BENTHIC HABITAT MAPPING SURVEYS OF EASTERN HAIDA GWAII AND THE NORTH COAST OF BRITISH COLUMBIA, 2013-2015

S.C. Davies, D. Bureau, J. Lessard, S. Taylor, G.E. Gillespie

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, British Columbia
V9T 6N7

2018

Canadian Technical Report of

Fisheries and Aquatic Sciences 3278

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of

Fisheries and Aquatic Sciences 3278

2018

BENTHIC HABITAT MAPPING SURVEYS OF EASTERN HAIDA GWAII AND THE NORTH COAST OF BRITISH COLUMBIA, 2013-2015

by

S.C. Davies, D. Bureau, J. Lessard, S. Taylor, G.E. Gillespie

Fisheries and Oceans Canada

Science Branch, Pacific Region

Pacific Biological Station

3190 Hammond Bay Road

Nanaimo, British Columbia

V9T 6N7

Cat. No. Fs 97-6/3278E ISBN 978-0-660-28262-6 ISSN 0706-6457 (print version)

Cat. Fs97-6/3278E-PDF ISBN 978-0-660-28218-3 ISSN 1488-5379 (online version)

Correct citation for this publication:

S.C. Davies, D. Bureau, J. Lessard, S. Taylor, G.E. Gillespie. 2018. Benthic habitat mapping surveys of eastern Haida Gwaii and the North Coast of British Columbia, 2013-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3278: vi + 24 p.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

S.C. Davies, D. Bureau, J. Lessard, S. Taylor, G.E. Gillespie. 2018. Benthic habitat mapping surveys of eastern Haida Gwaii and the North Coast of British Columbia, 2013-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3278: vi + 24 p.

Surveys of shallow benthic habitat and associated benthic marine invertebrate and algal communities were conducted in eastern Haida Gwaii and the North Coast of British Columbia between September 2013 and August 2015. A total of 800 transects were visually surveyed by SCUBA divers and 848 drop camera deployments were completed. The presence or absence of 102 invertebrate and 59 algae species or species groups was documented during the SCUBA dives. The three dominant substrate types and their respective percentages were recorded for both dives surveys and drop camera deployments. The purpose of these surveys was to document substrate types and associated algae and marine invertebrate species in order to map benthic habitat along the nearshore region of the British Columbia coast.

RÉSUMÉ

S.C. Davies, D. Bureau, J. Lessard, S. Taylor, G.E. Gillespie. 2018. Relevés cartographiques de l'habitat benthique de l'est de Haida Gwaii et de la côte nord de la Colombie-Britannique, 2013-2015. Rapp. tech. can. sci. halieut. aquat. 3278: vi + 24 p.

Des relevés de l'habitat benthique peu profond et des communautés d'invertébrés et d'algues marines ont été effectués dans l'est de Haida Gwaii et la côte nord de la Colombie-Britannique de septembre 2013 à août 2015. Un total de 800 transects ont été visuellement examinés par des plongeurs . Additionellement, 848 déploiements de caméras autonomes ont été effectués. La présence ou l'absence de 102 espèces d'invertébrés et de 59 espèces d'algues, ou de groupes d'espèces, a été documentée au cours de ces plongées. Les trois types de substrats dominants et leurs pourcentages respectifs ont été notés sur les plongées et les déploiements de caméra autonomes. Le but de ces enquêtes était de documenter les types de substrats et les associations d’espèces d'algues et d'invertébrés marins afin de cartographier l'habitat benthique le long de la côte littorale de la Colombie-Britannique.

INTRODUCTION

In recent years, there have been a number of marine-use planning initiatives along the British Columbia (BC) coast that have ranged from emergency oil spill response planning to the development of a marine protected area network. Relatively little is known regarding shallow (0 - 18 m depth) benthic habitat types and associated marine benthic invertebrate and algal communities along the BC coast, with most of the work concentrated on species of commercial interest. Benthic habitat types and community composition of the nearshore region represent data gaps that need to be addressed in order to provide scientific support to current and future marine-use planning initiatives. A new visual survey design was developed to help map the nearshore region using both SCUBA dive surveys and drop camera technology. Data from these surveys can be used in nearshore habitat models (e.g. Gregr et al. 2013), species distribution mapping, community analyses, and the empirical evaluation of Ecologically and Biologically Significant Areas (EBSAs).

This report describes the methods developed and used as well as summarizes the dominant species and substrates encountered at the transect level along eastern Haida Gwaii and the North Coast of BC between 2013 and 2015.

METHODS

Between 2013 and 2015, five surveys of shallow benthic habitats and their associated marine invertebrate and algal communities were conducted along the southeastern shores of Haida Gwaii and the North Coast of BC. Areas of interest were selected prior to the surveys with the number of sites surveyed based on the amount of field time available for each area. In 2013 and 2014, visual surveys were conducted by SCUBA divers along transects running perpendicular to the shoreline from 0 to 18 m depth. In 2015, the survey was expanded to include a drop camera system to gather images of the substrate between 30 and 50 m depth. With the addition of the drop camera, each site consisted of a SCUBA transect and up to three drop camera deployments. After an area of interest was delineated, sites were randomly selected using the Create Random Points tool in ArcToolbox 10.1 (Fig. 1). The points were selected along a Canadian Hydrographic Survey Pacific High Water Coastline dataset (Canadian Hydrographic Service 2018), representing the higher high water line for BC's tidal waters. Sites were generated prior to the survey and locations were reviewed on current charts; sites were removed if they were considered to be unachievable due to logistical challenges in accessing the site (e.g. sites located above tidal rapids, in intertidal lagoons, etc.).

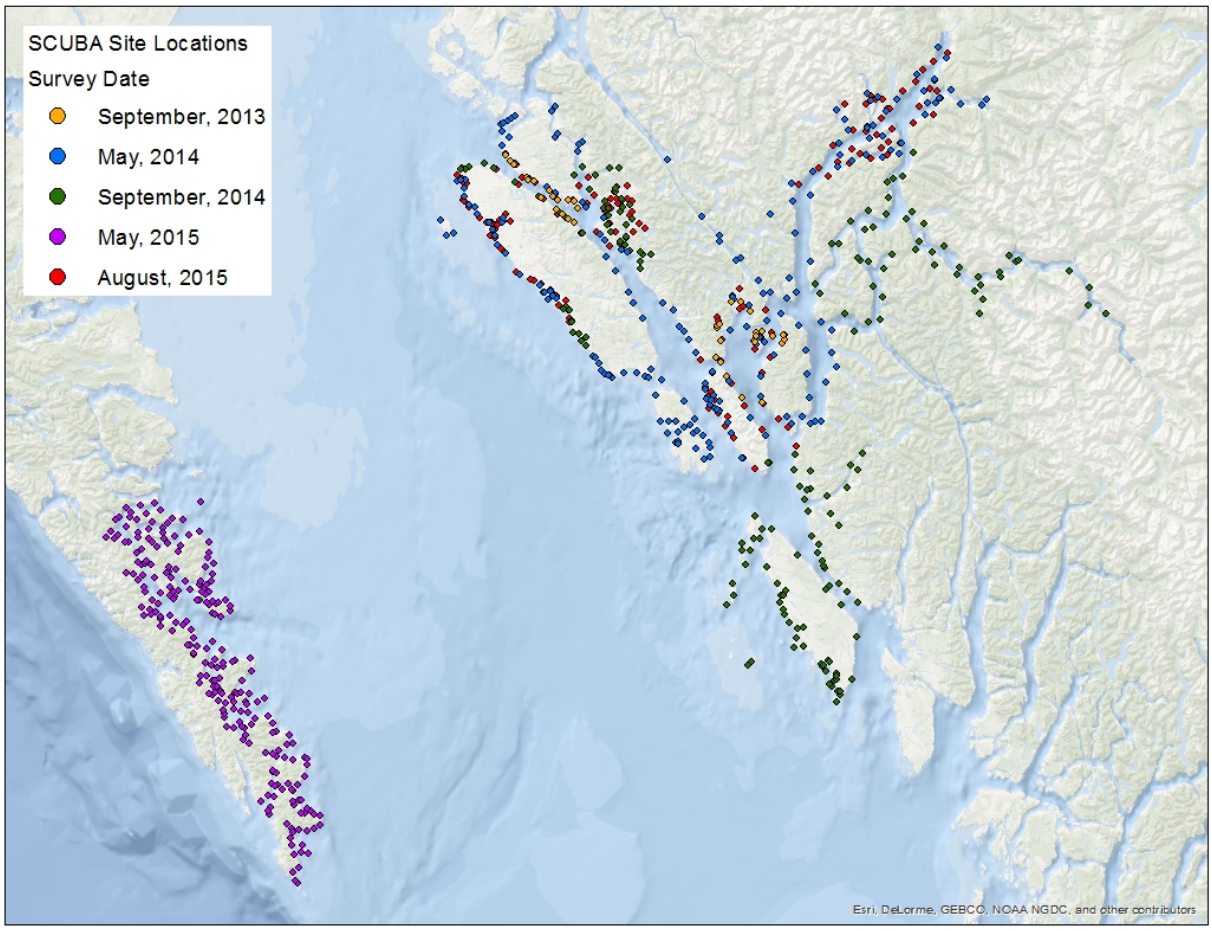

Figure 1. SCUBA survey locations (n = 800) in southeastern Haida Gwaii and the North Coast of British Columbia for five surveys from 2013 to 2015. Cruise date is used to represent sites completed during different surveys.

VISUAL DIVE SURVEYS

The survey design consisted of a two-stage design with randomly selected positions along the shoreline at the first stage and systematic quadrat spacing along transects from the shoreline at the second stage, similar to survey type 4 described by Campbell et al. (1998). At each site, a lead-line was laid perpendicular to the shoreline, from the shore to a depth of 18 m and a float was attached to the deep end. This transect line was marked every 5 m with cable ties and each 1 x 5 m section represented one quadrat. Latitude and longitude of the start and end positions of each transect were recorded from the boat's GPS. A team of two divers surveyed each transect from the deep end to the shoreline. Divers swam and made observations on either side of the transect line; the diver on the left side of the transect line recorded substrate and algae observed on the left side of the transect line while the diver on the right recorded invertebrate species

observed on the right side of the transect line. Each diver carried a clipboard attached to a 1 m bar and all observations were made between the transect line and the outside edge of the bar.

All quadrats along the transect were surveyed for transects up to 125 m long. For transects between 125 and 250 m long, every second quadrat was surveyed; for transects longer than 250 m, every third quadrat was surveyed, to a maximum of 300 m. For logistical reasons, the maximum length of a transect was 300 m, even if the maximum depth of 18 m was not achieved. The maximum number of quadrats that could be surveyed at any given site was 25. Divers also recorded time of day and depth at the end of each quadrat. Depth of each quadrat was later corrected to chart datum by subtracting tide height from diver's gauge depth. The underwater datasheets used are shown in Appendices 1 and 2, for invertebrate observations and substrate & algae observations, respectively.

Invertebrate Data

In 2013 species were recorded based on the author's knowledge of the study area; from this, a target species list of 102 species developed and used for subsequent surveys. Species that are morphologically similar and cannot be easily identified by divers while underwater were grouped together (e.g. Brown and Tan Cup corals (*Paracyathus stearnsi* and *Caryophyllia alaskensis*)). Divers recorded the presence of all species from the target species list that were encountered within each sampled quadrat (Appendix 1). Additional species not on the target list were documented by some, but not all divers, depending on their identification skills. These additional species were recorded in the survey database, but because they cannot be considered representative of the entire study area are not included in this analysis. Furthermore, species documented during the 2013 survey, but not included in the target list were either removed from this analysis or, where applicable, re-coded to an appropriate species group (i.e. Humpback Shrimp, Coonstripe Shrimp, and Prawn observations were re-coded to the shrimp species group). Scientific species names were confirmed using World Register of Marine Species (WoRMS 2018).

Relative abundance along the entire transect was also documented for 15 of the 102 target species (Table 1). In addition to recording presence in a quadrat, the relative abundance of these species was estimated based on one of four categories (None, 0 individuals; Few, 1 – 10 individuals; Many, 11 – 100 individuals; Abundant, > 100 individuals). The relative abundance estimates extended beyond the 1 x 5 m quadrats and included the entire area visible by the divers at each site during the entire dive. This distance varied (1 to 15 m) between dives depending on the visibility in the water during the dive.

Table 1. Invertebrate species recorded as Relative Abundance, SCUBA surveys in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015.

Species Name
Byrozoan, erect
Byrozoan, flat
Balanophyllia elegans
Metridium farcimen
Pachycerianthus fimbriatus
Pycnopodia helianthoides
Mesocentrotus franciscanus
Strongylocentrotus droebachiensis
Apostichopus californicus
Cucumaria miniata
Panopea generosa
Tresus spp.
Haliotis kamtschatkana
Sponge, erect
Sponge, flat

Algae and Substrate Data

For each 1 x 5 m quadrat, the three dominant substrate types and their percent cover were recorded using the substrate types described in Table 2. In cases where more than three substrate types were observed, the cumulative percent cover of the three most dominant substrate types did not reach 100%.

Table 2. Substrate types and descriptions, SCUBA and drop camera surveys in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015.

Substrate Type	Description
Bedrock, smooth	Smooth bedrock
Bedrock with crevices	Bedrock with crevices
Boulders	Rocks larger than basketball
Cobble	Rocks that are fist sized to basketball sized
Gravel	Particles that are 1 cm to fist sized
Pea gravel	Particles that are 2 mm to 1 cm
Sand	Particles that are < 2 mm
Mud	Mud
Crushed shell	Crushed shell, often seen as barnacle shell banks
Shell, whole or shell chunks	Whole or shell chunks
Wood	Wood, bark, or wood debris

The target species list for algae consisted of 59 species or species groups. Divers recorded which of these species/groups were present within each sampled quadrat along the transect (Appendix 2). As with the invertebrate species observations, divers were allowed to record additional species that were of note at a particular site. These observations were recorded in the database but have not been included in this analysis. Scientific species names were confirmed using World Register of Marine Species (WoRMS 2018).

The percent cover of four different structural categories of algae were also recorded (Table 3). For each category this estimated value represented the present cover of all algal species within the specific structural category, not the percent cover for individual species within a category. For each category, the percent cover may be as high as 100% and for each quadrat if all four structural categories were present then the percent cover over the four categories may sum to 400%. If drift algae was present in a quadrat, only the dominant species was recorded along with the percent cover of all drift algae present.

Canopy and understory algae were recorded to species level. Many turf-forming algae species are difficult to identify to species level while underwater. For this reason some turf-forming algae were identified to genus level or grouped in broader categories based on the type of algae (green, red or brown) and morphology (foliose, branched or filamentous).

Table 3. Algae Structural Categories and descriptions, SCUBA surveys in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015.

Structural category	Description	Example Species
Canopy	Tall, shading individuals greater than 2 m that may extend to the surface of the water	*Nereocystis luetkeana*
Understory	Individuals greater than 30 cm to 2 m in length	*Laminaria* spp.
Turf	Small foliose or branched individuals 0 to 30 cm in length	*Porphyra* spp., articulated corallines
Encrusting	Species that form a thin crusty layer on rocky substrate	*Lithothamnium* spp., *Codium setchelii*

DROP CAMERA

In 2014, three different camera configurations were tested to determine how to effectively collect substrate imagery at depths beyond 18 m (H. Herunter and S. MacDonald *pers. comm.*). Preliminary review of their data suggested that substrate type was easier to identify with still images than through video.

For the 2015 field season, a drop camera system was designed and built to take still photos of the substrate, between 30 and 50 m depth, to complement adjacent dive transects (0 - 18 m). The resulting images were reviewed after the survey to determine dominant substrate types present. Although algae and invertebrates were often present in the photos, they were not documented.

The drop camera consisted of a GoPro (https://gopro.com) HERO4 black camera equipped with a BackPac battery and contained in a GoPro Dive Housing which was mounted near the top of a monopod using an Inon (http://www.inon.jp) SD mount cage pointed downwards to provide images of the substrate (Fig. 2a). Lighting was provided by an Underwater Kinetics (http://www.uwkinetics.com) Aqualite Pro light with 100° light head mounted near the top of the monopod using an Ultra-Light Control Systems (http://www.ulcs.com) long clamp and ball mounts. The monopod was made of 5 cm square aluminium tubing with a small piece of flat bar welded perpendicular to the square tubing for mounting the light and camera (Fig. 2b). The square tubing was weighted at the bottom (6 kg lead poured inside the tube) and connected to a buoy so that it would maintain an upright position on the bottom. The drop-camera was attached to 250 lb test braided fishing line and was lowered and retrieved using an electric downrigger (Fig. 2c).

Figure 2. Photos of the drop camera to illustrate the design and scale; (a) the drop camera collecting still images on the seafloor; (b) a close-up of the camera and light housing units and their placement on the monopod; (c) the drop camera attached to a downrigger and ready for deployment in the field.

The boat's depth sounder was used to target three depths (30 m, 40 m and 50 m) that extended into deeper water beyond a completed dive transect (Fig. 3). The camera was set to time lapse mode to record one photo every 10 seconds. For each camera deployment, the camera was left on the bottom for approximately 30 seconds producing a series of images (Fig. 4). The 5 cm tubing on the camera monopod was used to indicate scale. Once on the bottom, the field of view is approximately 0.75 x 1 m. After the survey, the photos were reviewed and up to three dominant

substrates were recorded in order of prevalence using the same substrate types as those used by divers (Table 2, Appendix 5). Percent cover for each substrate type was not recorded in the drop camera image annotation because currents sometimes caused the camera to lean at a low angle relative to the bottom altering the field of view.

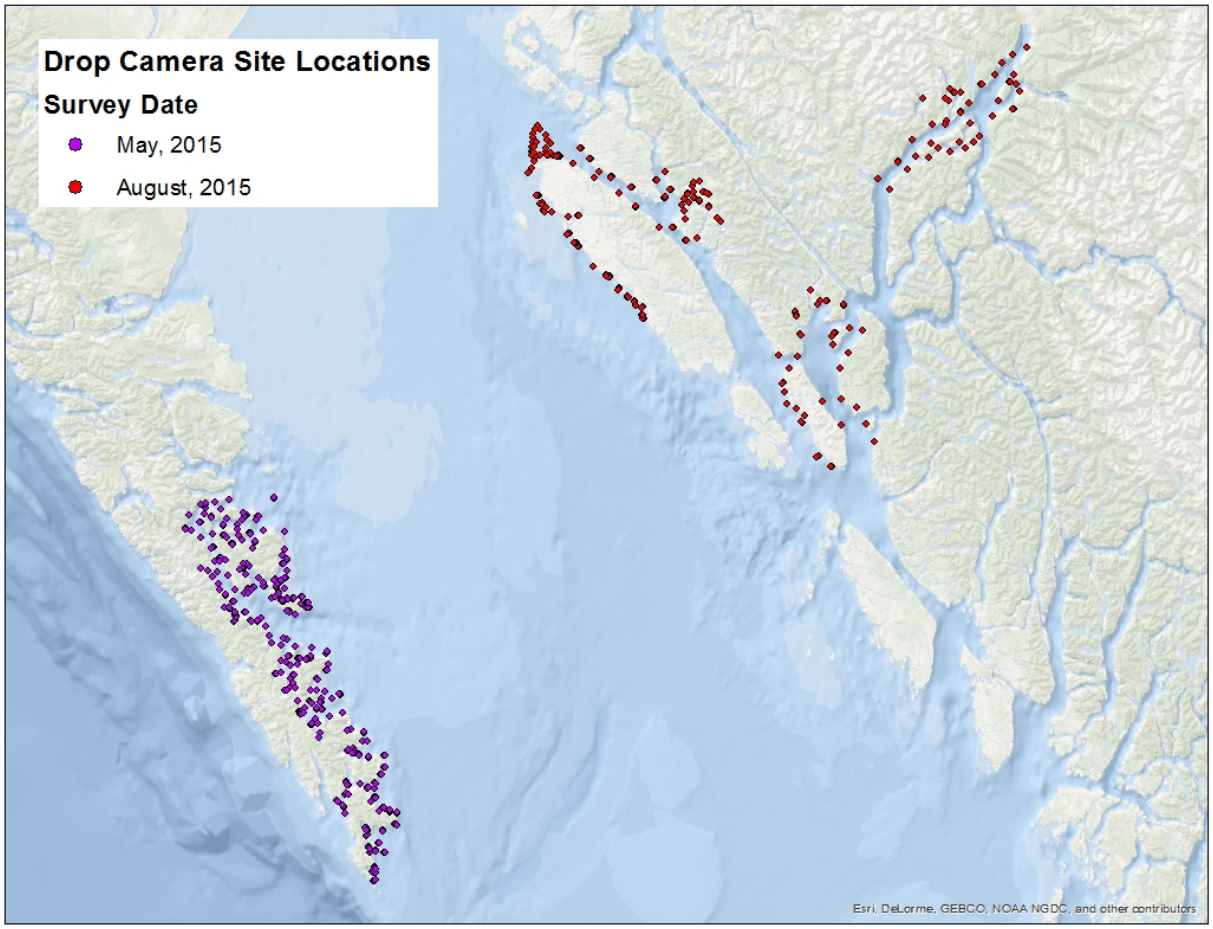

Figure 3. Drop camera deployment sites during 2015 surveys in southeastern Haida Gwaii and the North Coast of British Columbia. Survey dates correspond to the cruise number.

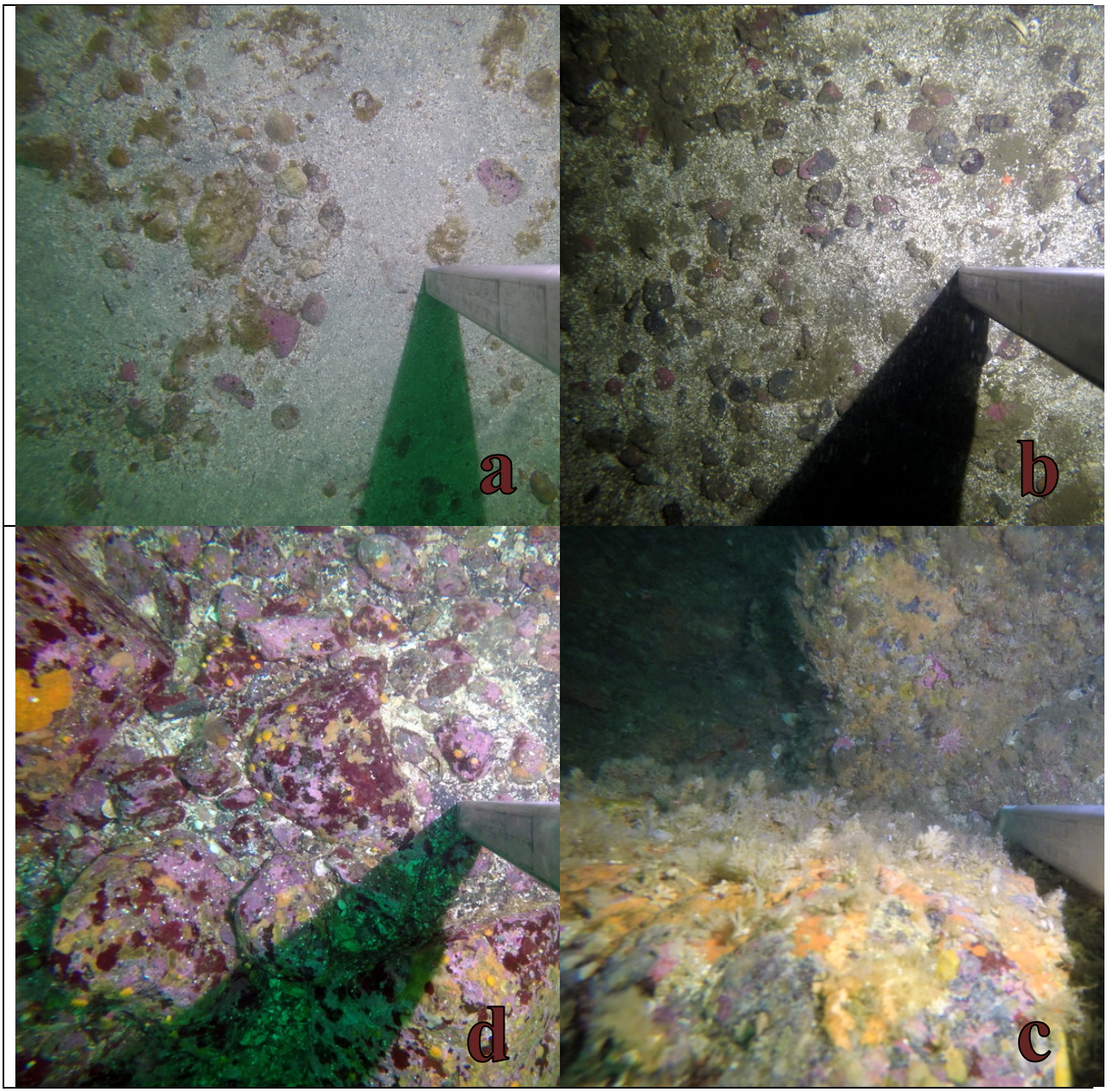

Figure 4. Still images collected by drop camera at different sites illustrate the camera's field of view and lighting capabilities. Different substrate types observed are (a) sand and gravel; (b) crushed shell, gravel, and sand; (c) boulder; and (d) boulder, cobble, and crushed shell.

ANALYSIS & RESULTS

Over the five surveys, a total of 800 SCUBA transects were surveyed (570 in the North Coast and 230 in eastern Haida Gwaii; Table 4). The target depth range was 0 to 18 m; corrected for tide height the actual depth range was 0 – 21 m. Actual range varied due to changes in the tidal

height during the day, with some transects starting deeper than 18 m and ending below chart datum during low tides while the reverse was true during periods of high tides.

Table 4. Number of SCUBA transects completed in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015.

Survey name	Year	Month	Region	Number of Transects completed
PAC 2013-62	2013	September	North Coast	38
PAC 2014-29	2014	May	North Coast	198
PAC 2014-58	2014	September	North Coast	174
PAC 2015-36	2015	May	Haida Gwaii	230
PAC 2015-52	2015	August	North Coast	160

Invertebrates

The proportion of transects where each of the 102 target invertebrate species/groups was found, is presented in Appendix 3. The proportions ranged from 0 to 0.779, with a skewed distribution and a median of 0.1595. The ten most frequently encountered invertebrate species/groups were flat bryozoans, Red Sea Cucumber (*Apostichopus californicus*), other barnacles, hydrozoans, shrimp, Sunflower Star (*Pycnopodia helianthoides*), erect bryozoans, Red Sea Urchin (*Mesocentrotus franciscanus*), compound tunicates, and flat sponges. The five target species observed the least were Pacific White Crust Tunicate (*Didemnum carnulentum*), Basket Star (*Gorgonocephalus eucnemis*), Scaled Crab (*Placetron wosnessenskii*), Clubbed Tunicate (*Styela clava*), and Pacific Sand Dollar (*Dendraster excentricus*). The Vase Tunicate (*Ciona intestinalis*) was on the target list because the invasive species is of ecological interest; however, there were no observations of this species. The Pacific Oyster (*Crassostrea gigas*) was also on the target list and was not encountered during the five surveys. The number of species observed per transect was normally distributed with a mean of 22.245.

For the 15 species/groups for which relative abundance along transects was recorded, the proportion of transects in each relative abundance category is presented in Figure 5. The species/groups most often recorded as Abundant were Giant Plumose Anemone (*Metridium farcimen*), Red Sea Urchin (*Mesocentrotus franciscanus*), and flat bryozoans, while Sunflower Star (*Pycnopodia helianthoides*), Green Sea Urchin (*Strongylocentrotus droebachiensis*), and Pacific Geoduck (*Panopea generosa*) were the least often recorded as Abundant.

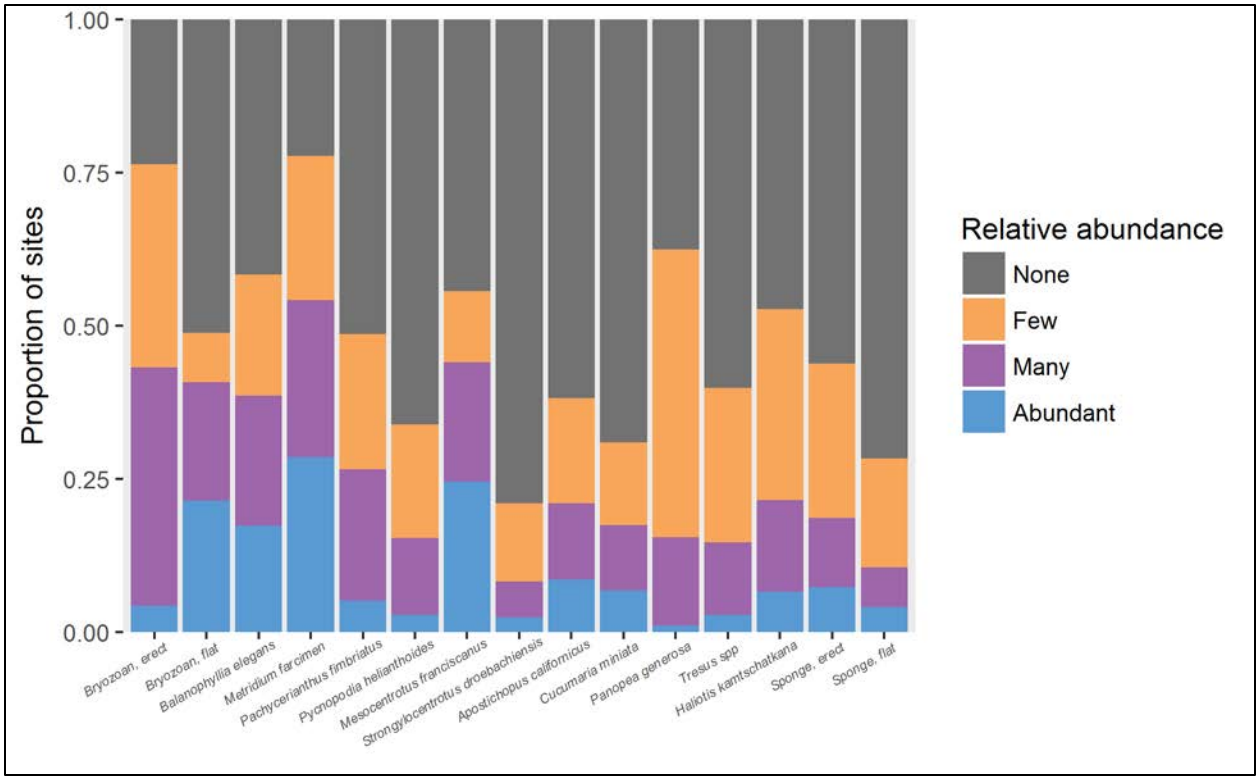

Figure 5. Relative abundance of 15 invertebrate species/species groups recorded on SCUBA dive surveys in the southeastern shore of Haida Gwaii and the North Coast of British Columbia, 2013-2015. Categories were determined based on the number of individuals observed: None, 0 individuals; Few, 1 – 10 individuals; Many, 11 – 100 individuals; Abundant, > 100 individuals. n = 800.

Algae

The proportion of transects where each of the 59 target algae species/groups was found, is presented in Appendix 4. The proportions ranged from 0.006 to 0.778, with a skewed distribution and a median of 0.136. The 10 most frequently encountered algal species/groups were red branched, *Ulva* sp., red foliose, articulated coralline algae, *Saccharina latissima*, *Fucus distichus*, brown filamentous, *Agarum fimbriatum*, *Nereocystis leutkeana*, and *Gloiocladia* sp. The number of species observed per transect was normally distributed with a mean of 12.04.

Median percent cover for each of the structural categories of algae varied (Fig. 6): canopy 0%, understory 12%, turf 14%, encrusting 18%, and drift 1%. Not all transects included algae in all structural categories; the minimum percent cover for each structural category was 0%. Maximum percent cover, for single transects, ranged from 53% for canopy to 96% for encrusting.

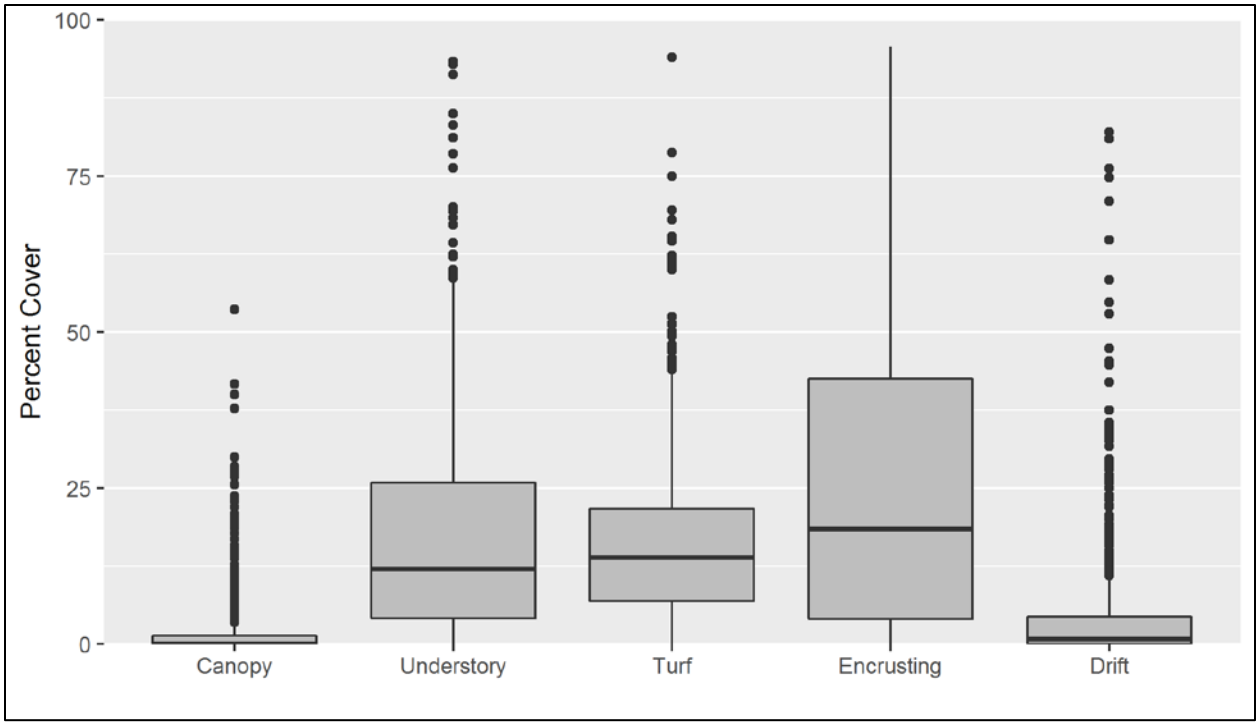

Figure 6. Percent cover for five different algal structure categories at SCUBA dive survey sites in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015. Horizontal bars represent the median value and the box identifies the upper and lower quartiles, while the vertical whiskers show the range of observations (excluding outliers). n = 800.

Substrate

Dive surveys

Eleven categories were used to describe substrate types. Data for each transect were pooled for all substrate observations (primary, secondary, and tertiary) and all quadrats to determine the proportion of transects where each substrate type was encountered (Fig. 7). This summary did not take into account the percent cover of each substrate, but rather the proportion of transects in which a given substrate was observed in at least one quadrat. The most commonly encountered substrates were boulders, crushed shell, and bedrock with crevices. The substrate types that were observed the least often were pea gravel and wood.

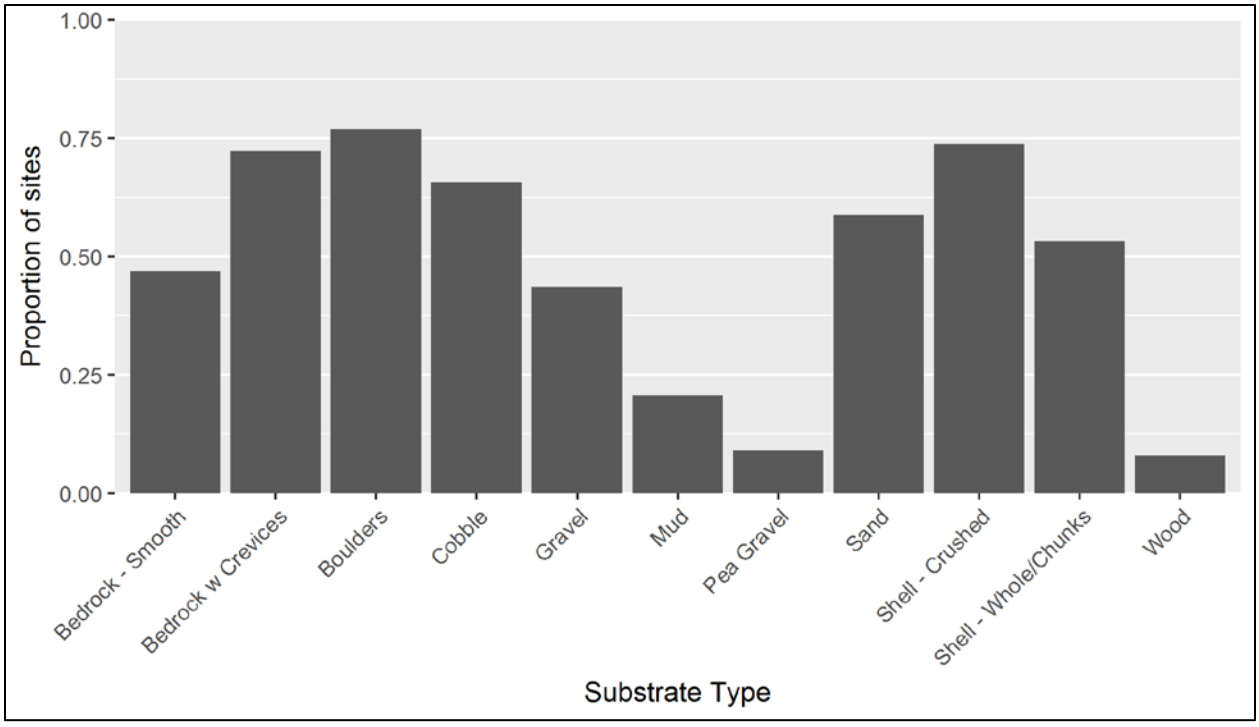

Figure 7. Proportion of dive transects (n = 800) in which each substrate type was observed during SCUBA dive surveys in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015. Depth range of observations was 0 to 18 meters.

Drop Camera

In 2015, drop camera deployments were completed at 337 sites (185 sites in Haida Gwaii and 152 sites in the North Coast), with up to three target depths per site, for a total of 848 deployments (498 in Haida Gwaii and 350 in the North Coast; Table 5). Drop camera target depths were between 30 and 50 m; actual depths varied from 16 - 60 meters. Drop camera data were grouped by site to determine the proportion of sites where each substrate type was observed. Crushed shell was the most frequently encountered substrate and was present at over 93% of sites. Substrate types that were observed the least frequently were bedrock with crevices and wood.

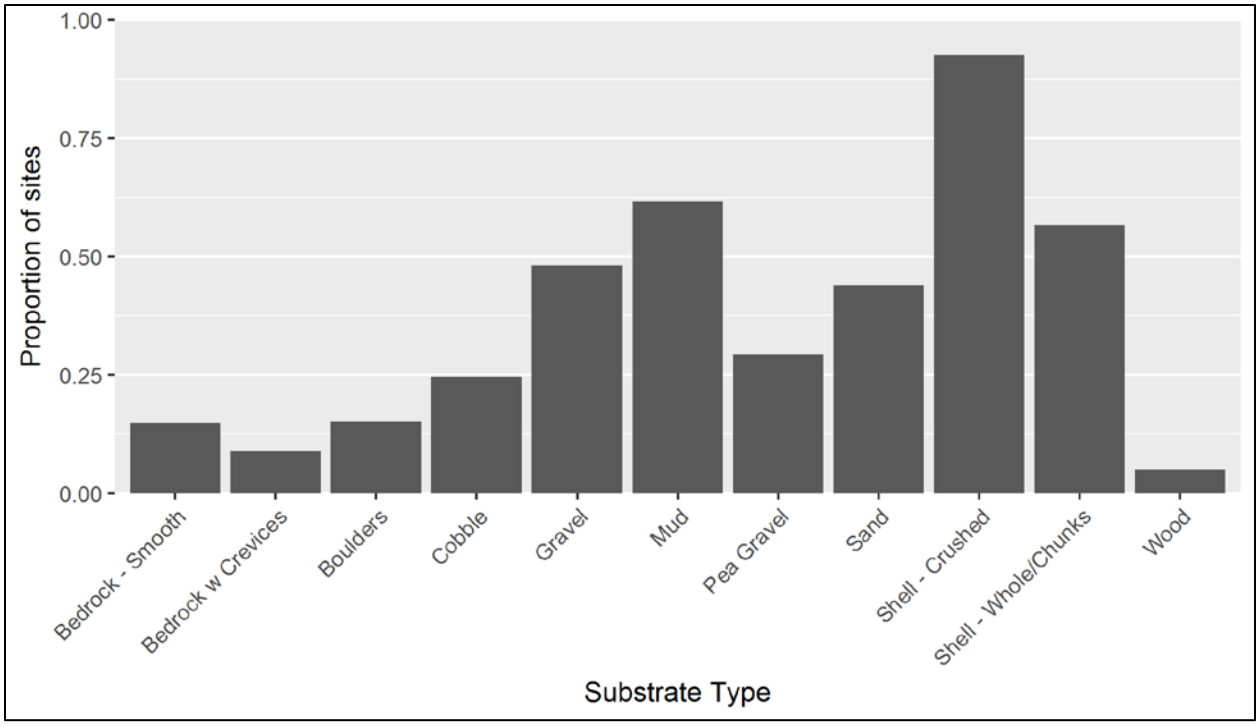

Figure 8. Proportion of drop camera sites (n = 337) in which each substrate type was observed in southeastern Haida Gwaii and the North Coast of British Columbia, 2015. Depth range of observations was 16 – 60 meters.

DISCUSSION

Between 2013 and 2015, 800 SCUBA transects and 848 drop camera deployments were completed to document benthic substrate and associated invertebrate and algae communities. The large target species list allowed for a wide range of invertebrate and algal species observations throughout the study area and identified the frequency of each species within the nearshore region.

Softer substrates (gravel, mud, sand, and shell) were encountered more frequently at deeper depths (Fig. 8) than at shallow depths (Fig. 7). The drop camera proved a useful tool to identify substrate in depths where little information exists in the nearshore (particularly between 20 and 50 m depth). The drop camera system is small and can be easily deployed after each dive from a small boat without the necessity of a dedicated platform.

Substrate data collected during the five surveys has been incorporated into updated bottom patch models developed by Gregr et. al. (2013). This model incorporates substrate type and depth from a number of data sources to characterize nearshore bottom types. Invertebrate data has been incorporated into a recent quantitative reassessment of the Ecologically and Biologically

Significant Areas (EBSAs) in the Pacific Northern Shelf Bioregion (Rubidge et. al. *In Press*). Presence/absence invertebrate and algae data will be included in future species distribution models to support marine planning initiatives for BC.

Additional surveys using the methodology presented in this document have taken place in Haida Gwaii and the Strait of Georgia. Analysis of this entire dataset is planned to identify community assemblages and indicator species. Environmental variables, including exposure to ocean swell and waves will be incorporated into the analysis to identify areas along the BC coast with similar species assemblages. The methodology presented in the document will provide scientific support to marine-use planning initiatives and increase our understanding of marine benthic invertebrate and algal communities in the nearshore region throughout the BC coast.

ACKNOWLEDGMENTS

We are thankful for the valuable comments Katie Gale provided to this manuscript. We thank the captains and crews of the *CCGS Vector* for their logistical support during the surveys. We also thank Mike Atkins, David Breault, Magalie Castelin, Dan Curtis, Janelle Curtis, Lyanne Curtis, Lindsay Dealy, Nick Duprey, Matt Grinnell, Joel Harding, Dan Leus, Janet Lochead, James Mortimor, Jill Packham, Pauline Ridings, Steve Romaine, and Doug Swanston for their diving expertise and data collection.

REFERENCES

Campbell, A., Hand C.M., Paltiel C., Rajwani K.N., and Schwarz, C.J. 1998. Evaluation of some survey methods for geoducks. pp. 5-42. In: Gillespie, G.E. and L.C. Walthers [eds.]. Invertebrate Working papers reviewed by the Pacific Stock Assessment Review Committee (PSARC) in 1996. Can. Tech. Rep. Fish. Aquat. Sci. 2221: 340p.

Canadian Hydrographic Service. 2018. *Data products and services*. Available from http://www.charts.gc.ca/data-gestion/index-eng.asp. Accessed 2018-01-23

Gregr, E.J., Lessard, J., and Harper J. 2013. A spatial framework for representing the nearshore ecosystems. Prog. in Oceanog. 115:189-201.

Rubidge, E., Nephin, J., Gale, K.S.P., and Curtis, J. In Press. Reassessment of the Ecologically and Biologically Significant Areas (EBSAs) in the Pacific Northern Shelf Bioregion. DFO Can. Sci. Advis. Sec. Res. Doc. XXXX/nnn. x + 96 p.

WoRMS Editorial Board 2018, World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. Accessed 2018-02-15. doi:10.14284/170

APPENDICES

Appendix 1. Invertebrate data sheet used for SCUBA dive surveys, in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015.

2014 Invert Inventory Dive Sheet.xlsx, 2014-04-11 Page __ of __

Invert Inventory Dive Sheet Survey _____ Transect _____

Diver _____ Buddy _____ Date _____

Comments: _____ Time In _____

Time Out _____

Quadrat	Depth	Geoduck	Red sea cuke	Red urchin	Green urchin	Abalone	Horse clam	Pycnopodia	Orange cuke	Bryozoan - Flat	Bryozoan - Erect	Sponge - Flat	Sponge - Erect	Orange cup coral	G Plumose anem	Tube dwell anem	Other Species Record species code in quadrat where encountered (see codes below)
0		← Record Starting Depth at Quadrat 0															
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
Rel Abund																	None = 0, Few = 1-10, Many = 11-100, Abundant >100

Cnidarians
TC Tan/Brown cup coral
SC Pink soft coral
HF Hydrocoral - Flat
HE Hydrocoral - Erect
SP Sea pen
HY Hydrozoans
PL Short Plumose Anemone
CA Crimson anemone
PA Painted anemone
WS White spot anemone

Cnidarians
FE Fish eating anemone
RA Stubby rose anemone
SR Sand rose anemone
SI Swimming anemone
GA Green surf anemone
PT Pink tip anemone
AA Burrowing anemone
BA Brooding/Proliferating anem
SA Strawberry anemone
ZO Zooanthids

Polychaetes
FD Feather duster worm
FW Filament worm
SF Slime feather duster

Chitons
GC Gumboot chiton
LC Black leather chiton

Cephalopods
OC Octopus

Gastropods
MS Moon snail
FS Fusitriton
LH Leafy hornmouth
AG Red turban snail
BT Black/Brown turban
PR Purple ring snail

Nudibranch
ME Hooded nudibranch
DI Giant Dentronotus

Tunicates
CI Ciona savignyi
IC Ciona intestinalis (invas)
ST Invasive stalked tun
SM Stalked tunicate
HA Sea peach
CF Broad Base Tunicate
OT Orange social tunicate
DD Didemnum (invasive)
CM Coumpnd Tun - Other
SL Solitary Tun - Other

Bivalves
OR Oyster
MU Blue Mussels
MC California mussel
PI Piddock
SS Swimming scallop
RS Rock scallop
GF Green false-jingle

Crustaceans
GB Giant barnacle
TB Thatched barnacle
OB Barnacle - Other
RR Red rock crab
DC Dungeness crab
CG Cancer gracilis
CB Hairy cancer crab
PS Puget Snd king c.
HC Heart crab
UC Umbrella/Butterfly c.
HM Helmet crab
PW Scaled crab
KC Kelp crab
RC Decorator crabs
CT Crab - Other
SH Shrimp

Echinoderms
PU Purple urchin
SD Sand dollar
SO Solaster
PB Giant pink star
CP Rose star
PO Ochre star
AM Bat star
LS Leather star
VS Vermillion star
CS Cookie star
CU Cushion/Wrinkle s.
HR Blood star
MT Mottled star
PN Painted star
LF Sand star
VC Velcro star
ZS Brittle stars
GE Basket star
WC White cucumbers
CR Crinoids

Data on reverse Y or N

Appendix 2.Algae and substrate data sheet used for SCUBA dive surveys in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015.

Page___of___

Algae Inventory Dive Sheet

Survey _____

Site # _____ Transect _____ Date _____

Diver _____ Buddy _____ Vis _____ Time In _____

Comments _____ Time Out _____

Qd	Depth	Time	Substrate 1	%	2	%	3	%	Algae Species	Percentage Can	Und	Trf	EN %	Drift Sp	%
0			← Record Starting Depth and Time at Quadrat 0												
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															

Substrate Codes: 1=Bedrock Smooth, 2=Bedrock w crevices, 3=Boulders, 4=Cobble, 5=Gravel, 6=Pea Gravel, 7=Sand, 9=Mud, 0=Wood/Bark, 10=Crushed Shell, 11=Whole/Chunk Shell

General Algae codes:
Combine 2 codes below
Colour - Morphology
G green algae
B brown
R red algae
B branched
F foliose
H filamentous

Grasses
PH Phyllospadix
ZO Zostera

AC Articulated Coraline
BH Diatom Mats
BT Beggiatoa

Green Algae
AP Acrosiphonia
CL Cladophora
Codium sp:
CF Codium fragile
CS Codium setchellii
UL Ulva

Brown Algae
Agarum sp:
AB A clathratum
AF A fimbriatum
Alaria sp:
AA A nana
AM A marginata
CP Colpomenia
CO Costaria
CG Cystoseria
CY Cymathere
DB Dictyota
Desmarestia sp:
DA D aculeata
DF D foliacea
DL D ligulata
DM D munda
DV D viridis
DY Dictyoneurum
EG Egregia
EI Eisenia
FU Fucus
HE Hedophyllum
Laminaria sp:
LB L bongardiana
LS L saccharina
LT L setchellii
LY L yezoensis
LE Leathesia
LO Lessoniopsis
MA Macrocystis
NT Nereocystis
PV Pelvetiopsis
PL Pleurophycus
PP Postelia
PT Pterygophora
SL Scytosiphon
SA Sargassum

Red Algae
CN Constantinea
CR Cryptopleura
FA Fauchea
GI Gigartina sp
GR Gracilaria
HA Haloscaccion
IR Iridea sp
PO Porphyra
PR Prionitis

Data on Reverse Side Y or N

Appendix 3. Frequency of occurrence of invertebrate species and species groups in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015. The 10 species with the highest frequency are bolded. Number of dive transects = 800.

Phylum	Class	Scientific Name	Proportion of dive sites
Annelida	Polychaeta	*Dodecaceria* spp.	0.302
Annelida	Polychaeta	*Eudistylia* spp.	0.159
Annelida	Polychaeta	*Myxicola infundibulum*	0.488
Arthropoda	Hexanauplia	*Balanus nubilus*	0.130
Arthropoda	**Hexanauplia**	**Barnacle, other**	**0.696**
Arthropoda	Hexanauplia	*Semibalanus cariosus*	0.161
Arthropoda	Malacostraca	*Cancer productus*	0.186
Arthropoda	Malacostraca	Crab, other	0.141
Arthropoda	Malacostraca	*Cryptolithodes* spp.	0.055
Arthropoda	Malacostraca	Decorator crabs	0.394
Arthropoda	**Malacostraca**	***Dendrobranchiata***	**0.630**
Arthropoda	Malacostraca	*Lopholithodes mandtii*	0.038
Arthropoda	Malacostraca	*Metacarcinus gracilis*	0.071
Arthropoda	Malacostraca	*Metacarcinus magister*	0.088
Arthropoda	Malacostraca	*Phyllolithodes papillosus*	0.046
Arthropoda	Malacostraca	*Placetron wosnessenskii*	0.008
Arthropoda	Malacostraca	*Pugettia producta*	0.231
Arthropoda	Malacostraca	*Romaleon branneri*	0.079
Arthropoda	Malacostraca	*Telmessus cheiragonus*	0.124
Bryozoa		**Bryozoan, erect**	**0.586**
Bryozoa		**Bryozoan, flat**	**0.779**
Chordata	Ascidiacea	*Ciona intestinalis*	0.000
Chordata	Ascidiacea	*Ciona savignyi*	0.120
Chordata	Ascidiacea	*Cnemidocarpa finmarkiensis*	0.376
Chordata	Ascidiacea	*Didemnum carnulentum*	0.002
Chordata	Ascidiacea	*Halocynthia aurantium*	0.135
Chordata	Ascidiacea	*Metandrocarpa taylori*	0.264
Chordata	Ascidiacea	*Styela clava*	0.010
Chordata	Ascidiacea	*Styela montereyensis*	0.071
Chordata		**Tunicate, compound**	**0.542**
Chordata		Tunicate, solitary	0.499
Cnidaria	Anthozoa	*Anthopleura artemisia*	0.069
Cnidaria	Anthozoa	*Anthopleura elegantissima*	0.071
Cnidaria	Anthozoa	*Anthopleura xanthogrammica*	0.110
Cnidaria	Anthozoa	*Balanophyllia elegans*	0.488
Cnidaria	Anthozoa	*Corynactis californica*	0.021
Cnidaria	Anthozoa	*Cribrinopsis fernaldi*	0.040
Cnidaria	Anthozoa	*Epiactis* spp.	0.055
Cnidaria	Anthozoa	*Gersemia rubiformis*	0.039
Cnidaria	Anthozoa	*Metridium dianthus*	0.185
Cnidaria	Anthozoa	*Metridium farcimen*	0.208
Cnidaria	Anthozoa	*Pachycerianthus fimbriatus*	0.410
Cnidaria	Anthozoa	*Paracyathus stearnsi, Caryophyllia alaskensis*	0.066
Cnidaria	Anthozoa	*Ptilosarcus gurneyi*	0.149
Cnidaria	Anthozoa	*Stomphia didemon, S. coccinea*	0.029
Cnidaria	Anthozoa	*Urticina* spp.	0.122
Cnidaria	Anthozoa	*Urticina columbiana*	0.035
Cnidaria	Anthozoa	*Urticina coriacea*	0.091
Cnidaria	Anthozoa	*Urticina lofotensis*	0.192
Cnidaria	Anthozoa	*Urticina piscivora*	0.172
Cnidaria	Anthozoa	*Zoantharia*	0.085
Cnidaria	**Hydrozoa**	***Hydrozoa***	**0.636**
Cnidaria	Hydrozoa	*Stylantheca* spp.	0.020

Phylum	Class	Scientific Name	Proportion of dive sites
Cnidaria	Hydrozoa	*Stylaster* spp.	0.022
Echinodermata	Asteroidea	*Ceramaster* spp.	0.024
Echinodermata	Asteroidea	*Crossaster papposus*	0.224
Echinodermata	Asteroidea	*Dermasterias imbricata*	0.434
Echinodermata	Asteroidea	*Evasterias troschelii*	0.362
Echinodermata	Asteroidea	*Henricia* spp.	0.434
Echinodermata	Asteroidea	*Luidia foliolata*	0.020
Echinodermata	Asteroidea	*Mediaster aequalis, Gephyreaster swifti*	0.256
Echinodermata	Asteroidea	*Orthasterias koehleri*	0.419
Echinodermata	Asteroidea	*Patiria miniata*	0.081
Echinodermata	Asteroidea	*Pisaster brevispinus*	0.130
Echinodermata	Asteroidea	*Pisaster ochraceus*	0.239
Echinodermata	Asteroidea	*Pteraster tesselatus*	0.042
Echinodermata	**Asteroidea**	***Pycnopodia helianthoides***	**0.628**
Echinodermata	Asteroidea	*Solaster* spp.	0.245
Echinodermata	Asteroidea	*Stylasterias forreri*	0.058
Echinodermata	Crinoidea	*Florometra serratissima*	0.064
Echinodermata	Echinoidea	*Dendraster excentricus*	0.010
Echinodermata	**Echinoidea**	***Mesocentrotus franciscanus***	**0.566**
Echinodermata	Echinoidea	*Strongylocentrotus droebachiensis*	0.449
Echinodermata	Echinoidea	*Strongylocentrotus purpuratus*	0.056
Echinodermata	**Holothuroidea**	***Apostichopus californicus***	**0.768**
Echinodermata	Holothuroidea	*Cucumaria miniata*	0.496
Echinodermata	Holothuroidea	White sea cucumbers	0.381
Echinodermata	Ophiuroidea	*Gorgonocephalus eucnemis*	0.002
Echinodermata	Ophiuroidea	Brittle stars	0.394
Mollusca	Bivalvia	*Chlamys hastata, Chlamys rubida*	0.205
Mollusca	Bivalvia	*Crassadoma gigantea*	0.195
Mollusca	Bivalvia	*Mytilus californianus*	0.035
Mollusca	Bivalvia	*Mytilus edulis*	0.169
Mollusca	Bivalvia	*Panopea generosa*	0.312
Mollusca	Bivalvia	*Pododesmus macrochisma*	0.409
Mollusca	Bivalvia	*Tresus* spp.	0.281
Mollusca	Bivalvia	*Zirfaea pilsbryi*	0.031
Mollusca	Cephalopoda	*Octopus californicus*	0.026
Mollusca	Gastropoda	*Calliostoma annulatum*	0.042
Mollusca	Gastropoda	*Ceratostoma foliatum*	0.450
Mollusca	Gastropoda	*Dendronotus iris*	0.094
Mollusca	Gastropoda	*Euspira* spp.	0.028
Mollusca	Gastropoda	*Fusitriton oregonensis*	0.171
Mollusca	Gastropoda	*Haliotis kamtschatkana*	0.342
Mollusca	Gastropoda	*Melibe leonina*	0.161
Mollusca	Gastropoda	*Pomaulax gibberosus*	0.354
Mollusca	Gastropoda	*Tegula funebralis*	0.178
Mollusca	Polyplacophora	*Cryptochiton stelleri*	0.149
Mollusca	Polyplacophora	*Katharina tunicata*	0.160
Porifera		Sponge, erect	0.410
Porifera		**Sponge, flat**	**0.532**

Appendix 4. Frequency of occurrence of algal species and species groups in southeastern Haida Gwaii and the North Coast of British Columbia, 2013-2015. The 10 species with the highest frequency are bolded. Number of dive transects = 800.

Algae Group	Name	Proportion of dive sites
Brown	*Agarum clathratum*	0.258
Brown	***Agarum fimbriatum***	**0.528**
Brown	*Alaria marginata*	0.238
Brown	*Alaria nana*	0.111
Brown	Brown Branched	0.071
Brown	**Brown Filamentous, includes Diatom Mats**	**0.534**
Brown	Brown Foliose	0.200
Brown	*Colpomenia* spp.	0.131
Brown	*Costaria costata*	0.328
Brown	*Cymathere triplicata*	0.225
Brown	*Cystoseira geminata*	0.009
Brown	*Desmarestia aculeata*	0.075
Brown	*Desmarestia foliacea*	0.030
Brown	*Desmarestia ligulata*	0.237
Brown	*Desmarestia munda*	0.155
Brown	*Desmarestia viridis*	0.277
Brown	*Dictyoneurum californicum*	0.008
Brown	*Dictyota binghamiae*	0.109
Brown	*Egregia menziesii*	0.073
Brown	*Eisenia arborea*	0.006
Brown	***Fucus distichus***	**0.577**
Brown	*Laminaria setchelii*	0.170
Brown	*Laminaria yezoensis*	0.054
Brown	*Leathesia difformis*	0.029
Brown	*Lessoniopsis littoralis*	0.025
Brown	*Macrocystis pyrifera*	0.128
Brown	***Nereocystis leutkeana***	**0.370**
Brown	*Pelvetiopsis limitata*	0.014
Brown	*Pleurophycus garderni*	0.085
Brown	*Pterygophora californica*	0.041
Brown	*Saccharina groenlandica*	0.170
Brown	***Saccharina latissima***	**0.610**
Brown	*Saccharina sessilis*	0.116
Brown	*Sargassum muticum*	0.010
Brown	*Scytosiphon lomentaria*	0.084
Green	*Acrosiphonia* spp.	0.089
Green	*Cladophora* spp.	0.136
Green	*Codium fragile*	0.021
Green	*Codium setchellii*	0.121
Green	Green Branched	0.008
Green	Green Filamentous	0.116
Green	Green Foliose	0.009
Green	***Ulva* sp., *Monostroma* sp, *Ulvaria* sp., *Enteromorpha* sp.**	**0.768**
Other	*Beggiatoa (Bacterial mats)*	0.035
Red	**Articulated Corraline Algae**	**0.648**
Red	*Chondracanthus* spp.	0.208
Red	*Constantinea* spp.	0.185
Red	*Cryptopleura* spp., *Polyneura* sp.	0.220
Red	***Gloiocladia* spp.**	**0.367**
Red	*Gracilaria pacifica, Sarcodiotheca* spp.	0.183
Red	*Haloscaccion glandiforme*	0.178
Red	*Mazzaella* spp.	0.176
Red	*Porphyra* spp.	0.228

Algae Group	***Name***	**Proportion of dive sites**
Red	*Prionitis* spp.	0.103
Red	**Red Branched**	**0.778**
Red	Red Filamentous	0.347
Red	**Red Foliose**	**0.742**
Vascular plant	*Phyllospadix* spp.	0.151
Vascular plant	*Zostera* spp.	0.133

Appendix 5. Drop camera substrate data entry form used in surveys of southeastern Haida Gwaii and the North Coast of British Columbia, 2015.