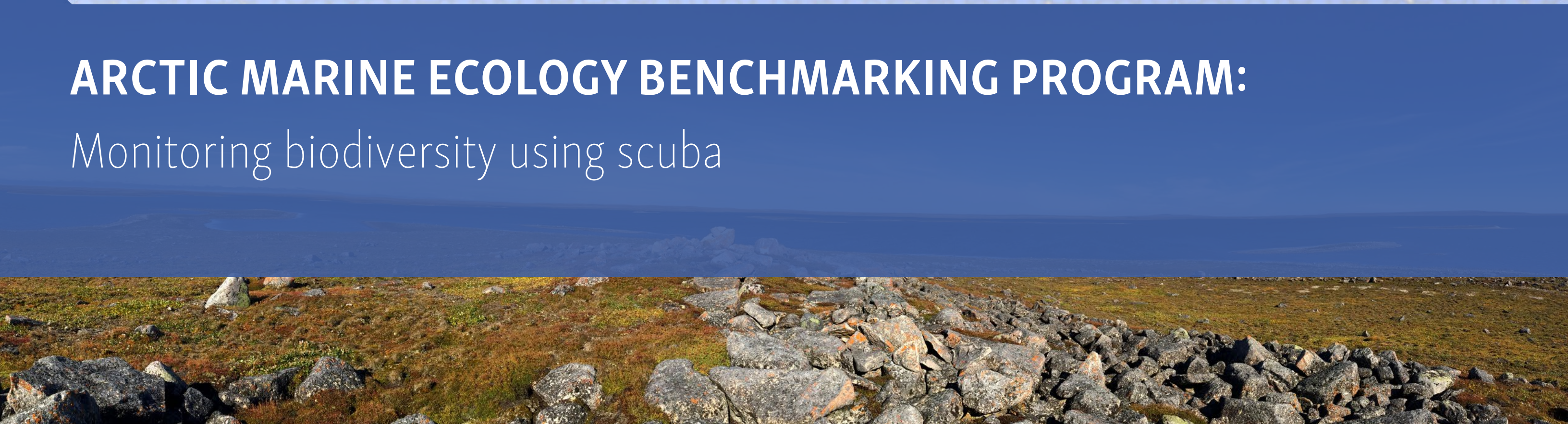
ARCTIC MARINE ECOLOGY BENCHMARKING PROGRAM:

Monitoring biodiversity using scuba



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The Ocean Wise Conservation Association (OWCA, ocean.org) is a global ocean conservation organization focused on protecting and restoring our world's oceans.

Abstract

Building on the catalogue of data gathered during the 2015 and 2016 Nearshore Ecological Surveys, the 2017 Arctic Marine Ecology Benchmarking Program (AMEBP) collected biodiversity and abundance data on marine algae, invertebrates, and fish species using scuba diving at selected sites near Cambridge Bay, Nunavut, in the summer of 2017. The project served as a pilot study to assess scuba diving survey modes (transect vs. taxon) and make recommendations for future research and monitoring efforts. This paper is a summary of the 2017 Arctic Marine Ecology Benchmarking Program Final Report (available on request).

Résumé

En s'appuyant sur le catalogue des données recueillies au cours des relevés écologiques du littoral en 2015 et 2016, le programme d'analyse comparative de l'écologie marine de l'Arctique (Arctic Marine Ecology Benchmarking Program ou AMEBP) de 2017 a permis de recueillir des données sur la biodiversité et l'abondance des algues marines, des invertébrés et des espèces de poissons au moyen de la plongée sous-marine à des sites choisis près de Cambridge Bay, au Nunavut, à l'été 2017. Le projet a servi d'étude pilote pour évaluer les modes de relevé de plongée sous-marine (transect c. taxon) et formuler des recommandations pour les futurs efforts de recherche et de surveillance. Le présent document est un résumé du rapport final du programme d'analyse comparative de l'écologie marine de l'Arctique de 2017 (disponible sur demande, en anglais seulement).

Introduction

Reliable baseline data and ongoing monitoring are essential for developing a full understanding of the changes underway in Canada's Arctic, thereby enabling the development of effective management strategies and conservation plans. The nearshore ecosystem is a key part of the larger marine ecosystem, because it is where most direct human impact, such as boating, hunting, and harvesting, takes place. However, there have been very few scuba diving surveys of nearshore marine flora and fauna in the Canadian Arctic, which faces increasing risk due to climate change, invasive species, and increased human activity. This project addresses this significant gap

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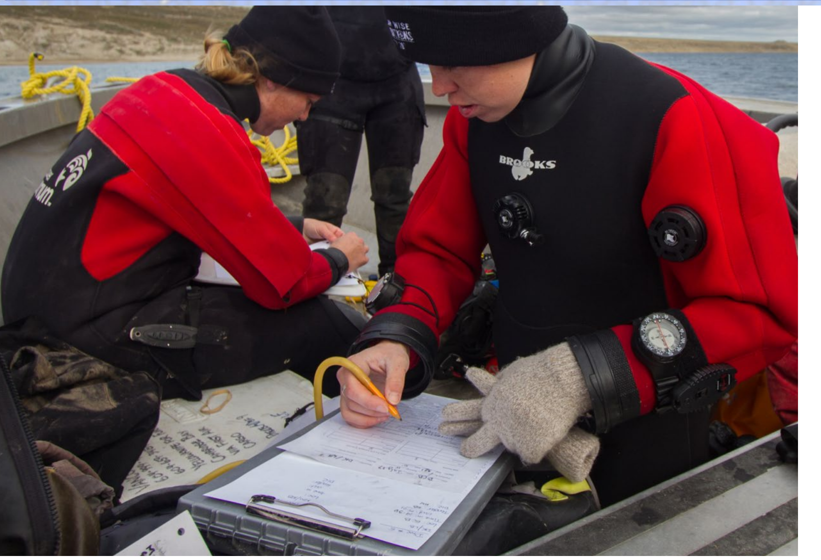

Figure 1: Ocean Wise dive team members making notes after a survey dive.

by establishing baseline biodiversity data and initiating long-term nearshore monitoring near Cambridge Bay, Nunavut.

Methods

Scuba diving

Dives were completed by Ocean Wise divers holding a Scientific Diver Level II rating, as defined by the Canadian Association for Underwater Science (caus.ca) Standard of Practice for Scientific Diving, and were planned using DCIEM Air Diving Tables as no-decompression dives using compressed air. No more than two dives per day per diver were undertaken. Dives met the requirements of the Nunavut Occupational Health and Safety Regulations: Part 20, Diving Operations. The project included a combination of shore- and boat-based dives.

Benchmarking surveys (transect dives)

Appropriate sites were randomly selected from a list of previously explored sites. Two sites from each of three sampling areas — Cambridge Bay, West Arm, and the Findlayson Islands — were selected (Table 1).

Table 1: Pilot survey monitoring sites near Cambridge Bay.

Site name	Area	Substrate	Latitude	Longitude
West of 5 Island	Cambridge Bay	mud, dropstones	69.0687	-105.1967
Cape Colborne Inside	Cambridge Bay	sand, silt, mud, slope	68.9668	-105.2304
Old Camping Spot	West Arm	silt, boulders, flat	69.1104	-105.0761
West Arm BCB	West Arm	sloping shale, mud	69.1093	-105.1717
Starvation Cove Point	Findlayson Islands	sand, cobble	69.1492	-105.9233
Unnamed Island 1 South End	Findlayson Islands	cobble, boulders	69.0938	-105.8989

Four benchmarking survey transect dives (Fig. 2) were conducted at each of the six sites. Transects were centred on the site coordinates, and followed a bearing on the 10-metre-depth contour parallel to shore (as closely as was practical). Each transect dive consisted of a fish transect, an invertebrate and algae swath survey, and a habitat survey, following the methods of the subtidal monitoring protocols of the Pacific Rim National Park Reserve (Jennifer Yakimishyn: personal communication, 2015), with the exception that the taxa recorded were specific to Nunavut (Table 2).

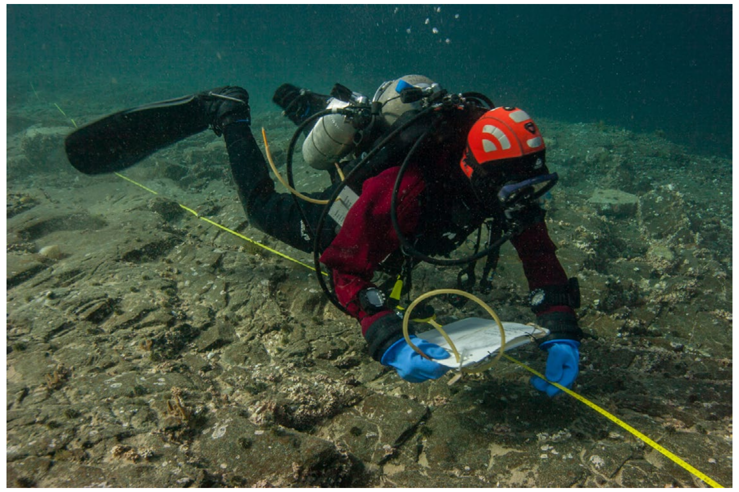

Figure 2: Ocean Wise diver completes transect dive.

Roving biodiversity surveys (taxon dives)

At least one taxon dive was conducted at each transect site. Divers navigated using the bottom topography, recorded all organisms observed (to the lowest taxonomic level possible), and estimated the approximate abundance of each.

Data analysis

Community composition and habitat characteristics

We calculated the mean and standard deviation of fish, invertebrate, and algae counts for each transect survey. Species composition was summarized by comparing the three sampling areas using an Analysis of Similarity (ANOSIM; Primer 6) of the square root transformed abundance data. Habitat characteristics among the three areas were compared using mean proportions and standard deviation. We also totalled the number of each species observed at each site using the taxon dive method, and calculated the average abundance following the methods in Marliave et al. 2011.

Power analysis of benchmarking sampling design

Green urchins (*Strongylocentrotus droebachiensis*) were used as a case study species to evaluate the benchmarking survey sampling design as a tool for long-term ecological monitoring. Urchins are an abundant and ecologically important indicator species (Coyer et al. 1993; Estes and Duggins 1995; Chen and Hunter 2003; DFO 2013). Following the methods in Green and McLeod 2016, we conducted a linear mixed-effects-model power analysis to assess the power of the sampling design. Two types of power analyses were conducted using the model output: the first was to determine the number of monitoring years needed under the present sampling design (six sites with four transects each) to detect a 25% change in the urchin population with 80% power, and the second was to determine the number of study sites required to detect a 25%, 50%, and 2×SD change in the population from one year to the next (i.e., with two years of sampling; Munkittrick et al. 2009).

Comparison of transect and taxon dive methods

To illustrate the different potential applications of each method, species accumulation curves of the benchmark transects were compared with those of the taxon

Table 2: The mean abundance of taxa enumerated in 60 m^2 transects (n = 24) at six sites in Cambridge Bay, in order of abundance.

Scientific name	Common name	Mean Abundance	Standard Deviation
Hiatella arctica	Arctic saxicave	520.6	725.4
Strongylocentrotus droebachiensis	Green urchin	430.6	583.6
Pachycerianthus borealis	Tube dwelling anemone	223.2	330.7
Various	Non-sessile polychaetes	12	18.3
Utricina spp.	Urticina anemones	11.7	17.5
Hormathia spp.	Rugose anemone	8.9	23.1
Psolus fabricii	Scarlet sea cucumber	2.4	4.3
Buccinum spp.	Buccinum snail	1.1	2.3
Dendronotis spp.	Dendronotid nudibranchs	0.8	2.7
Cottoidea	Sculpins	0.8	0.9
Hyas coarctatus	Arctic lyre crab	0.6	1
Various	Solitary tunicates	0.6	1.1
Stichaeidae	Pricklebacks	0.5	0.9
Various	Bladed red algae	0.3	0.5
Cucumaria frondosa	Giant black sea cucumber	0.2	0.6
Icasterias panopla	Red spiky sea star	0.2	0.6
Saccharina latissima	Sugar kelp	0.2	0.5
Various	Non-sessile nemerteans	0.2	0.5
Lebbeus polaris	Polar lebbeid shrimp	0.1	0.4
Urasterias lincki	Frilled sea star	0.1	0.3
Various	Dorid nudbranchs	0	0.2
Zoarcidae	Eelpouts	0	0.2

dive technique. Species accumulation curves were constructed by ordering surveys chronologically and then plotting the cumulative number of species detected with each additional survey for both transect surveys and roving biodiversity surveys.

Results and discussion

Benchmarking surveys (transect dives)

Community composition and habitat characteristics

The most abundant taxa were Arctic saxicave, green urchins, and tube-dwelling anemones (Table 2). The abundance of Arctic saxicave should be interpreted with caution because the species was challenging to identify when buried in the sediment.

Overall, there was no difference in the community composition among sites in Cambridge Bay, West Arm, and the Findlayson Islands (ANOSIM: R = 0.557, p = 0.10). The average abundance of invertebrates and algae was higher in the Findlayson Islands than in the other two areas, but the abundance of fish was low (less than two individuals per 60 m^2) in all areas (Fig. 3).

The habitat of most sites was characterized by low-relief and low-complexity mud or sediment. At all sites, most intersection points had no organic cover (84.4% ±14.3 SD) and had smooth habitat complexity (score = 0; 70.8% ±30.8 SD). However, the Findlayson Island sites had proportionately less sediment compared with the other areas, a greater proportion of cobbles and boulders, and a lower proportion of zero-complexity points (38.3% ±25.4 SD; Fig. 4). Almost all points along all transects had a relief value of <1m.

Differences in abundance of fish, invertebrates, and algae between the Findlayson Islands and the other areas could be attributed to differences in habitat characteristics. The Findlayson Islands are more exposed to tidal current than the other two areas, exposing a higher proportion of hard substrate habitat, such as cobble and boulders.

Power analysis

The sampling design used in this pilot study would be adequate to detect large (e.g., 50% or 2×SD) changes in the abundance of individual species from one year to the next, but a smaller effect size (e.g., 25%) would require several years of sampling and/or more survey sites. With six sites (24 transects total), five years of sampling would be required to achieve greater than 80% power to detect a 25% change in the population of green sea urchins (power at n = five years is 97.8% ± 1.3% [95% CI]). In order to detect a 25% change over two years, the number of sites would need to increase to an unreasonably high number (Fig. 5a). However, if a larger effect size is acceptable (e.g., a 50% change in the population), approximately 17 sites would be adequate (Fig. 5b). The most appropriate approach for future monitoring will depend on the long-term monitoring objectives and species of interest. Power analyses should be rerun for specific species of interest to ensure that the monitoring program meets specific targets for effect size and power.

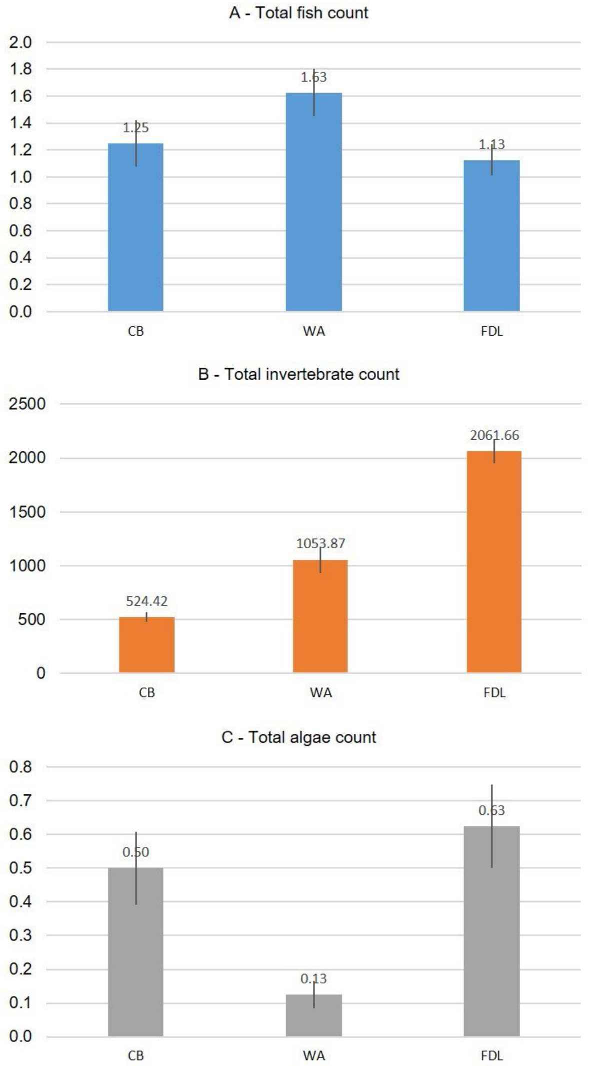

Figure 3: The mean abundance of (A) fish, (B) invertebrates, and (C) algae counted along 60 m2 transects in three areas near Cambridge Bay (CB = Cambridge Bay; WA = West Arm; FDL = Findlayson Islands). n = 8 transects in each area. Error bars represent standard error.

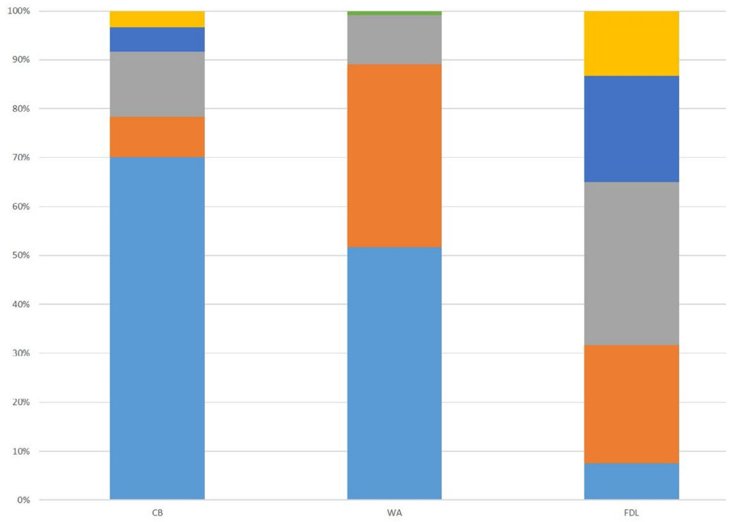

Figure 4: Proportion of substrate type for three areas near Cambridge Bay (CB = Cambridge Bay; WA = West Arm; FDL = Findlayson Islands). n = 8 surveys for each area.

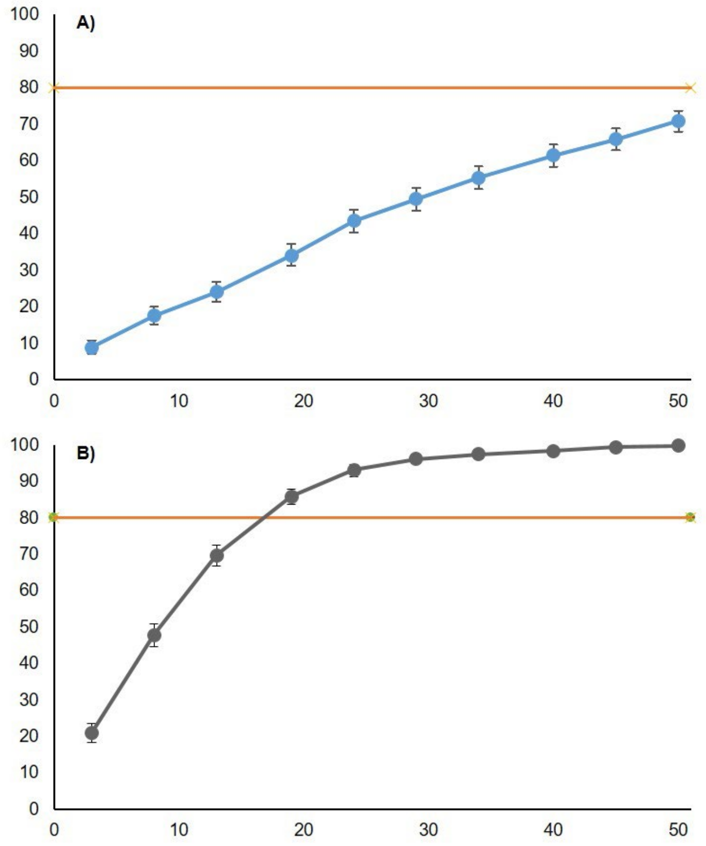

Figure 5: The estimated power to detect (a) a 25% change and (b) a 50% change in the population of green urchins for a given number of survey sites (with four transects per site) using a linear mixed-effects model (R "simr" package; Green and McLeod 2016). Horizontal dashed lines represent 80% power, which is a common target in ecological studies (Munkittrick et al. 2009).

Roving biodiversity surveys (taxon dives)

Eighteen roving biodiversity surveys (taxon dives) were

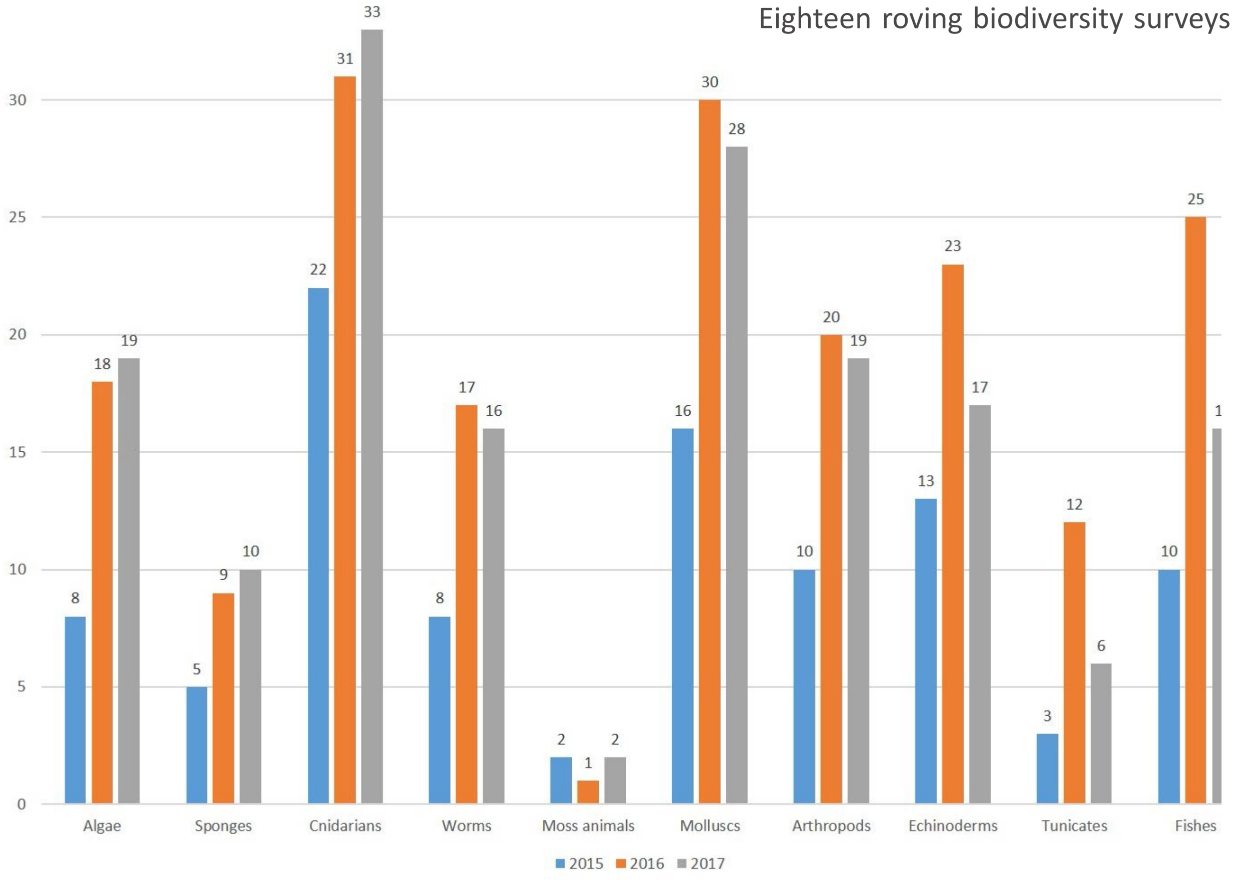

Figure 6: Comparison of number of species observed during the 2015 NES (6 dives), 2016 NES (14 dives), and 2017 AMEBP (18 dives).

undertaken, during which 161 species were noted (Fig. 6), including 20 not previously recorded during the 2015 or 2016 NES (2015 and 2016 NES final reports available on request). The observation of previously unobserved species suggests a need to continue this type of taxonomic work.

Comparison of transect and taxon dive methods

The species accumulation curve (Fig. 7) maintained an upward trajectory for roving biodiversity surveys, demonstrating that species richness would continue to climb with additional surveys, while the species accumulation using the transect method was, of course, maximized at the number of target species predetermined in the methods. On the other hand, the transect method provides a more rigorous estimate of species abundance (Table 2) than the taxon method, which only approximates abundance and is therefore more subjective.

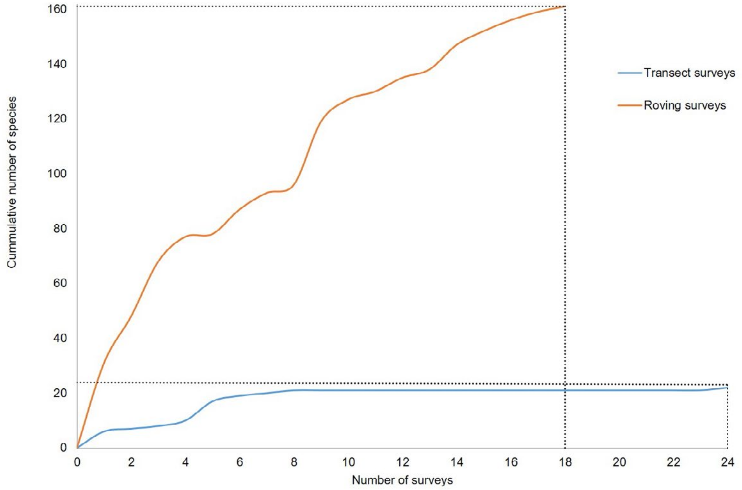

Figure 7: The cumulative number of taxa observed with each additional transect (solid blue line) or taxon dive survey (solid orange line). Surveys are in chronological order. Twenty-two taxa were observed after 24 transect dives, and 161 taxa were observed after 18 taxon dives.

The most appropriate method for future monitoring will depend on the objectives of the program. Taxon dive surveys may be more appropriate if the objectives include capturing a greater breadth of biodiversity or detecting rare, endangered, or invasive species. However, if more repeatable and quantifiable data are required, the transect method may be more appropriate.

Figure 8: Children encounter live marine specimens at the community open house.

Next Steps

While traditional approaches to biodiversity research have made important strides in characterizing Arctic nearshore ecosystems, they have some limitations. For instance, because transect dives target specific species of interest and specific depths, they do not capture the full breadth of diversity at a given location. Likewise, taxonomic experts with experience scuba diving in the Arctic are rare, so precise species identification during a taxon dive can be challenging. One way to bolster traditional survey methods is to incorporate molecular methods such as DNA barcoding (Hebert et al. 2003). We recommend using the results of the 2017 AMEBP to adapt and continue transect surveys at select sites. However, we also recommend augmenting and continuing roving biodiversity surveys and site exploration with DNA barcoding. In addition, we propose hosting a workshop with Cambridge Bay stakeholders to determine local priorities for future research.

Community Considerations

We strongly believe that increased awareness of the local underwater environment will lead to enhanced respect for its complexity and fragility, and serve to strengthen community support for ongoing monitoring efforts. To this end, the 2017 AMEBP included several hands-on community engagement events, including an open house for all Cambridge Bay residents and a program to introduce Kullik Ilihakvik Elementary School students to live specimens.

As well, we conducted a number of interviews with Cambridge Bay youth about environmental changes and the capacity of science and traditional knowledge to address the impact of climate change on the Arctic. The varied and thoughtful responses touched on concerns about food security, threats to animal populations, thinning ice, and invasive species. These interviews clearly indicated that future research projects must be structured to be relevant to Inuit concerns and priorities.

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