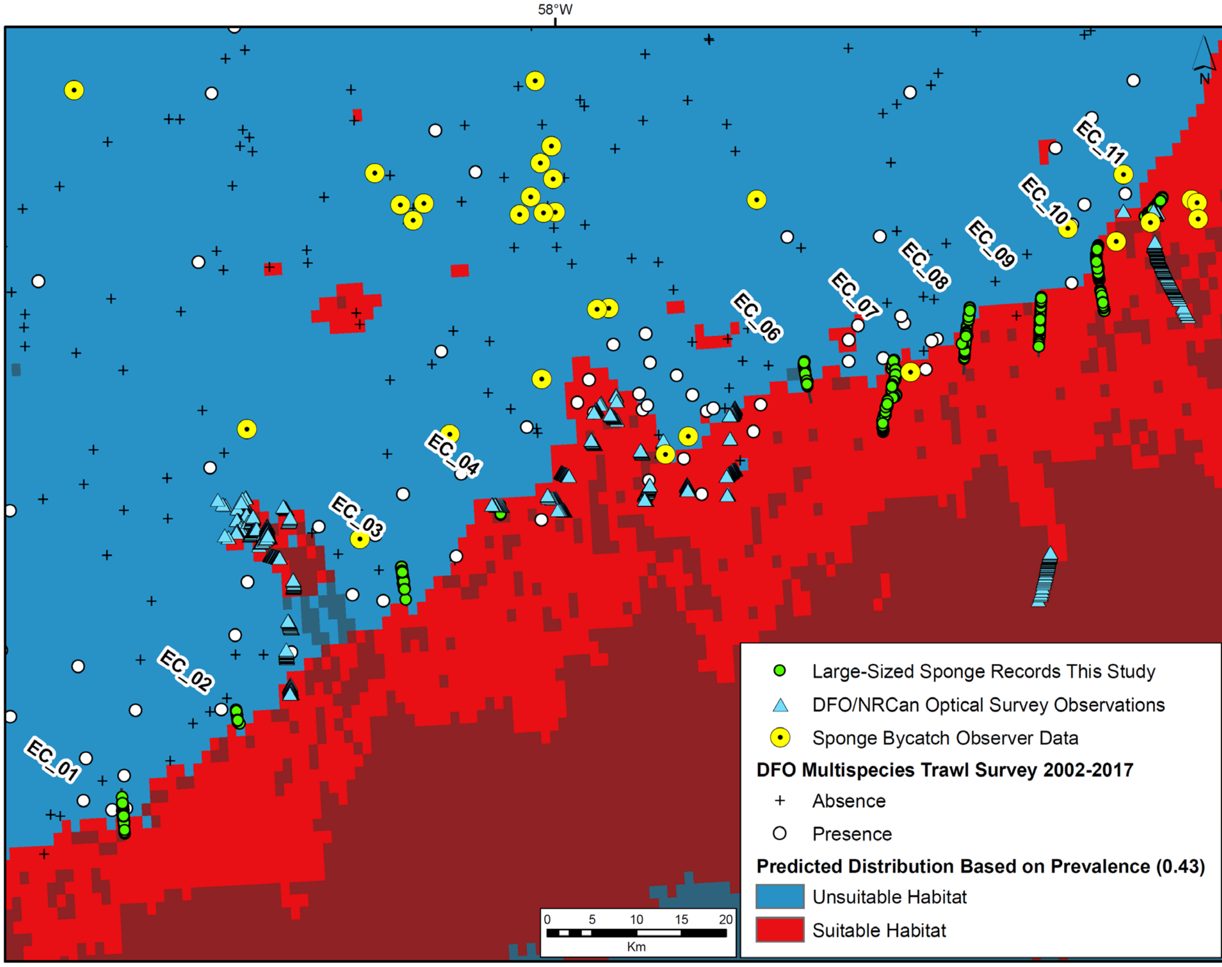

Figure 31. Location of sponge records from all data sources against the predicted sponge distribution based on prevalence (0.43) from Beazley et al. (2016). Areas in red show predicted suitable habitat for sponges and areas in blue show unsuitable habitat. Grey areas show areas of model extrapolation.

Co-occurrence of Groundfish Fishing Effort and Coral Distributions

Figure 32 shows the spatial distribution of large gorgonian coral colonies at each station in relation to mobile- and fixed-gears groundfish fishing effort compiled from VMS and logbook data from 2005 – 2014 (Koen-Alonso et al. 2017). The data are represented by percentiles where increasing values represent decreasing effort, i.e., the highest effort concentration is represented by the top 20%. The total number of colonies observed and the depth range (minimum, maximum, and average ± standard deviation) of large gorgonian observations associated with the different effort percentiles is shown in Table 11.

Effort from groundfish mobile gears was generally low to moderate across the study area. This effort was associated with the location of some large gorgonian corals, particularly on transects located within the eastern portion of the large gorgonian coral SBA (EC_07 to EC_11, Figure 32 top panel). The depth distribution of this effort varied across the study area but typically occurred between 200 and 500 m depth, overlapping the distribution of all large gorgonian species but particularly the full depth distribution of iconic branching corals *Paragorgia arborea* and *Primnoa resedaeformis*. In areas of low effort on Station EC_10, several broken and tipped colonies of *P. arborea* were noted at ~260 m depth (see Figure 33), and trawl marks in the near vicinity.

In contrast, effort from groundfish fixed gears was more concentrated in the study area compared than that of mobile gears (Figure 32 bottom panel) and 47% (3974 colonies) of the large gorgonians recorded fell into areas with the highest fishing effort (<20th percentile; Table 11). The highest effort was associated with those shallow gorgonian records (272 ± 6 m) located within and outside the northeast portion of the LCCA.

Of the groundfish fisheries in the region, the redfish fishery is particularly active in the eastern portion of the study area, and overlap between moderate redfish landings and the location of large gorgonian corals at Stations EC_08 through EC_11 was identified (Figure 34 top panel). Similarly, halibut longline landings also overlapped the distribution of large gorgonian corals (Figure 34 bottom panel). Although the bottom longline is considered a passive fishing gear with relatively low impact on the seabed (Auster et al. 2011), bycatch of corals and sponges have been reported for some bottom longline fisheries (Muñoz et al. 2011; Sampaio et al. 2012).

The groundfish mobile-gear effort data was examined in and around the LCCA in order to assess whether compliance issues potentially exist with its boundaries. Low to moderate effort was identified inside the boundaries of the LCCA (Figure 35). Higher effort

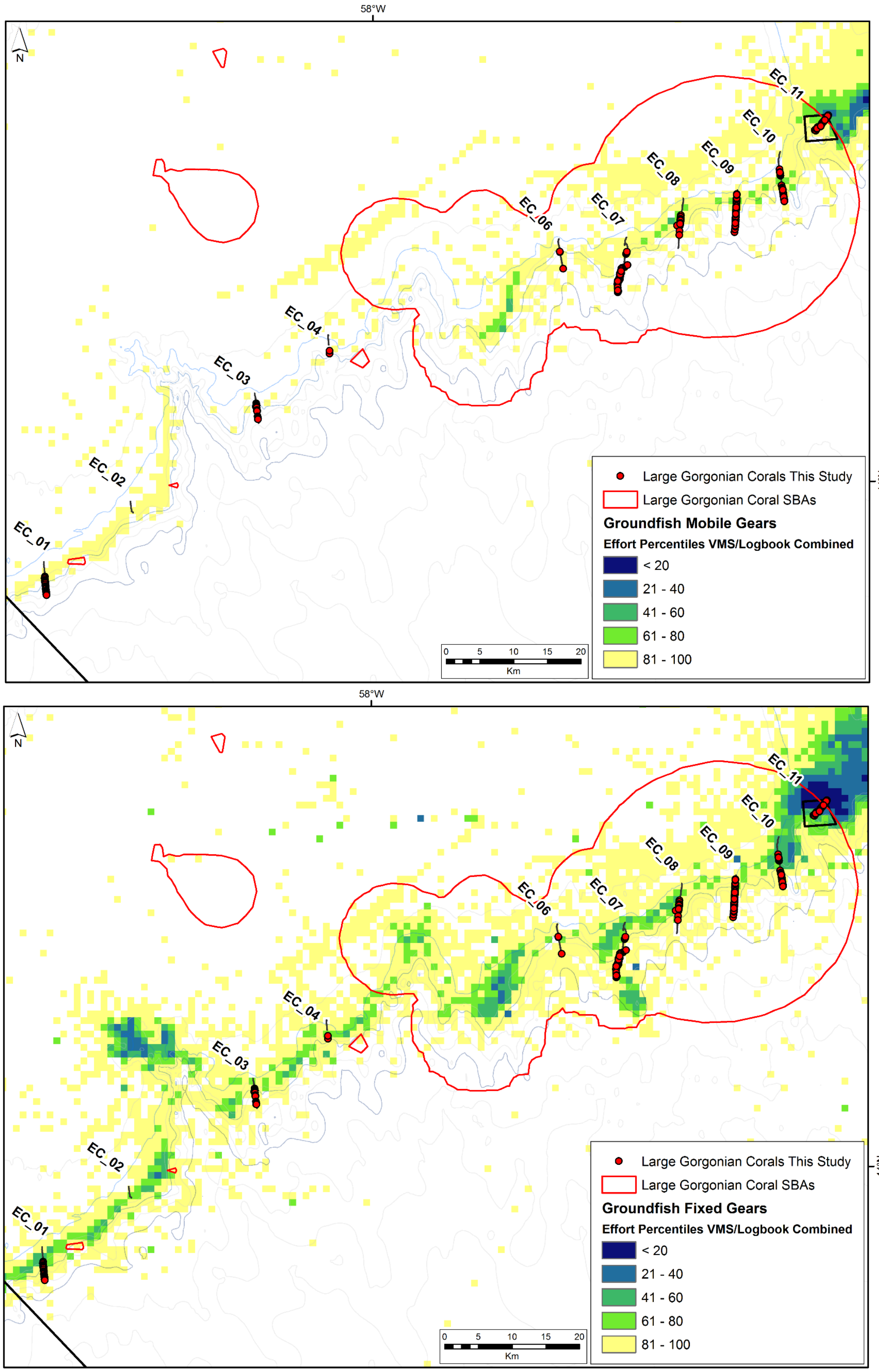

Figure 32. Overlap between groundfish mobile- (top) and fixed- (bottom) gear fishing effort percentiles and the distribution of large gorgonian corals recorded across all 10 stations on the Eastern Scotian Slope. Also shown are the large gorgonian coral Significant Benthic Areas (SBAs) outlined in red. Effort was calculated from VMS and logbook data collected between 2005 and 2014.

Table 11. Number of large gorgonian corals associated with groundfish mobile- and fixed-gear fishing effort percentiles. The highest effort is represented by the <20% percentile. No data means that no logbook or VMS data was available, i.e., no effort.

Effort Percentile	Number of Colonies		Depth Range (m)		Average Depth (m)	
	Mobile	**Fixed**	**Mobile**	**Fixed**	**Mobile**	**Fixed**
<20	0	3974		264 – 287		272 ± 6
21-40	702	0	279 – 287		283 ± 34	
41-60	0	838		232 - 426		281 ± 32
61-80	3630	469	264 – 437	335 – 633	281 ± 34	395 ± 29
81-100	1739	2099	245 – 832	271 - 896	404 ± 142	574 ± 93
No Data	2267	958	232 – 914	437 – 914	608 ± 104	618 ± 133

Figure 33. Tipped colony of *Paragorgia arborea* (lower left) observed on the Campod transect collected at Station EC_10. Depth is 269 m.

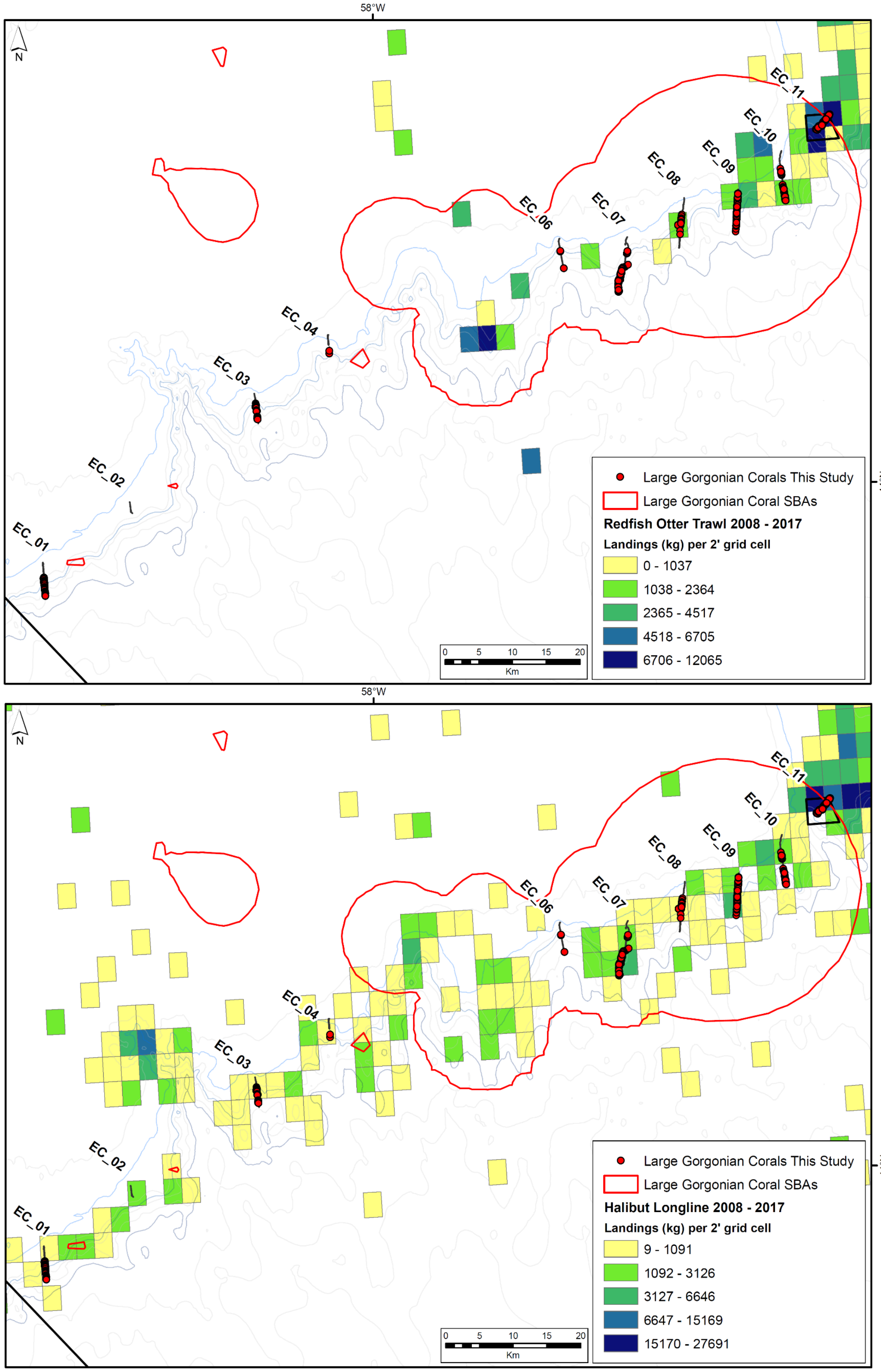

Figure 34. Landings (kg) of otter trawl-caught redfish (top panel) and longline halibut (bottom panel) from 2008 to 2017 across the Eastern Scotian Slope. Landings data were collated to 2-minute (2') grid cells. Also shown are the large gorgonian coral records identified at each of the 10 video/photo stations, and the large gorgonian coral Significant Benthic Areas (SBAs).

was observed along the northern boundary of the closure, suggesting that fishing may have occurred within the closure since its implementation in 2004. The transect conducted at Station EC_11 (CON 039) was specifically designed to traverse towards the northeast portion of the closure area across this effort gradient, in order to determine whether the presence of *in situ* observations of fishing impacts could corroborate any bottom fishing activity. Analysis of this transect revealed the presence of fishing gear (both nets and line) near the centre of the closure. The gear are likely remnants from before the closure was implemented, as epibenthic fauna such as anemones were often observed attached to the fishing gear. However, broken and tipped-over corals were also observed, some of which still had live tissue present on the coral skeleton and therefore appeared more recent.

Immediately adjacent to the northeastern boundary of the LCCA moderate effort between the 20^{th} and 40^{th} (31% specifically) percentile was associated with colonies of *A. armata* observed on Station EC_11 (Figure 35, upper panel). This effort data is collated to a relatively large grid size (1 km), and so the exact location of these corals may not have been directly impacted. However, a possible trawl mark was observed in the video in the same location (Figure 35, lower panel). The large gorgonian coral SBA does not fully encompass the LCCA and those records of *A. armata* that fall outside its boundaries.

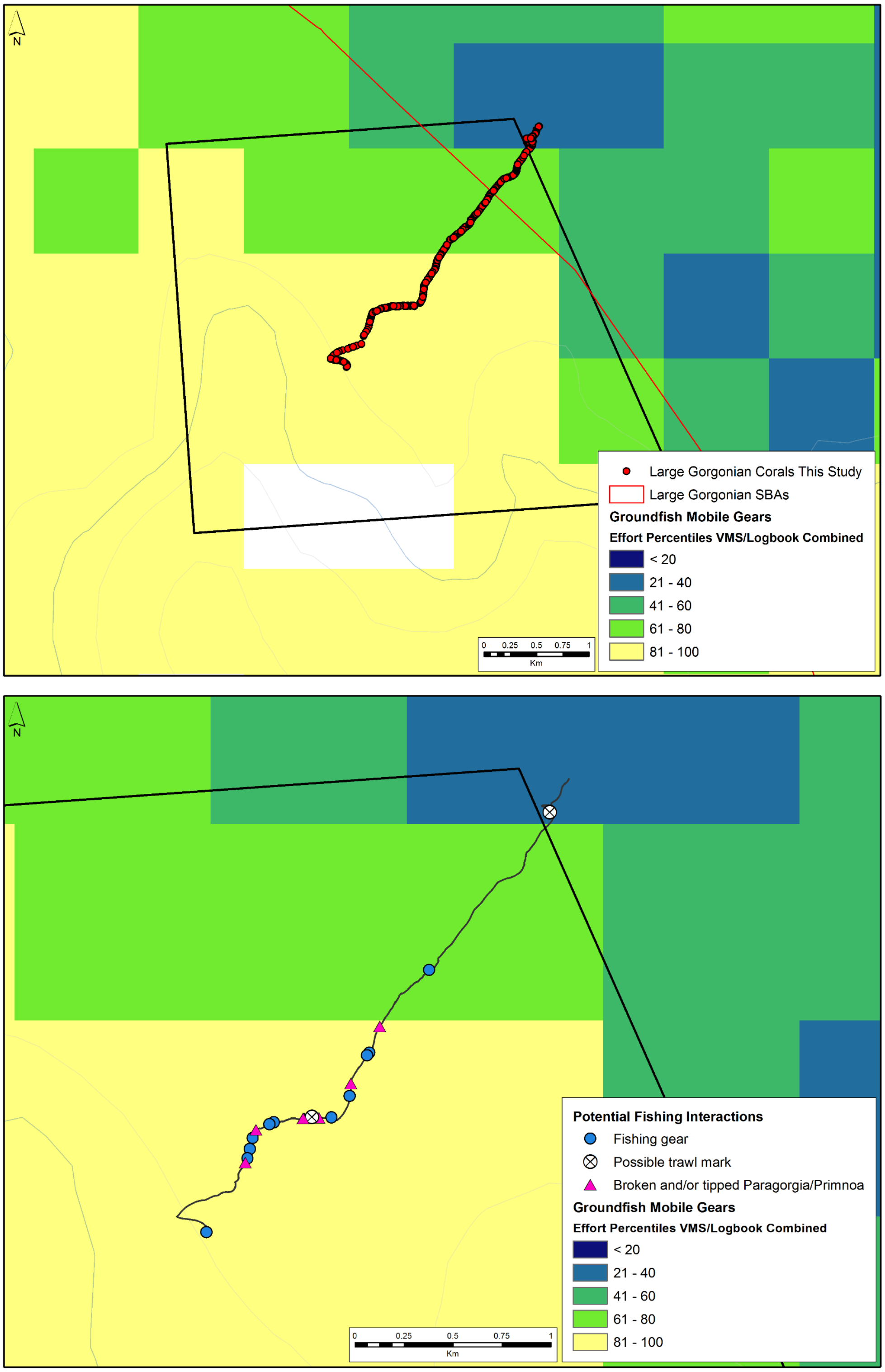

Figure 35. Overlap between groundfish mobile-gear fishing effort percentiles and large gorgonian corals recorded from a Campod video transect collected at Station EC_11 in the *Lophelia* Coral Conservation Area (top panel), observations of fishing interactions (gear, trawl marks, and broken and/or tipped over large branching corals; bottom panel) observed along Station EC_11.

DISCUSSION

This study represents the first systematic survey of the deep-water corals and sponges of the Eastern Scotian Slope. Previous efforts to survey the benthos of this area using specialized camera equipment were focused in the canyons (the Gully, Shortland and Haldimand canyons) and in the *Lophelia* Coral Conservation Area (see Cogswell et al. (2009) for summary of data collected up to 2008) where corals are known to aggregate. This study highlights the importance of the slope outside the canyons for the distribution of corals, tube-dwelling anemones, and sponges, where nearly 25 taxa were recorded between 167 – 970 m depth, from an overall depth range sampled of 140 – 971 m.

The study by Breeze et al. (1997) identified 35 coral taxa in the Maritimes Region from all available data sources (scientific literature, museum collections, and bycatch reports). This diversity was later increased in 2007 to 45 species occurring off Nova Scotia and New Brunswick (http://science.gc.ca/eic/site/063.nsf/eng/h_EE39B64D.html). From the Gully MPA, Gordon and Kenchington (2007) reported 16 taxa consisting of 5 Alcyonacea, 6 "Gorgonacea" (now Alcyonacea), and 5 Scleractinia taxa, which was later increased to a total of 28 taxa by Cogswell et al. (2009) that included 1 additional Scleractinia, 3 Gorgonacea, 1 Antipatharia (black coral), and 7 Pennatulacea. In this study, we observed 18 coral taxa from 3 functional groups: 5 large and 3 small branching "Gorgonacea", and 10 Pennatulacea (Pennatulacea_juvenile not considered here). Similarly, dense, localized patches of the tube-dwelling anemone *Pachycerianthus borealis* were for the first time enumerated and described from the area. True soft corals (e.g. family Nephtheidae) were also observed in dense aggregations particularly in the eastern portion of the study area including the LCCA, but were not considered here as they do not fit the definition of a VME or SBA. The majority of coral taxa observed here had been previously reported to occur along the Eastern Scotian Slope or elsewhere in the Maritimes Region. However, several unidentified sea pens may represent new species records for the region. Pennatulacea Type 2, a morphotype group of at least two taxa, included a species that closely resembled *Protoptilum carpenteri*. This species has not yet been reported for the region but is found in nearby canyons that excise the Newfoundland shelf (Baker et al. 2012). It is possibly represented by one of the unidentified, order-level Pennatulacea taxa reported for the Eastern Scotian Slope in Cogswell et al. (2009). The identification of sponges and an assessment of their diversity in the Maritimes Region is lagging behind that of corals due to the difficulty in identifying these organisms, which often requires examination of their microscopic spicules. To date, only the large glass sponge *Vazella pourtalesi*, which forms a dense aggregation in Emerald Basin on the Scotian Shelf, has been consistently identified in the annual multispecies trawl survey. In this study, identification of sponges from the video and photographs was based on an assessment of their gross morphological features (e.g., presence of papillae to indicate sponges of the family Polymastiidae), which could be prone to error. Collection of specimens would aid in species-level identifications and help confirm the diversity of sponges in the area.

While the functional role of corals and sponges in deep ocean ecosystems remains poorly understood compared to their shallow-water counterparts, aggregations of deep-water corals and sponges are considered biogenic habitats that modify the surrounding substrate and increase the availability of microhabitats on otherwise featureless bottom types. Consequently, aggregations of deep-water corals and sponges have been linked to a higher diversity of invertebrates and fish (Klitgaard 1995, Freese and Wing 2003, Watling et al. 2011, Beazley et al. 2013;2015) and are recognized as refugia, spawning and nursery grounds for commercially harvested fish species (Krieger and Wing 2002, Etnoyer and Warrenchuk 2007, Buhl-Mortensen et al. 2010, Baillon et al. 2012). Sponges play an important role in benthic-pelagic coupling and the cycling of nutrients due to the large volume of water they filter, a feature which is enhanced in aggregations of these organisms commonly referred to as sponge grounds. For instance, a population of massive sponges on the Norwegian Shelf was estimated to filter approximately 250 million m^3 of water per day and consume 60 tonnes of carbon (Kutti et al. 2013). The importance of these organisms and their functional roles, combined with their slow growth, long-lived nature, and vulnerability to fishing disturbance was the basis of the call for the protection of deep-water corals and sponges under several domestic and international treaties and policies, of which Canada has committed.

In international waters, Canada, through the Northwest Atlantic Fisheries Organization (NAFO), has led the science advice for the protection of coral and sponge vulnerable marine ecosystems in response to the 2006 United Nations General Assembly (UNGA) Resolution 61/105 to protect VMEs on the high seas from bottom fishing impacts. In domestic waters Canada has committed to the protection of deep-water coral and sponge aggregations through DFO's 2009 SeBA policy, which was established in response to the same UNGA resolution. Under this policy and its associated Ecological Risk Assessment Framework for Coldwater Coral and Sponge Dominated Communities (DFO 2013), consideration is given only to coral and sponge-dominated communities that are deemed "significant" (referred to as Significant Benthic Areas or SBAs). In eastern Canada, SBAs have been delimited using a combination of KDE analysis, which as applied identified hotspots in biomass from research vessel trawl survey data, and SDMs, which highlight areas of predicted presence based on species-environment relationships (see DFO 2017b). While the latter analyses incorporated observations from video and photographic surveys, to date no universal definition exists on the identification of SBAs or VMEs from *in situ* data. Thus, the results of this study point to areas along the Eastern Scotian Slope that are important for the presence of deep-water corals and sponges. Although the coral and sponge densities observed here could be further evaluated within and between transects to identify areas of higher importance, further information is required in order to identify a regional or global standard for which to judge the significance of these areas as coral and sponge habitat. Morato et al. (2018) describe a multi-criteria assessment method which, when applied to the ICES VME Database, identified a spatially aggregated, weighted estimate of how likely a given area was to contain VMEs. This method could be applied to the data collected here.

Although comparisons between those transects collected within and outside the large gorgonian coral SBA could not be directly made due to differences in sampling effort, the overall diversity of corals and sponges appeared to follow a west-to-east trend across the study area, with higher diversities observed on those transects (Stations EC_08 to EC_10) within the SBA and closest to the LCCA. The substrate at these stations was more variable in its size distribution than that observed elsewhere in the study area, with expansive sections of cobble/boulder fields between ~200 and 500 m enveloped by soft sediments on the shallow and deep portions of the transects. The large gorgonians *P. arborea* and *P. resedaeformis*, which were observed from ~232 to ~500 m depth at Station EC_08 onward, are commonly associated with deposits of winnowed till (Edinger et al. 2011), whereas *A. armata* and *K. grayi*, which had a wider distribution across the study area, were often observed settled in areas dominated by soft substrate with few cobbles and boulders. The LCCA is characterized by a cobble-boulder environment exposed through past glacial erosion (Fader et al. 1982; Edinger et al. 2011) that is maintained by the strong southwesterly flow of cool and relatively fresh water along the shelf break that originates from the Gulf of St. Lawrence and the Newfoundland Shelf (Loder et al. 1998). The higher diversity of corals and sponges immediately west of the LCCA may be due to the greater diversity of glacial deposits and settlement substrate in the region and/or the winnowing of subsurface till from the strong westerly flow that bends around the Stone Fence to continue along the shelf break. It’s possible that the LCCA represents a source population for deep-water coral and sponge larvae, which are transported to the adjacent slope by the shelf-edge current. Population genetic work of *P. arborea* across the Scotian Shelf is currently ongoing which may provide more information on the pathways of larval transport and the possible connectivity between the LCCA and the canyons to the west.

Our study showed low to moderate groundfish mobile-gear and moderate to high groundfish fixed-gear fishing effort in parts of the study area. For mobile gears this effort was more concentrated within the large gorgonian coral SBA and between 200 and 500 m depth where it overlaps the distribution of the large branching corals *P. arborea* and *P. resedaeformis*. Furthermore, low to moderate effort of mobile gears was observed along the northern boundary of the LCCA, suggesting that fishing may have also taken place within the closure since its implementation in 2004. In 2014 both VMS and logbook entries within and around the LCCA were examined by the Oceans and Coastal Management Division (OCMD) and Conservation and Protection (C&P) in the Maritimes Region in order to assess compliance with the closure. While generally it was determined that the boundaries of the LCCA were respected by the fishing industry, some indications of incursions within the closure were noted with selected fixed-gear operators. Potential issues with compliance and monitoring were attributed to the strong currents in the LCCA, which increase the risk of gear and vessel drift into the closure, as well as its small size, which limits the ability to effectively monitor activity inside and around the LCCA. VMS pings of vessel location are transmitted only once per hour, which is often too infrequent to clearly determine whether activities are occurring in an area as small as the LCCA. An extension of the boundaries of the closure may ensure its continued effectiveness and provide protection for the diverse and abundant coral and sponge communities that reside beyond its boundaries.

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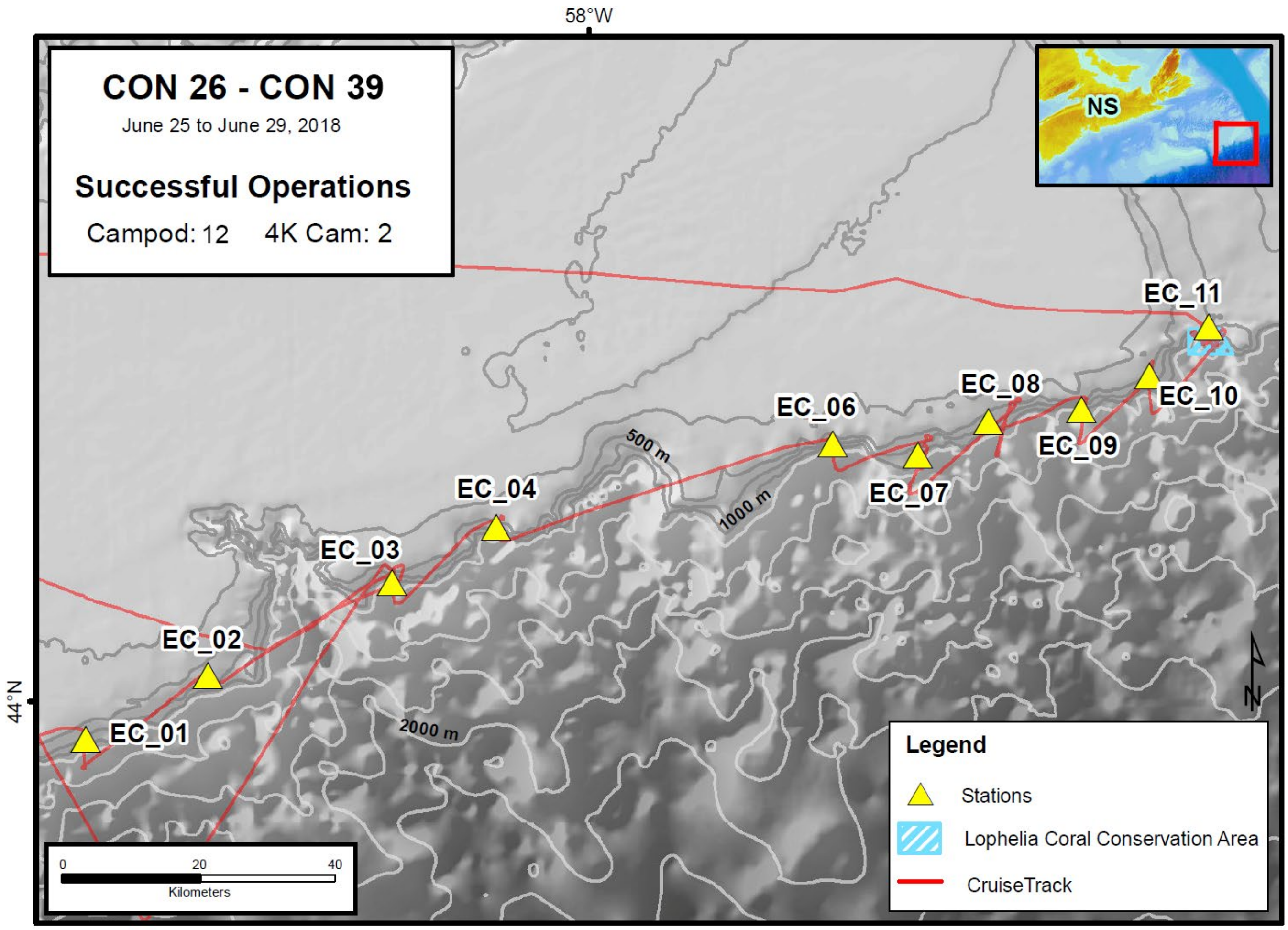
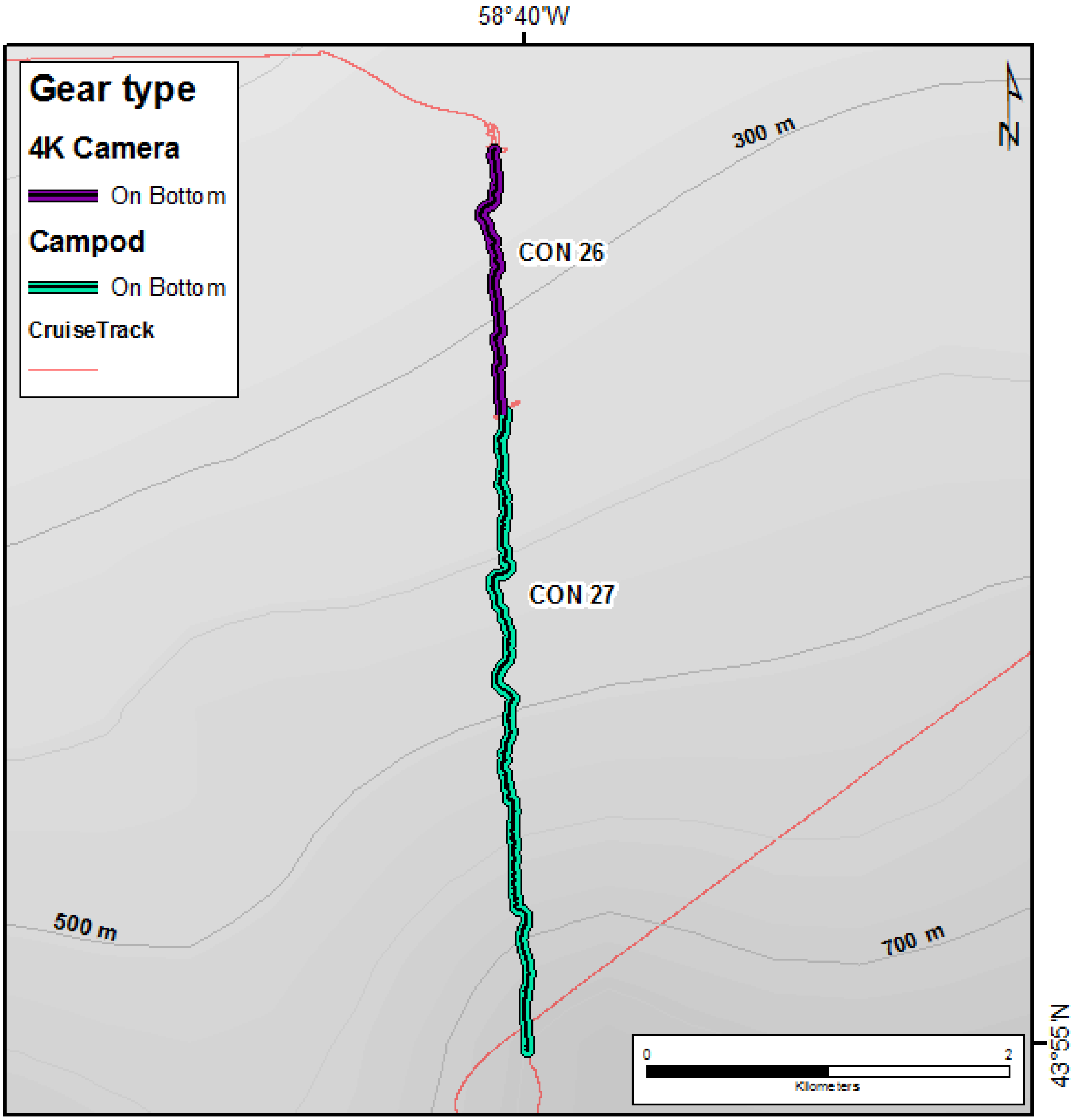
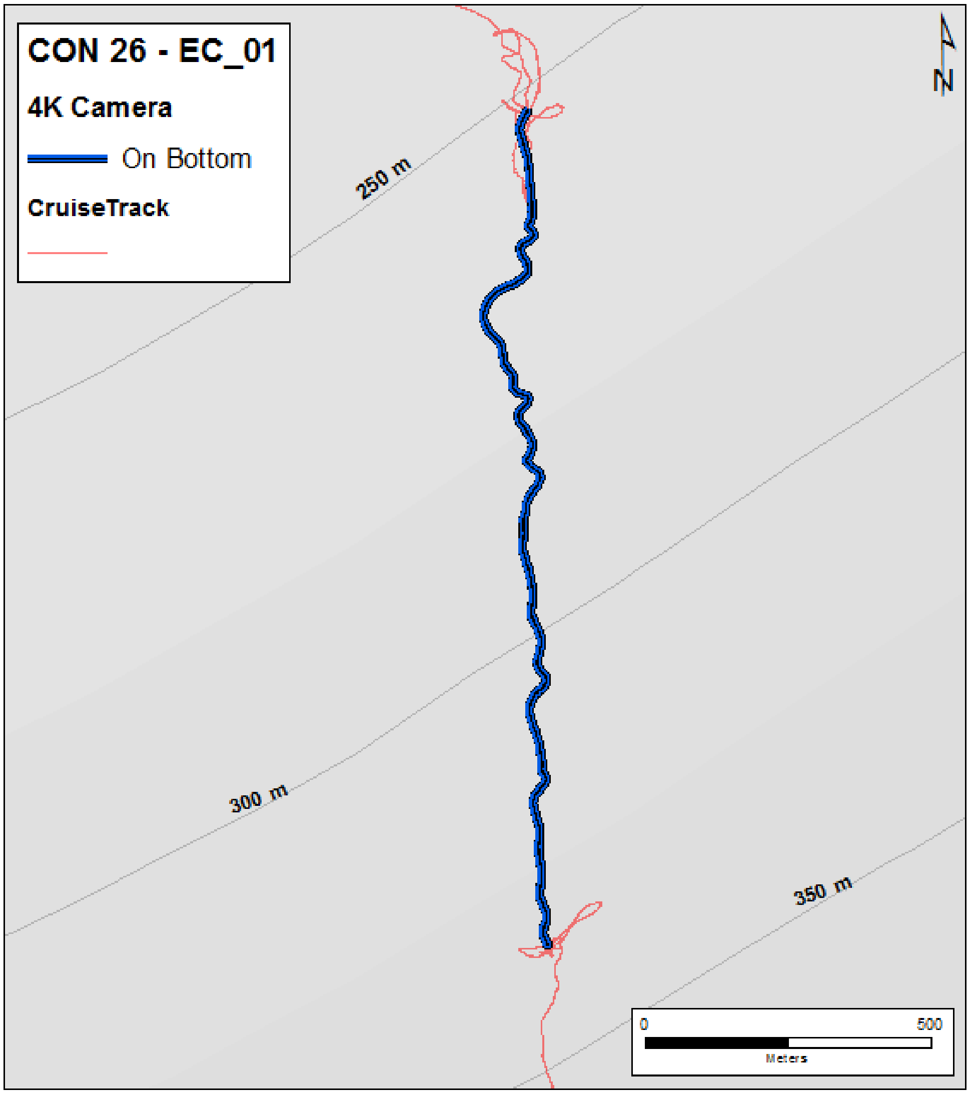
APPENDIX 1 – Detailed Mapbook of Data Collected at each Station



Station EC 01 Overview



Eastern Canyons Station: EC_01 Gear Type: 4K Cam

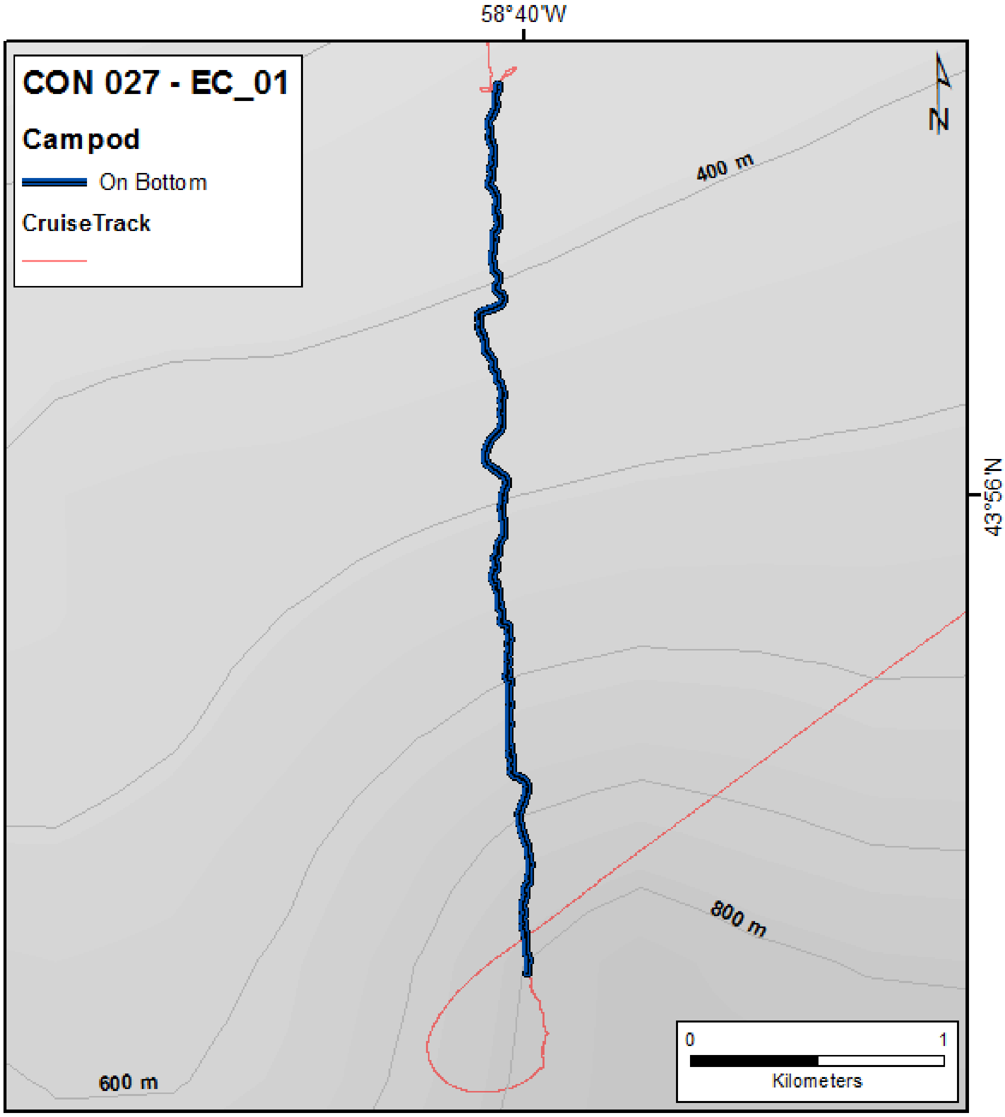


Con 026

Location	*Latitude*	*Longitude*	*Time*
In Water	43.961978	-58.668358	176151725
On Bottom	43.961223	-58.668325	176152711
Off Bottom	43.947923	-58.667810	176164704
Out of Water	43.948117	-58.667557	176165344
Time On Bottom (h:mm)	1:20		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 1500 Metres	240	256

Eastern Canyons **Station: EC_01** **Gear Type: Campod**

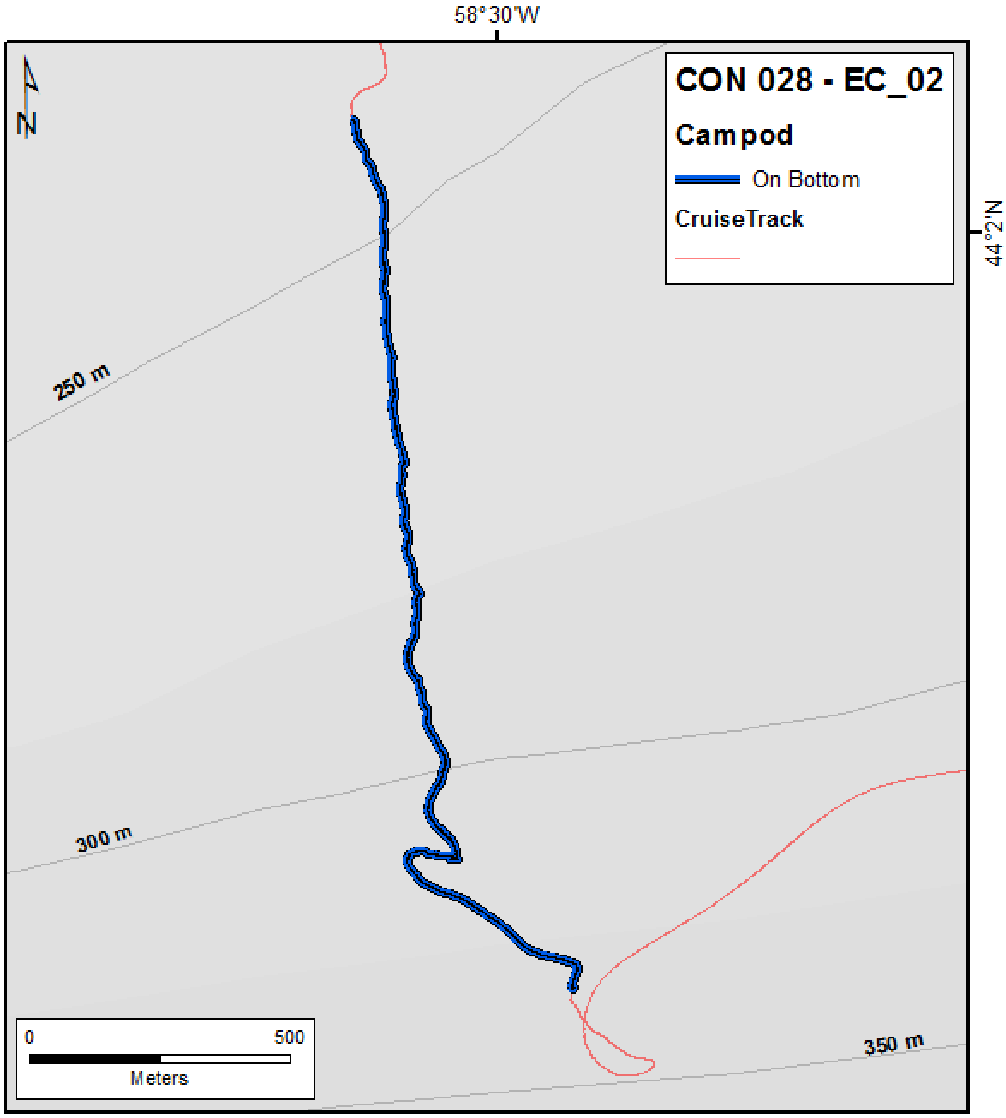


Con 027

Location	*Latitude*	*Longitude*	*Time*
In Water	43.947790	-58.667835	176171730
On Bottom	43.948018	-58.667595	176172847
Off Bottom	43.916280	-58.666525	176213618
Out of Water	43.913303	-58.665997	176220035
Time On Bottom (h:mm)	4:08		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 3600 Metres	320	780

Eastern Canyons **Station: EC_02** **Gear Type: Campod**

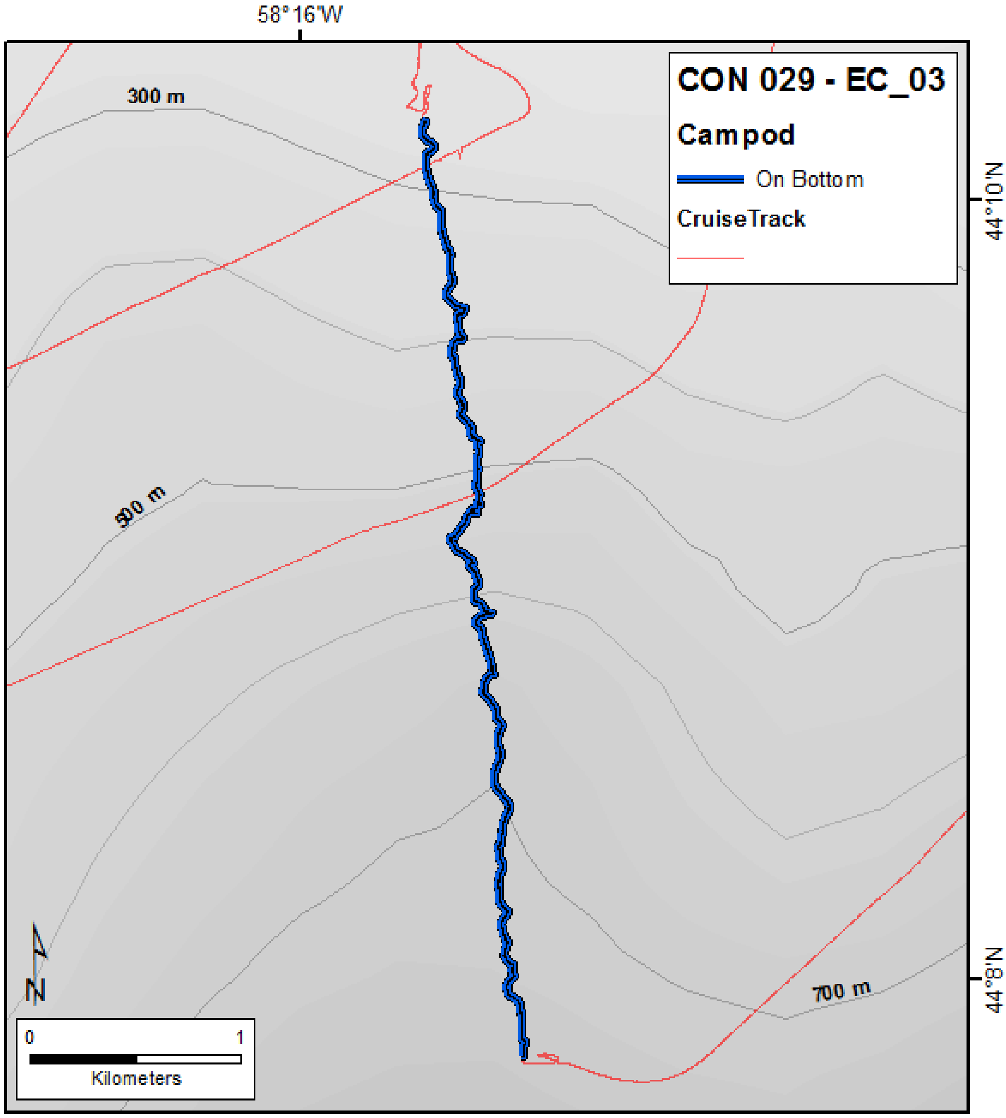


Con 028

Location	*Latitude*	*Longitude*	*Time*
In Water	44.036058	-58.501958	176232704
On Bottom	44.035318	-58.502518	176233329
Off Bottom	44.020177	-58.498712	177012511
Out of Water	44.019032	-58.498057	177013207
Time On Bottom (h:mm)	1:52		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 1900 Metres	220	361

Eastern Canyons **Station: EC_03** **Gear Type: Campod**

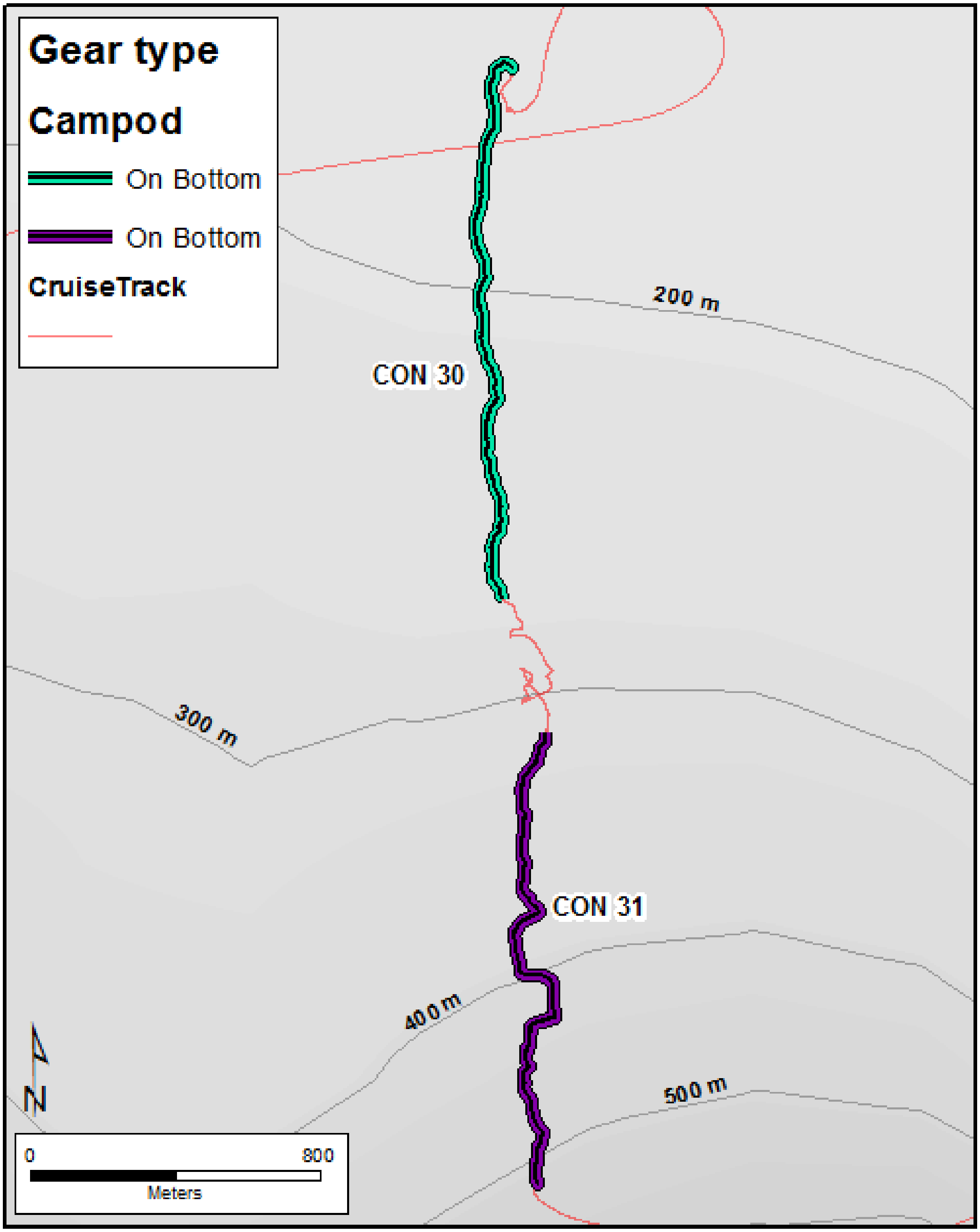


Con 029

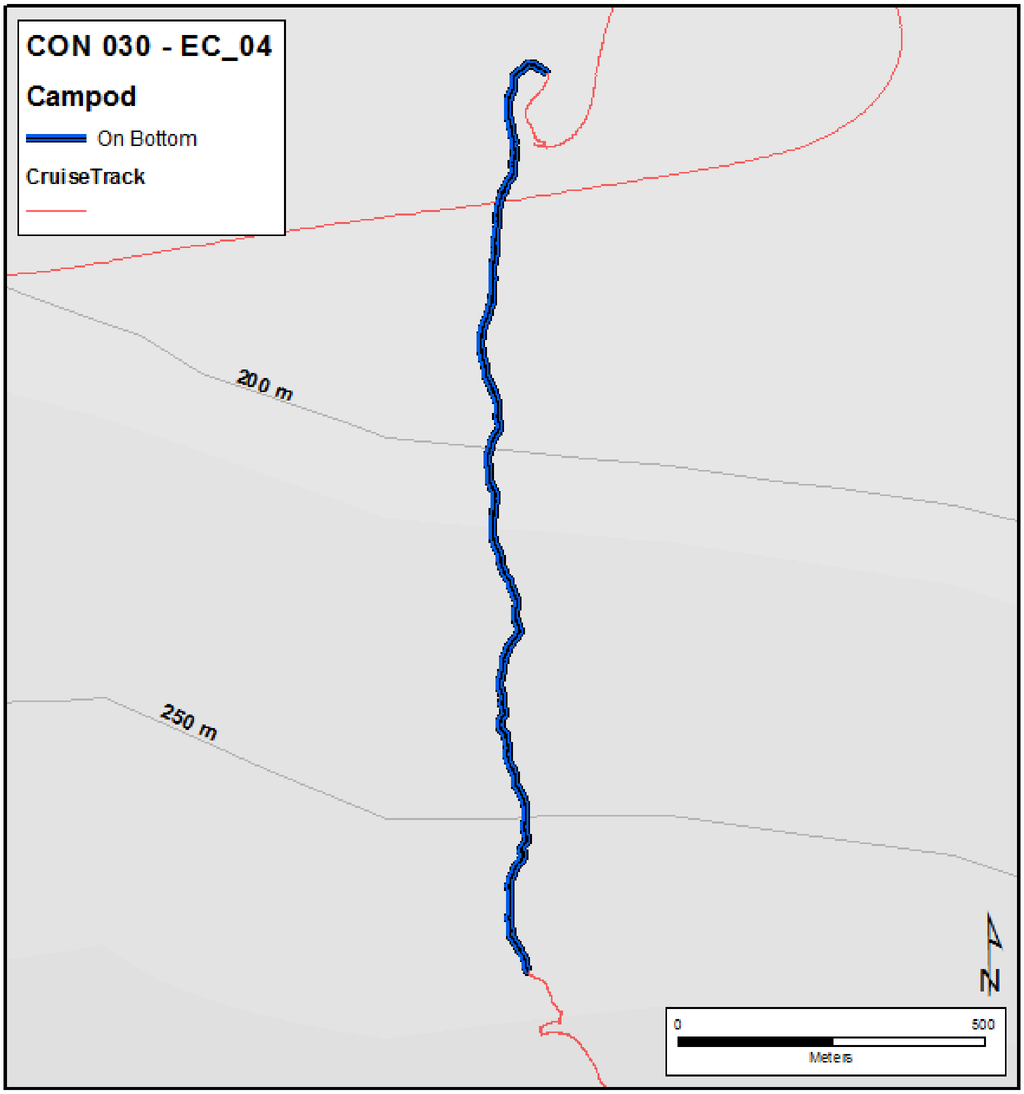
Location	*Latitude*	*Longitude*	*Time*
In Water	44.171612	-58.261237	178031643
On Bottom	44.170117	-58.261353	178032908
Off Bottom	44.12997	-58.257143	178083039
Out of Water	44.129695	-58.255222	178085305
Time On Bottom (h:mm)	5:01		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 4600 Meters	265	888

Station EC 04 Overview



Eastern Canyons **Station: EC_04** **Gear Type: Campod**

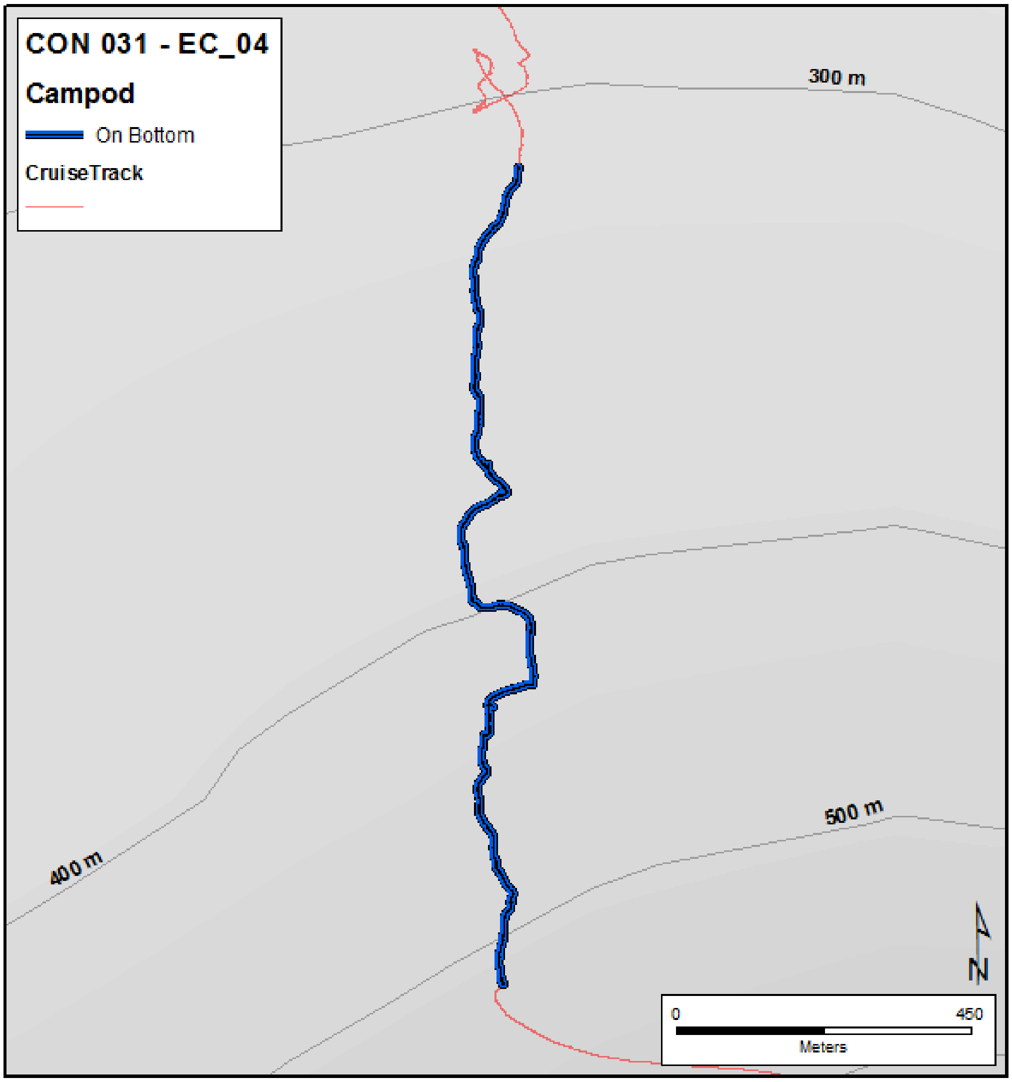


Con 030

Location	*Latitude*	*Longitude*	*Time*
In Water	44.241941	-58.118595	178101120
On Bottom	44.241928	-58.118493	178101216
Off Bottom	44.228697	-58.118755	178114148
Out of Water	44.227958	-58.118293	178115029
Time On Bottom (h:mm)	1:29		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 1500 Meters	140	287

Eastern Canyons **Station: EC_04** **Gear Type: Campod**

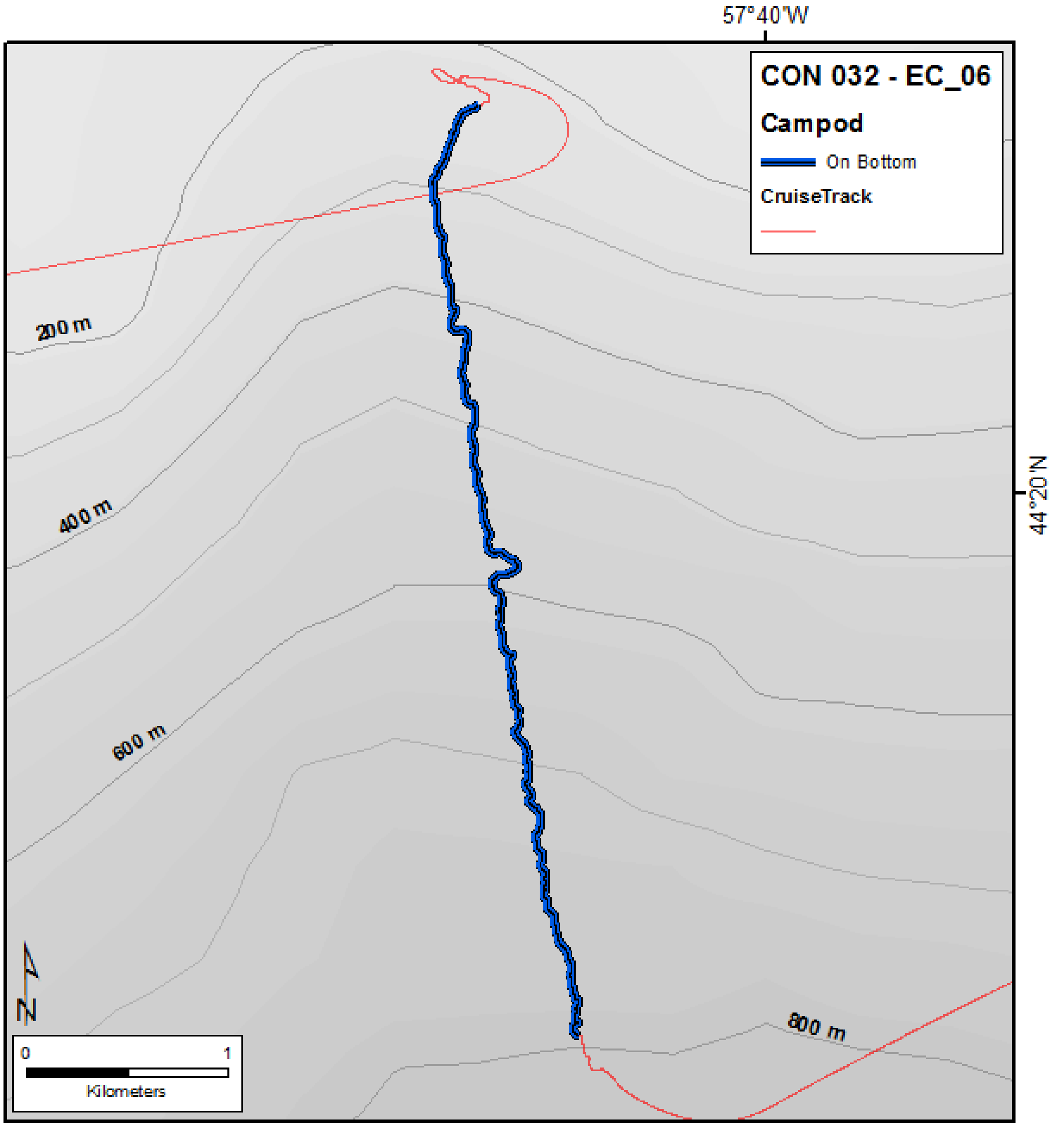


Con 031

Location	*Latitude*	*Longitude*	*Time*
In Water	44.226773	-58.118213	178122412
On Bottom	44.225372	-58.117677	178123313
Off Bottom	44.214003	-58.117988	178135822
Out of Water	44.212938	-58.114448	178141226
Time On Bottom (h:mm)	1:25		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 1350 Metres	363	490

Eastern Canyons **Station: EC_06** **Gear Type: Campod**

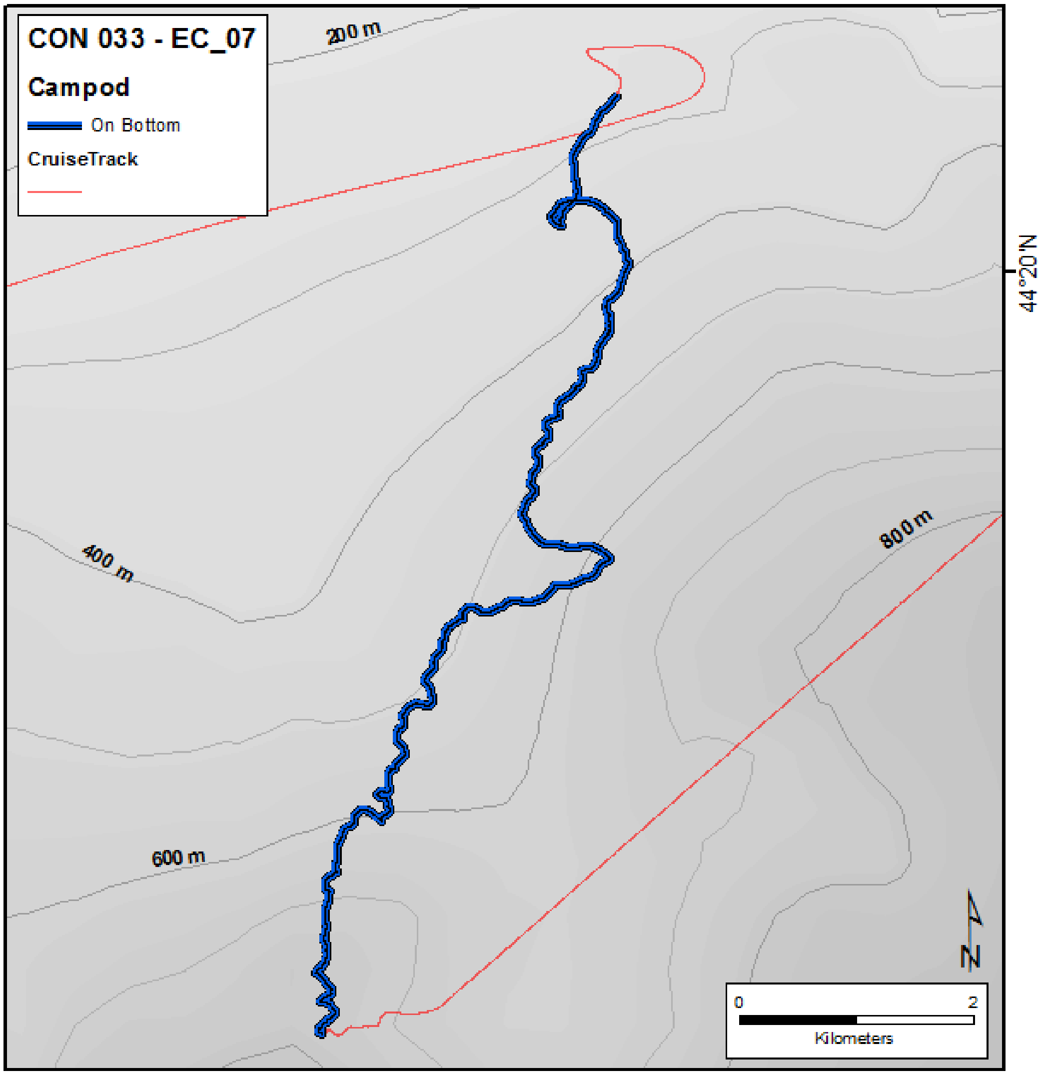


Con 032

Location	*Latitude*	*Longitude*	*Time*
In Water	44.351818	-57.681167	178161219
On Bottom	44.350745	-57.679555	178162308
Off Bottom	44.309347	-57.675575	178212712
Out of Water	44.307555	-57.673913	178214955
Time On Bottom (h:mm)	5:04		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 4800 Meters	332	877

Eastern Canyons **Station: EC_07** **Gear Type: Campod**

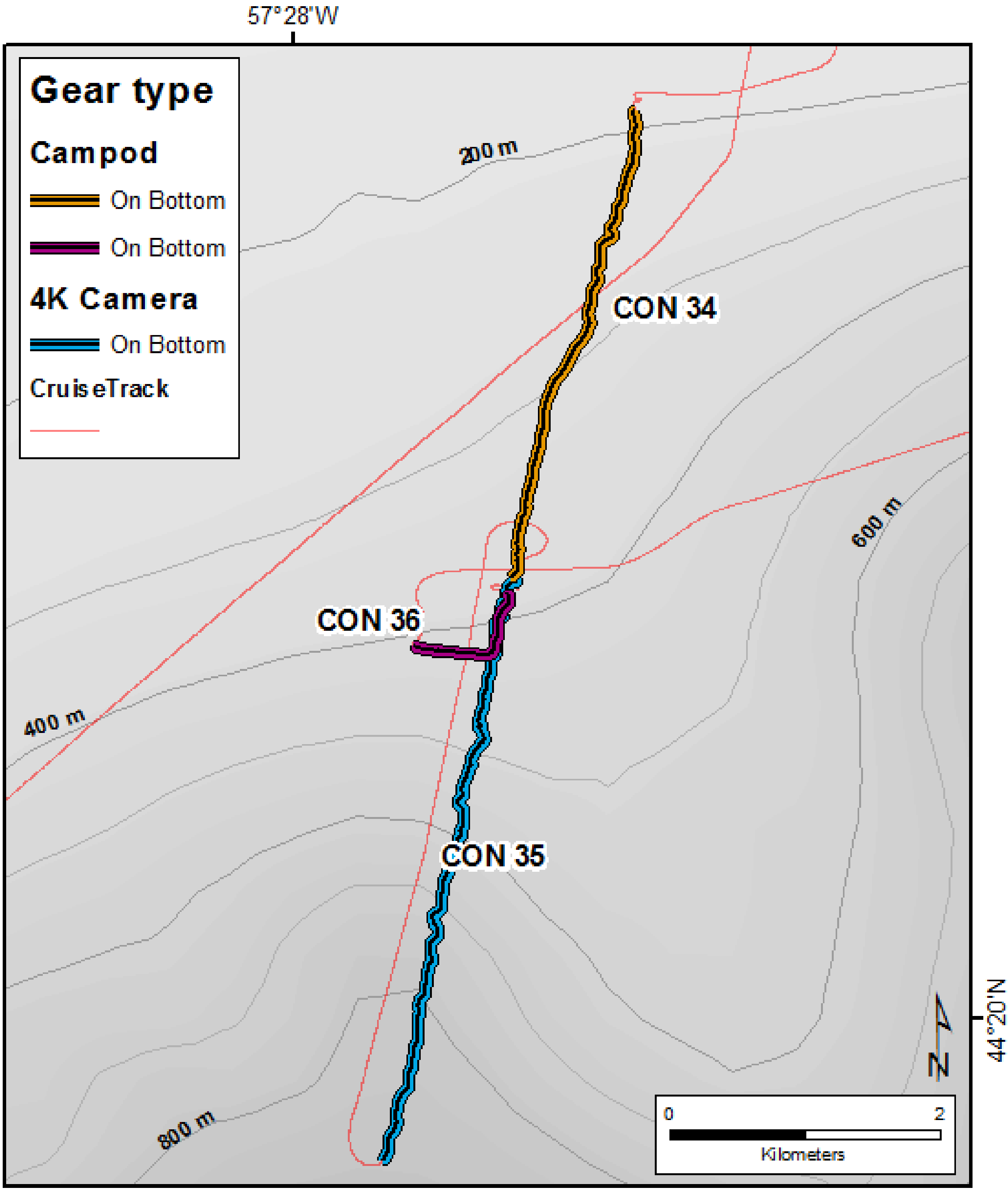


Con 033

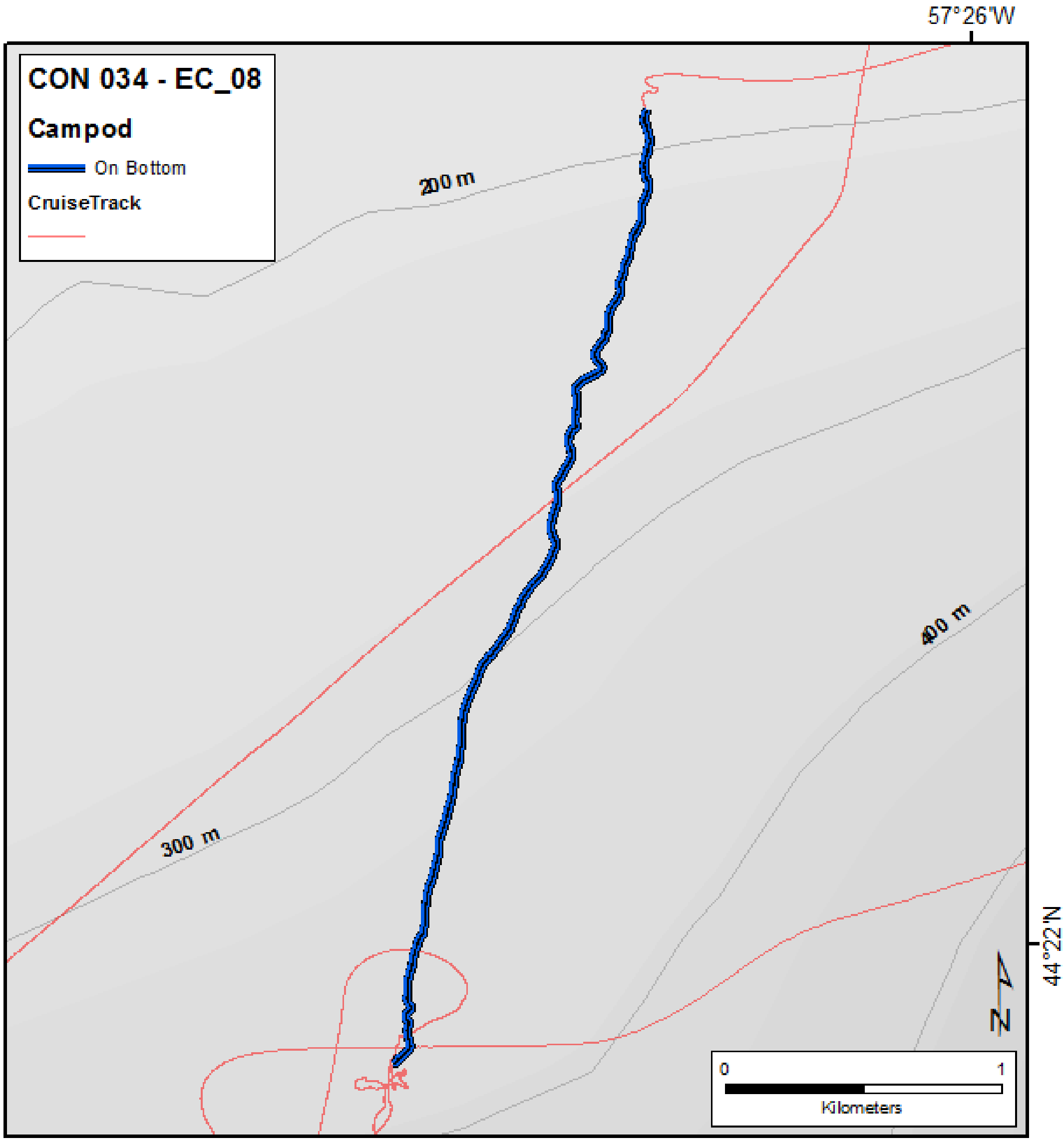
Location	*Latitude*	*Longitude*	*Time*
In Water	44.34926	-57.555015	178230008
On Bottom	44.347023	-57.554047	178230818
Off Bottom	44.274275	-57.576852	179075715
Out of Water	44.275543	-57.572367	179081641
Time On Bottom (h:mm)	8:49		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 10500 Meters	293	833

Station EC 08 Overview



Eastern Canyons **Station: EC_08** **Gear Type: Campod**

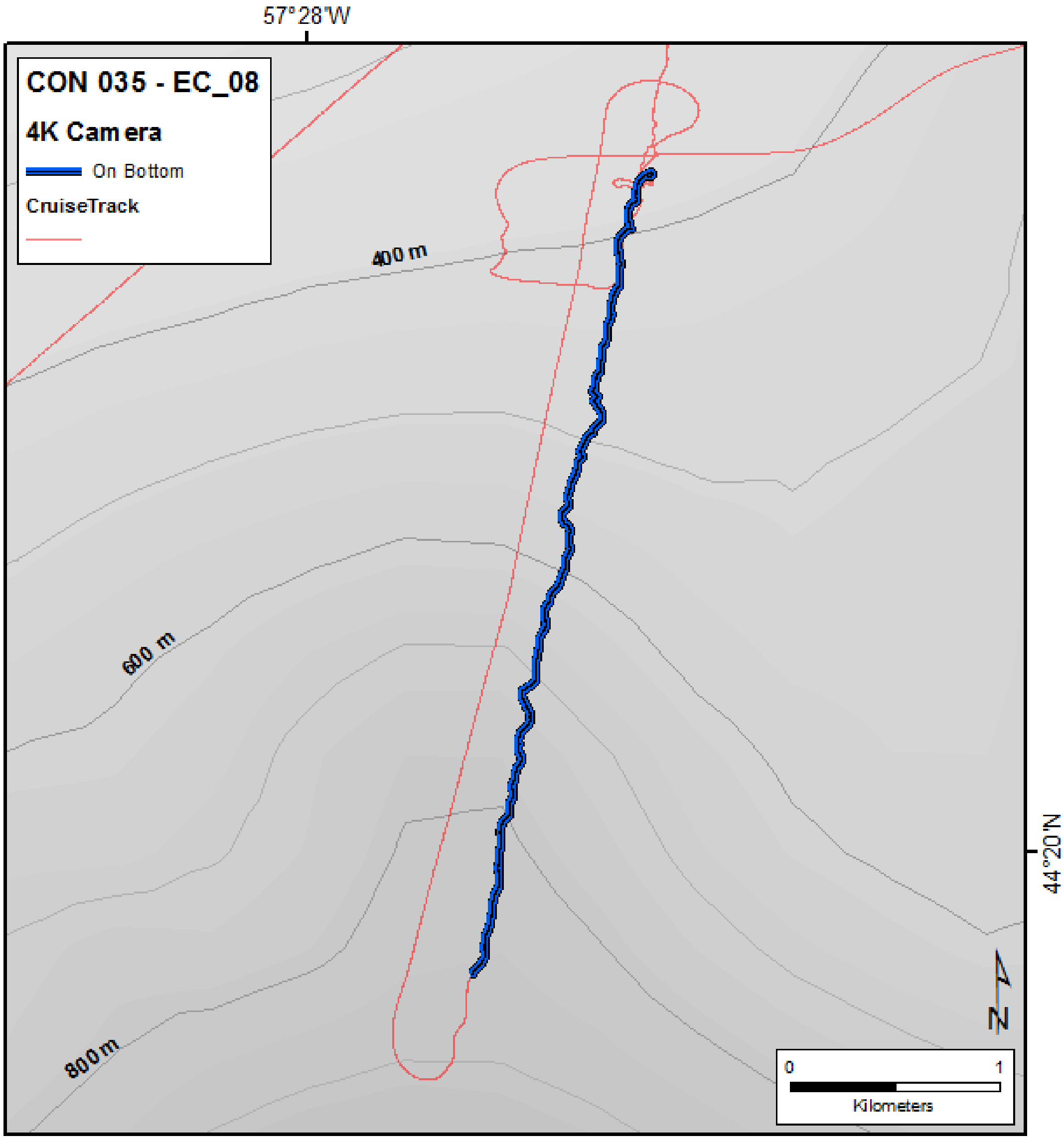


Con 034

Location	*Latitude*	*Longitude*	*Time*
In Water	44.394492	-57.443717	179100613
On Bottom	44.393873	-57.444018	179101321
Off Bottom	44.362258	-57.452338	179131437
Out of Water	44.362148	-57.453548	179132350
Time On Bottom (h:mm)	3:01		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 3500 Meters	185	388

Eastern Canyons **Station: EC_08** **Gear Type: 4K Camera**

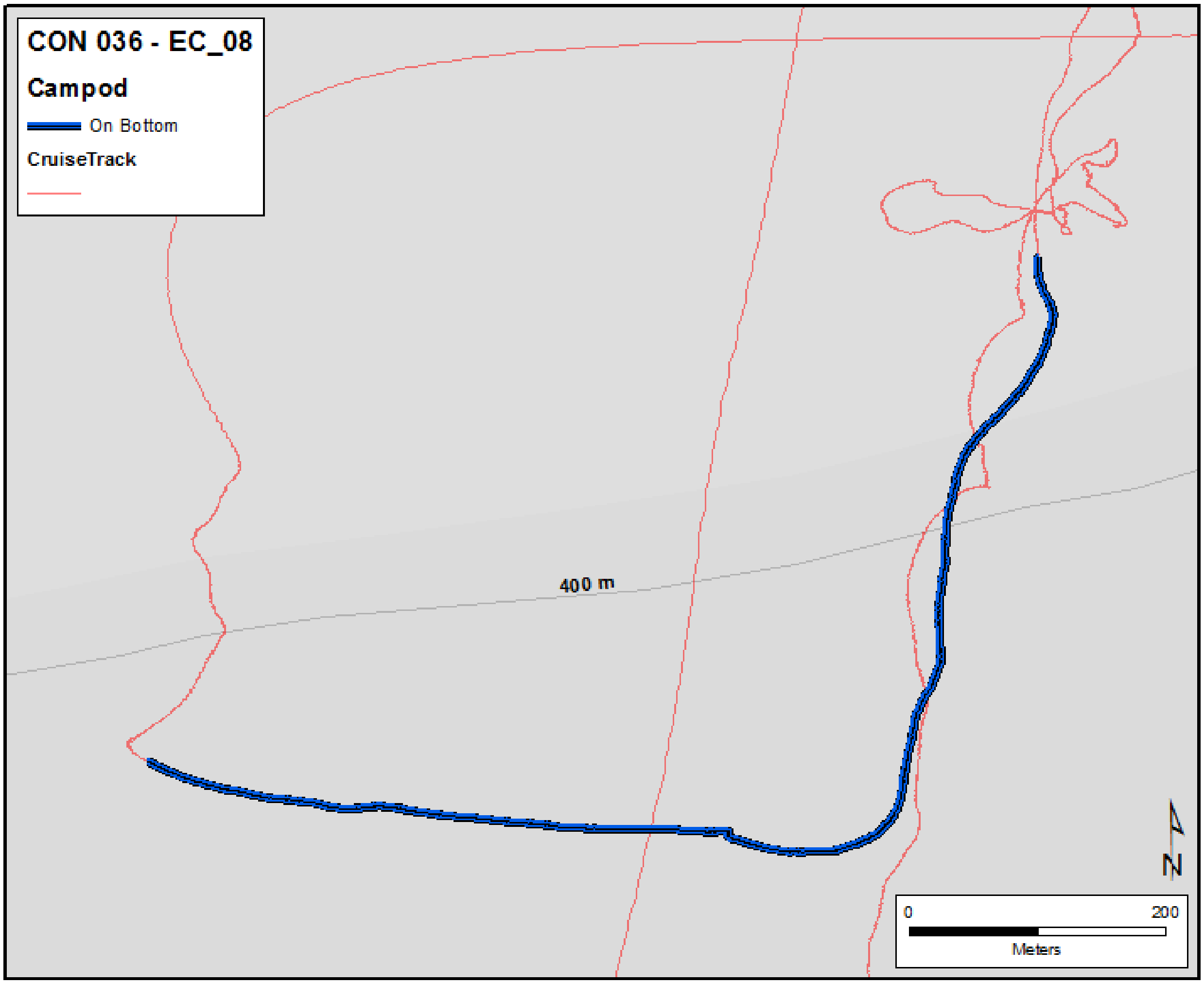


Con 035

Location	*Latitude*	*Longitude*	*Time*
In Water	44.3622	-57.45205	179135447
On Bottom	44.362397	-57.452102	179140002
Off Bottom	44.328048	-57.459653	179165659
Out of Water	44.324337	-57.460498	179171417
Time On Bottom (h:mm)	2:56		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 3600 Meters	154	927

Eastern Canyons **Station: EC_08** **Gear Type: Campod**

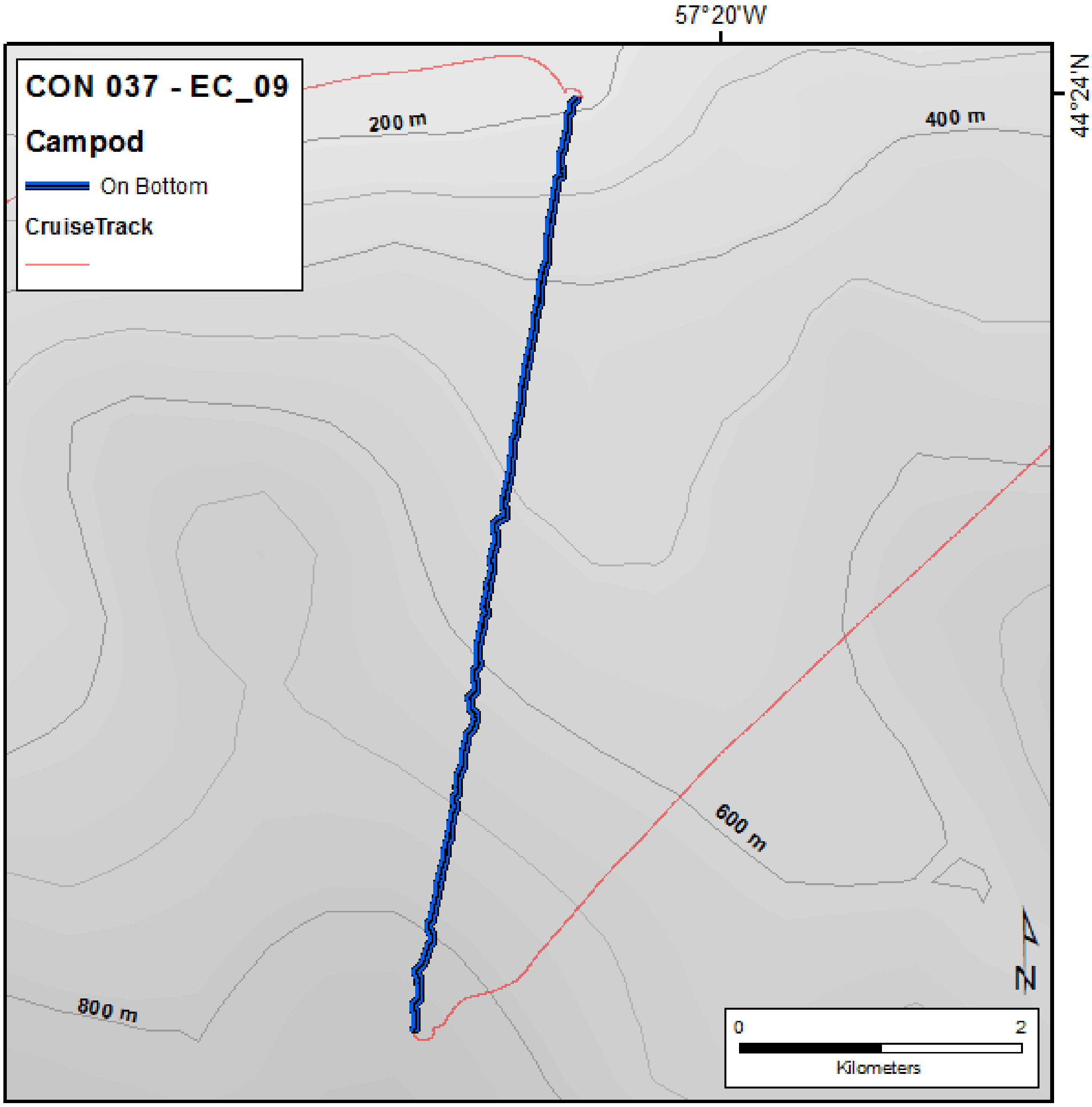


Con 036

Location	*Latitude*	*Longitude*	*Time*
In Water	44.363808	-57.451612	179174851
On Bottom	44.361733	-57.452455	179180219
Off Bottom	44.358177	-57.458733	179183954
Out of Water	44.359858	-57.458317	179185224
Time On Bottom (h:mm)	0:37		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 890 Meters	369	444

Eastern Canyons **Station: EC_09** **Gear Type: Campod**

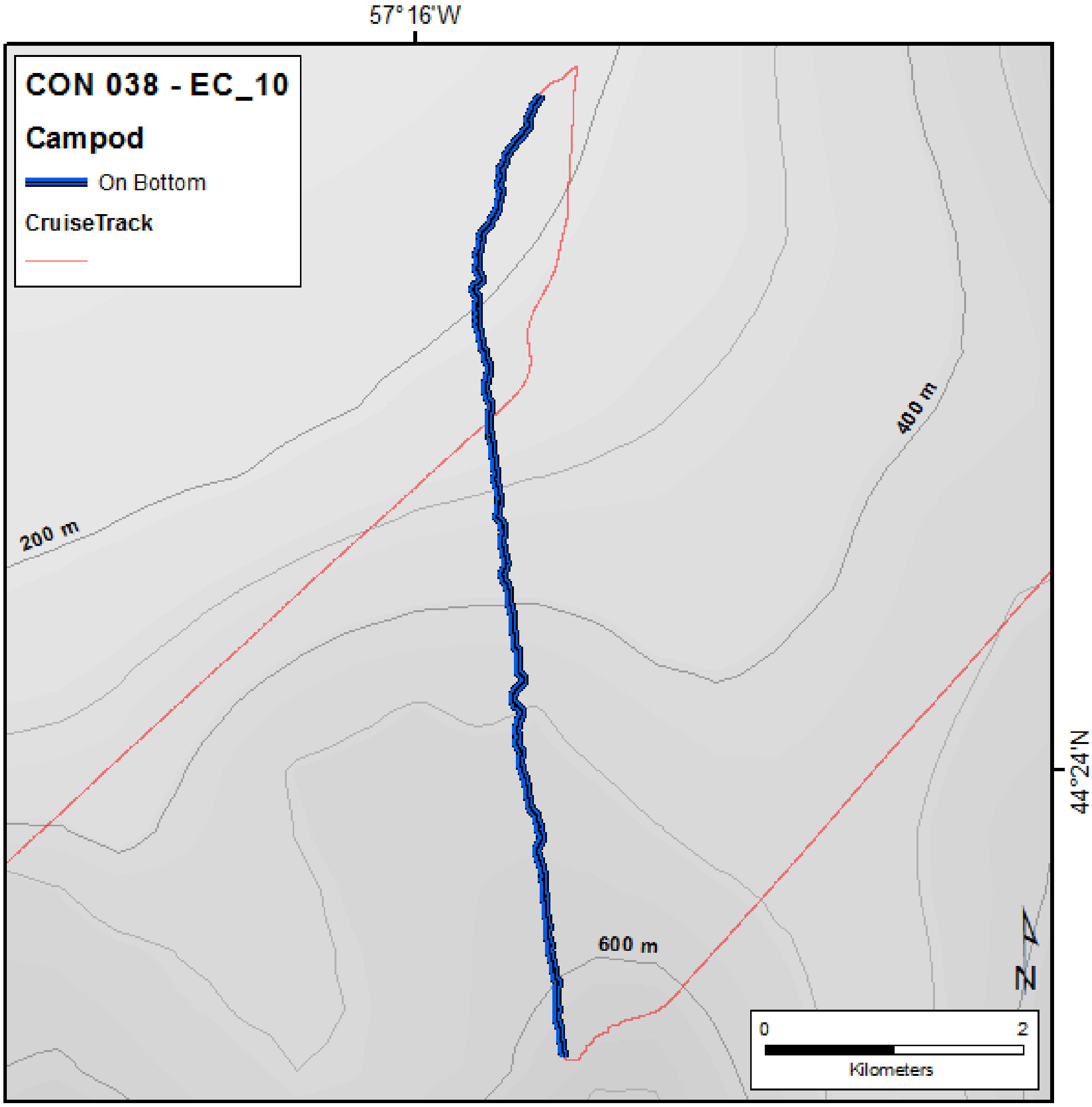


Con 037

Location	*Latitude*	*Longitude*	*Time*
In Water	44.39963	-57.342672	179194217
On Bottom	44.399817	-57.342503	179194800
Off Bottom	44.340343	-57.352943	180020230
Out of Water	44.341993	-57.350273	180022308
Time On Bottom (h:mm)	6:14		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 6500 Meters	187	887

Eastern Canyons **Station: EC_10** **Gear Type: Campod**

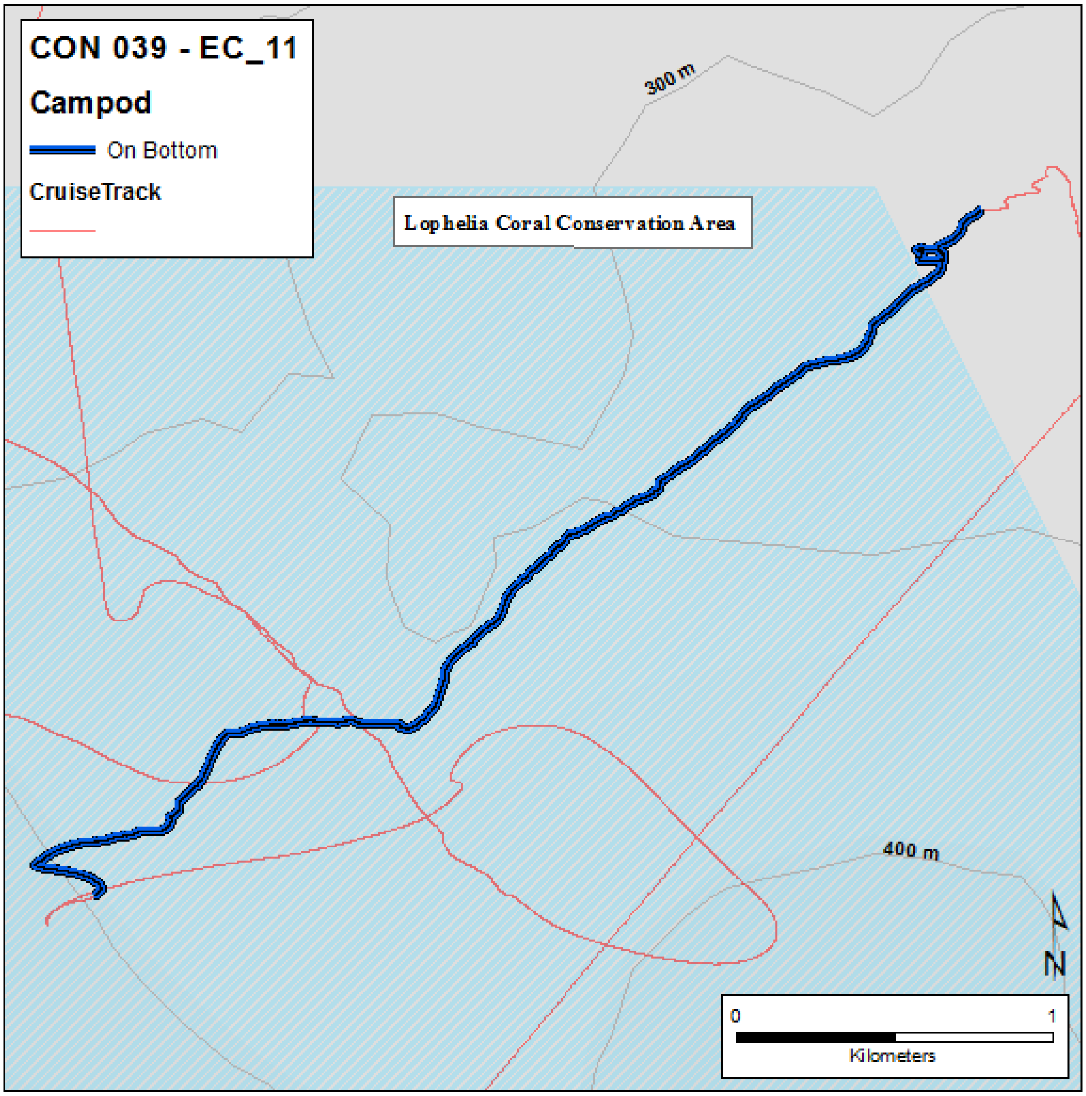


Con 038

Location	*Latitude*	*Longitude*	*Time*
In Water	44.447542	-57.257608	180032117
On Bottom	44.447012	-57.258077	180032811
Off Bottom	44.380023	-57.256373	180093302
Out of Water	44.382278	-57.252978	180095240
Time On Bottom (h:mm)	6:05		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 7500 Meters	162	804

Eastern Canyons **Station: EC_11** **Gear Type: Campod**



Con 039

Location	*Latitude*	*Longitude*	*Time*
In Water	44.49151	-57.162073	180110532
On Bottom	44.49103	-57.163617	180111304
Off Bottom	44.471473	-57.188868	180134740
Out of Water	44.470952	-57.190128	180135728
Time On Bottom (h:mm)	2:34		

Dive Length ~ on bottom – off bottom	*Start Depth (m)*	*End Depth (m)*
Approx – 3500 Meters	255	382

APPENDIX 2 – Temperature Associated with each Taxon

Table A2.1. Total number, and minimum (Min.), maximum (Max.), and average (Avg.) temperature (Temp.) of all taxa recorded from the 10 video/photo stations on the Eastern Scotian Slope. Temperature is from the SBE 39 attached to Campod/4K Camera. Average temperature is ± standard deviation.

	Total Observed	Min. Temp. (°C.)	Max. Temp. (°C)	Avg. Temp. (°C)
Large gorgonian corals				
Acanthogorgia armata	5658	4.2	6.5	5.8 ± 0.6
Keratoisis grayi	2294	4.2	5.9	4.6 ± 0.2
Paragorgia arborea	96	4.7	8.6	5.8 ± 0.9
Paramuricea sp.	1	4.7	4.7	
Primnoa resedaeformis	289	4.7	8.7	6.3 ± 1.2
Small gorgonian corals				
Acanella arbuscula	1181	4.2	6.0	4.6 ± 0.2
cf. *Anthothela grandiflora*	1	6.0	6.0	
Radicipes sp.	181	4.2	5.6	4.7 ± 0.3
Sea pens				
Anthoptilum grandiflorum	224	4.2	6.2	4.9 ± 0.3
Kophobelemnon spp.	1411	4.2	6.1	4.6 ± 0.3
Pennatula aculeata	2703	4.2	8.4	6.1 ± 1.5
Pennatula grandis	308	4.3	8.2	5.5 ± 0.8
Pennatula sp.	1	7.9	7.9	
Umbellula sp.	1	5.7	5.7	
Pennatulacea Type 1	1080	4.2	8.0	5.2 ± 0.6
Pennatulacea Type 2	915	4.2	5.7	4.4 ± 0.2
Pennatulacea sp. 3	11	4.2	4.5	4.3 ± 0.1
Pennatulacea_juvenile	1	4.4	4.4	
cf. Pennatulacea	6	6.0	7.8	6.3 ± 0.7
Tube-dwelling anemones				
Pachycerianthus borealis	10656	4.5	10.2	9.2 ± 0.7
Large-Sized Sponges				
Asconema foliatum	55	4.4	6.1	5.4 ± 0.6
Astrophorina spp.	5	4.4	8.6	5.6 ± 1.8
Chondrocladia grandis	19	4.4	4.9	4.6 ± 0.2
Polymastiidae spp.	12502	4.2	8.9	7.3 ± 1.6
Large-Sized Porifera spp.	4100	4.2	8.9	6.9 ± 1.5