APPENDICES

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

Final report prepared under
BOEM Agreement Number M12AC00011

Principal Investigators

Brenda Norcross
Bodil Bluhm
Sarah Hardy
Russell Hopcroft
Katrin Iken

Institute of Marine Science
College of Fisheries and Ocean Sciences (CFOS)
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

BOEM
Bureau of Ocean Energy Management

December 2017

LIST OF APPENDICES

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix A

Details of Field Sampling Plan

Author
Brenda Norcross

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

DETAILS OF FIELD SAMPLING PLAN

The original proposal was for seasonal sampling (September vs. August) in the eastern Beaufort Sea, however that plan was thwarted in the first year of sampling due to unique circumstances with our relationship with indigenous communities practicing subsistence hunting. The initial plan was for a cruise the last 10 days of September 2012. We had assumed that the Kaktovik subsistence bowhead whaling season would be finished by early September as had occurred in all recent years. Instead, the death of an elder in the village of Kaktovik suspended the hunt during the first week of our cruise. We were unable to secure permission to sample east of 150º W during the hiatus. Thus, from 20 September to 1 October 2012, we sampled along transects at in the central US Beaufort Sea at 150.1º W (B1), 150.6º W (BX), and 151.1º W (B2). Depths to the west, on the central Beaufort Sea shelf and slope of 20 m, 50 m, 100 m, 200 m, 350 m, 500 m and 1000 m were sampled on the outer transects and the deepest four depths were sampled on the middle transect.

Sampling successfully occurred in the eastern US Beaufort Sea and western Canadian Beaufort Sea 12 August–2 September 2013 and 17 August–2 September 2014. Exact dates were dependent upon availability of the contracted ship R/V *Norseman II*, the only vessel capable of doing the planned interdisciplinary work and housing the necessary number of scientists. Start dates were further modified by weather delays. Our agreement with the Alaska Eskimo Whaling Commission was that we would be out of Alaska waters by 25 August in 2013 and 2014 so as not to spook bowhead whales and disturb the hunt; all sampling starting on that date occurred in Canadian waters. Transects were centered on predetermined longitudes of 146.1º W (A6), 145.1º W (A5), 144.1º W (A4), 142.1º W (A2), 141.1º W (A1), and 140.1º W (TBS). TBS had been sampled by Canadian scientists in earlier years. The plan also included another Canadian transect (GRY) on the east side of the Mackenzie River delta (Majewski et al. 2013). Collaborative plans had been made for both the US and Canadian field components to sample transects closest to the international border, A2, A1, TBS, and GRY, thus those were of highest priority. Because of extremely good weather in 2013 one additional transect was added in Canadian waters in the Mackenzie River outflow channel (MAC). In 2013 it quickly became apparent that stations would not be located exactly on the predetermined longitude lines as finding relatively smooth bottom for trawling was difficult. In 2014 stations were on the Global Positioning System (GPS) coordinates established in 2013.

As we evaluated the success of the previous cruise, field sample and analysis plans were refined to incorporate that knowledge. For example, difficulties with deploying the box corer to collect bottom sediments and infauna in 2012 meant that we opted for a Van Veen grab instead, but never deeper than 350 m. Section 3.0 reflects these changes. The focus of that project component was changed from infauna to fish and invertebrate fatty acids in support of food web knowledge.

LITERATURE CITED

Majewski, A.R., B.R. Lynn, M.K. Lowdon, W.J. Williams, and J.D. Reist. 2013. Community composition of demersal marine fishes on the Canadian Beaufort Shelf and at Herschel Island, Yukon Territory. Journal of Marine Systems 127:55–64.

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix B

UAF Fisheries Oceanography Field Manual – Beaufort Sea

Authors
Lorena E. Edenfield
Bodil A. Bluhm
Sarah M. Hardy
Brenda A. Holladay, Lab Manager
Russell R. Hopcroft
Katrin Iken
Andres Lopez
Brenda L. Norcross, Principal Investigator

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Appendix B Table 1. Gears using during BOEM-funded Beaufort cruises BOEM-2011, TB-2012-US, TB-2013-US and TB-2014-US in the Beaufort Sea.

Gear	Type	Complete name of gear	BOEM -2011	TB-2012 -US	TB-2013 -US	TB-2014 -US
Environmental Gear						
Box Core	Sediment sampler		--	X	--	--
Van Veen grab	Sediment sampler		X	X	X	X
CTD	Water profiles and samples	Conductivity Temperature Density measuring device	X	X	X	X
SIMRAD™	Depth and height sensor		--	--	X	X
TDR	Temp & depth recorder		X	X	X	X
Biological Gear						
Aluette or AMT	Pelagic trawl	Aluette midwater trawl	--	--	--	X
IKMT	Pelagic trawl	Isaacs-Kidd midwater trawl	X	X	X	--
Bongo	Plankton net		X	X	X	X
Multinet	Plankton net		--	X	X	X
Vertical Bongo	Plankton net		X	X	X	X
CBT	Bottom trawl	Canadian benthic trawl	--	X	X	--
OT	Bottom trawl	Otter trawl	X	X	X	--
PSBT	Bottom trawl	Plumb staff beam trawl	X	--	--	--
PSBT-A	Bottom trawl	Modified plumb staff beam trawl	X	X	X	X

UAF
Fisheries Oceanography
Beaufort Sea U.S.-Canada Transboundary
Field Manual

Lorena E. Edenfield
Bodil A. Bluhm
Sarah M. Hardy
Brenda A. Holladay, Lab Manager
Russell R. Hopcroft
Katrin Iken
Andres Lopez
and
Brenda L. Norcross, Principal Investigator

Fisheries Oceanography Laboratory
Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
Room 134 O’Neill Bldg.
905 N. Koyukuk Dr.
Fairbanks AK 99775-7220 v. 10 November 2017

This manual describes fieldwork activities used during the BOEM-funded projects Central Beaufort Sea Marine Fish Monitoring (BOEM Agreement Number M10AC20004, OCS Study BOEM-033) and US-Canada Transboundary Fish and Lower Trophic Communities (BOEM Agreement Number M12.1C00011, OCS Study BOEM-034). Field methodology for Transboundary was developed based on methods used during Central Beaufort.). The manual lists some trade names and commercial products presently used by the Fisheries Oceanography Laboratory, University of Alaska Fairbanks; mention does not constitute endorsement by the University of Alaska or the Bureau of Ocean Energy Management.

Corresponding Author:
Brenda A. Holladay
Manager, Fisheries Oceanography Laboratory
baholladay@alaska.edu

Table of Contents

This field manual was developed based on project "Central Beaufort Sea Fish Monitoring", cruise BOEM-2011, and refined on project "US-Canada Transboundary Fish and Lower Trophic Communities", cruises TB-2012-US, TB-2013-US and TB-2014-US. All cruises were aboard the *R/V Norseman II.* These projects were designed to collect quantitative data to assess abundance and distribution of marine fishes and invertebrates that occupy the eastern Alaskan part of the Beaufort Sea during the arctic open-water season. Samples collected include water column hydrography data, water, zooplankton, ichthyoplankton, pelagic and demersal fishes, epibenthic invertebrates, sediment, and infauna.

Recommended sequence of gear deployment at each station

1. CTD with rosette (hydrographic data, water chemistry)
2. Vertical net, at 20 and 50 m (zooplankton)
3. Multinet, at stations deeper than 50 m (zooplankton, ichthyoplankton)
4. Van Veen grab (sediments)
5. Box core (infauna and sediments)
6. IKMT (Isaacs-Kidd midwater trawl; small pelagic fishes and zooplankton)
7. Bongo (zooplankton, ichthyoplankton)
8. PSBT-A (modified plumb staff beam trawl; demersal fishes and epibenthic invertebrates)
9. Canadian benthic trawl for gear comparisons with Norcross/UAF PSBT-A (demersal fishes and epibenthic invertebrates)
10. Otter trawl (bottom fishes and epibenthic invertebrates)

By necessity, all field plans must be subject to change based on current weather, gear, and local subsistence restrictions. Often, the CTD, multinet, vertical net, van Veen, and box core are cut first in poor weather due to difficulty with vertical deployments in rough seas. If sampling time is not available or is cut short by weather delays, sampling gears will be cut based on the following criteria: 1) weather conditions, 2) performance and efficiency of gear on previous transects, and 3) wire time required to deploy and retrieve gear. In ideal weather, sampling the vertical gears should be prioritized over otter trawls or benthic net comparisons. To ensure adequate coverage of pelagic and benthic communities, a predetermined sampling plan (Table 1) can be helpful. Stations that are close spatially but differ greatly in depth, as stations on the Beaufort Sea slope tend to be, do not need to be sampled for zooplankton every time. Instead, a mid-shelf station will sample zooplankton at a location that is spatially approximately halfway between the 50 and 100 m depths. Additionally, a CTD drop is recommended every 5-10 miles from previous stations so that adequate coverage of oceanographic data may be obtained.

Appendix A Table 1. Recommended sampling at certain depths

Sampling Gear	**20 m**	**50 m**	**Mid-shelf**	**100 m**	**200 m**	**350 m**	**500 m**	**750 m**	**1000 m**
CTD (every 5-10 nm, as necessary)	X	X	X	X	X	X	X	X	X
Vertical Net	X	X	X						X
Multinet				X	X		X		X
Bongo	X	X	X	X	X		X		X
Van Veen	X	X	X	X	X				
Box Core	X	X	X	X	X	X	X	X	X
IKMT	X	X	X	X	X	X	X	X	X
CBT	X	X		X	X	X	X	X	X
PSBT-A	X	X		X	X	X	X	X	X
Otter Trawl	X	X		X	X	X	X	X	X

Standard Deployment Procedures

CTD

A CTD/rosette is deployed at each station and at regular intervals between stations.

- Seabird SBE-25 Sealogger with PAR sensor, Fluorometer/transmisometer, and altimeter mounted onto SBE-55 Eco-Water sampler with six 4-L Niskin bottles, deployed with SOSI ECO-Winch 265
- Weight of package ~200 lbs. when bottles empty
- Spares for many items prone to failure (mostly electronic cables and termination) are available for the CTD and rosette.
- An SBE 19 SeaCat profiler is be taken as backup – this instrument does not allow for the full suite of sensors that the SBE-25 handles, and can either be installed on the rosette or deployed autonomously and downloaded post-cast.

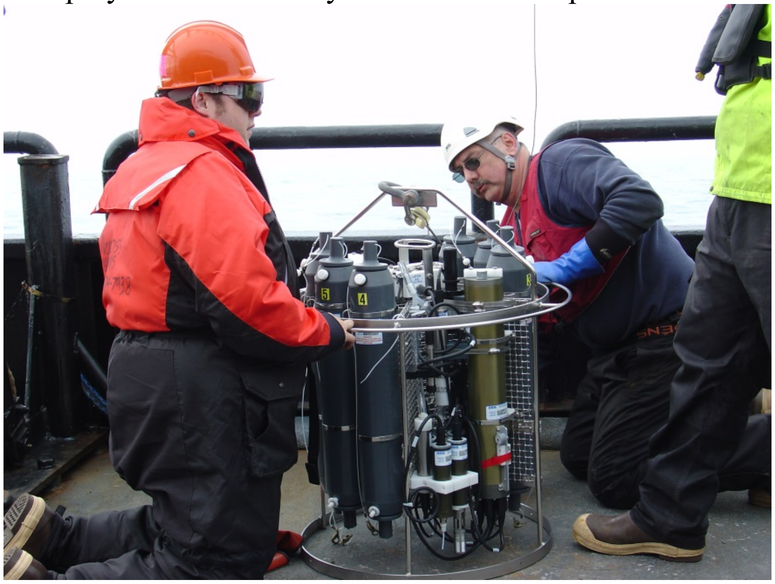


Photo credit: Kate Wedemeyer 2011

The CTD measures basic water quality, including temperature, conductivity (salinity), pressure (depth), dissolved oxygen, pH, Fluorescence (Turner Fluorometer), and PAR (Biospherical Par sensor) at up to 8 times per second in real time. Bottles are triggered at fixed depths during the up-cast to collect water samples. Water samples are filtered and frozen for chlorophyll a extraction, and whole water aliquots are frozen to assess dissolved nutrients post-cruise. Several trace metals and stable isotope signatures are also be determined post-cruise.

CTD launch and recovery protocols are weather dependent. In calm seas, control may be maintained by one individual working in conjunction with the winch and/or A-frame operator(s). As weather state increases, direct control of the CTD will require use of tag-line.

Upon launch, the CTD is immediately lowered to 3–5 m of water depth to remove it from potential harm by the ship. Power is then turned on, logging of data is commenced, and several minutes may be required for the pump on the unit to start. Once the pump starts, the unit is raised to just below the surface then descent begins at ~0.5 m/sec on shallow cast and up to 1 m/sec on deeper casts. The cast is stopped ~2–3 meters above the bottom based on information provided by an altimeter that is mounted on the bottom of the CTD.

A water bottle is electronically triggered at the bottom of the cast; at pre-determined depths on the ascent, the CTD is stopped and a bottle is trigger to collect water samples. The last bottle is triggered at the surface while observed by deck personal, logging is stopped, and the power is turned off prior to retrieval. In rougher seas tag lines may need to be clipped onto the CTD to assist save retrieval. The CTD is generally lifted or dragged to suitable location on deck and secured prior to removing samples from the water bottles.

Particulate organic matter as the baseline reference for food web analysis is collected from Niskin bottles from CTD up-casts at every station. Water collected either from the chlorophyll maximum layer identified from the CTD down-casts, or from about 10 m depth, is filtered onto pre-combusted, 25 mm diameter GFF filters using a filtration manifold and vacuum pump, until filters show slight color. Care is taken that no larger plankton animals remain on the filters by pre-filtering the water over 200 µm mesh. Three replicate filters are prepared, if possible from water from different Niskin bottles. Filters are placed in small petri-dishes and kept frozen at -20 °C until further processing.

Sensor failures are generally obvious, and where possible, alternate sensors will be installed. Periodic QC checks/calibrations will be made using samples collected for distilled oxygen (DO; Winkler titration), pH, and salinity to be determined post-cruise. All sensors are periodically calibrated; the temperature and conductivity sensors are typically calibrated at both the beginning and end of the field season.

Vertical net

- Frame: twin Stainless-steel 60 cm ring net frame
- Net: 60 cm x 2.5 m 150 µm mesh cylindrical/conical MARMAP style
- Codend: 150 µm, 11 cm (diameter) x 21 cm (length), PVC
- Weights ~50 lbs.
- Backups available for all components

Photo credit: Bluhm/Iken, SFOS, UAF 2013

Zooplankton collection methods follow those currently employed by Hopcroft's lab, including the Chukchi Sea Environmental Studies Program (CSESP). Zooplankton are collected by a pair of 150 µm mesh Bongo nets of 60 cm diameter hauled vertically (or obliquely at slow ship-speed in shallow water, approximately 0.5 m/sec wire speed) from within 3 m of the bottom; the volume of water filtered is measured by one-way General Oceanics flowmeters in each net rigged not to record during descent.

Nets are deployed by one individual on deck working in conjunction with the A-frame and winch operator. Ascent speed is ~0.5 m/sec. Flowmeter readings are recorded immediately before and after the casts, nets are washed down to consolidate the catch prior to sample removal from the codend, then preserved in 5% buffered formalin and 95% ethanol.

Planktonic organisms for food web analysis are sampled using a vertical haul 505 µm ring net to a maximum depth of 100 m. Dominant representatives covering a range of taxonomic groups and feeding guilds are collected as representatives of the pelagic food web at each station, including copepods, chaetognaths, and amphipods. Planktonic organisms are collected in replicates of three, but several individuals may have to be combined to achieve sufficient mass for an individual sample. Plankton samples are kept frozen until further processing. Vouchers are kept in 10% buffered formalin. Should time on board the vessel allow, we dry all isotope samples at 60 °C for 24 h in a drying oven. This reduces the danger of sample loss should freezer failure occur, and reduces freezer space needs on board.

Bongo net

- Net #1 (collected for Hopcroft – preserve in formalin)
- Net #2 (collected for Norcross – preserve in ethanol)
    - Frame: twin aluminum 60 cm ring net frame (sturdy)
    - Net: 60 cm x 2.6 m 505 µm mesh MARMAP style nets
    - Codend: 505 µm, 11 cm (diameter) x 21 cm (length), PVC
    - Bongo weight: ~70 lbs.

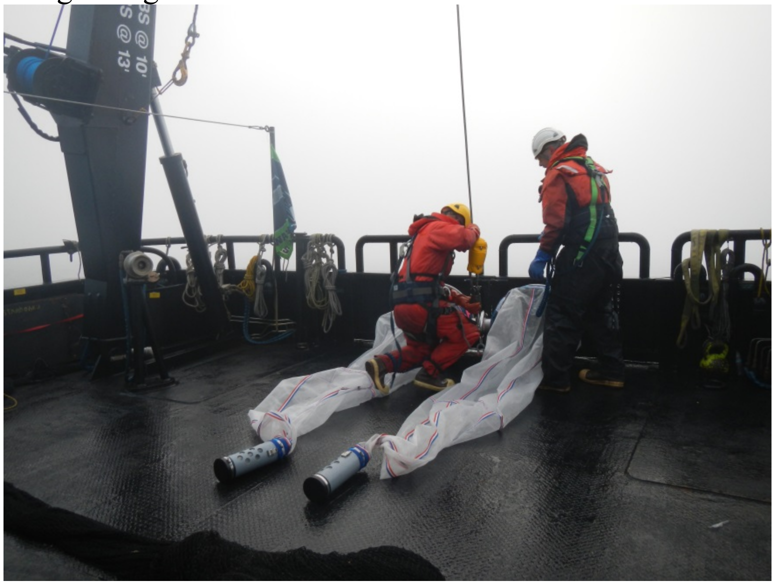


Photo credit: UAF Fisheries Oceanography Laboratory, UAF 2013

One sample of zooplankton and one of ichthyoplankton is collected at each station using a paired 60 cm bongo frame deployed with two nets of 505 µm mesh. The bongo is towed in a double oblique haul as the vessel moves ahead at 2 kts. Each net has a General Oceanic mechanical flowmeter (model 2030R Standard flowmeter) attached in the mouth to calculate volume of water filtered. As the vessel moves ahead at 2 kts, the bongo net is deployed from a single cable at a constant wire speed of 40–45 m per minute to a maximum depth of 5–10 m above the bottom, or a maximum depth of 200 m at deep stations. Once the desired depth is reached, the bongo is retrieved at a wire speed of 20 m/min. The ship's speed is adjusted to maintain a wire angle of 45º ±5º (~1–2 kts) during the entire tow. Time, maximum depth (recorded by a TDR), wire out, and flow meter count are recorded. Once on deck, catches are washed into the codend, and preserved in 5–10% buffered formalin or 95% ethanol.
As time allows, replicate samples are collected from sites at which large amounts of ichthyoplankton were collected.

Multinet

- Hydrobios MIDI Multinet, 3000 m depth rating, rigged for vertical operations with 4 –point bridle
- 5 net system, 0.25 m^2 mouth, electronic flowmeters, 150 µm mesh 2 m long standard nets
- Weighted codend holder
- Unit weight ~400 lbs., length ~3.5 m plus bridle

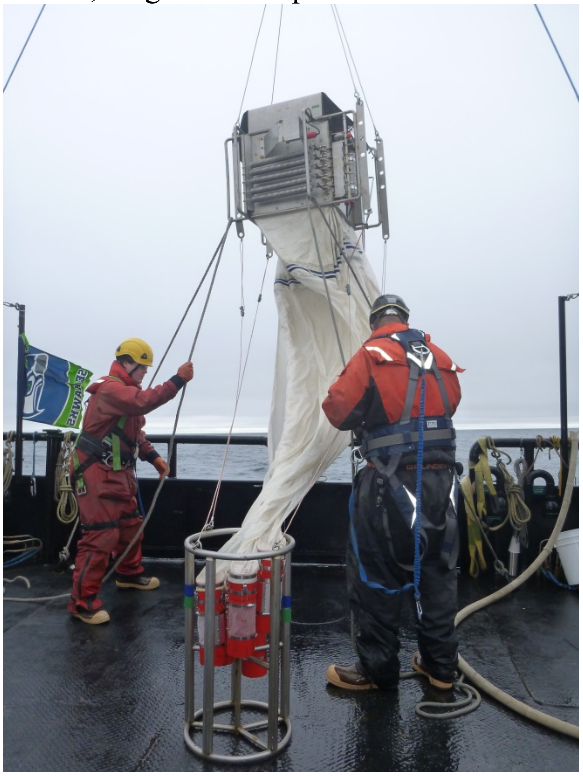


Photo credit: Bluhm/Iken, SFOS, UAF 2013

The Multinet is intended for use at stations in excess of 100 m to provide information the layering of zooplankton and ichthyoplankton. A non-closing side net may be attached to the system to provide non-quantitative samples for various analyses.

Prior to deployment, the spring-loaded nets are cocked and the safely latch engaged. The net is powered up to ensure communications to the logging computer then powered down. The net is positioned under the A-frame and lifted (with stabilizing tag lines used where needed) – generally the load-bearing lines to the codend basket can be used to adequately stabilize the unit. In coordination with the A-frame and winch operator the net is deployed, the safety latch disengaged, the unit powered up, and the system lowered at ~0.5–1 m/sec (dependent on weather) until the basket is as close to the bottom as practical. Depth is monitored by onboard depth sensors as well as observations by the ship's echo-sounder. The first net is opened at the bottom and the unit is raised at 0.5 m/sec with nets triggered electronically at pre-determined depths. Ascent continues until the net is 1–2 m clear of the water, where upon logging is stopped and the unit powered down. Tag lines are employed as needed during retrieval. To facilitate access to the nets, the Multinet is rolled onto the "bottom" side while on deck, then dragged into position where it can be secured prior to wash down. Collections from the Multinet are preserved in 5–10% buffered formalin.

Van Veen grab

- 0.1 m^2 single Van Veen grab (KC Denmark)
- Sample surface of Van Veen for grain size and stable isotope analysis
- Remaining grab sample can be used for infauna (if permits allow)

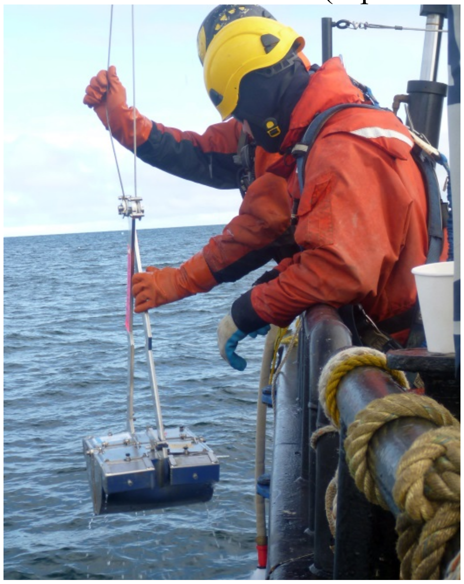


Photo credit: Bluhm/Iken, SFOS, UAF 2013

The single Van Veen 0.1 m^2 sampler is used to collect sediments for grain size. Where time permits and at depths of no more than 200 m, a Van Veen grab is deployed. All metal parts of the Van Veen grab are fabricated from stainless steel components. Before deployment, the grab is opened and the latch positioned into place to keep the grab open. Tension on the arms or wire keeps the latch in place until the grab is lifted. The grab is lowered at 30 m/min until it reaches the bottom. Upon bottom contact the wire tension releases and the grab closes. The grab is retrieved at 30 m/min and brought onto deck. Each grab is evaluated upon retrieval to the deck through the top doors to ensure that the sample is good. A grab is rejected if it looks like the surface has been disturbed, has obstructions in the jaws, and did not have good penetration. The sampler is thoroughly rinsed with seawater after sampling to remove all collected sediments.

Approximately 20 g of surface sediment sample are deposited into a labeled Whirl-Pak® bag and frozen for later grain size analysis. Additionally, samples of surface (upper 1 cm) sediment chlorophyll a, organic matter, and stable isotopes are collected from the van Veen grabs. Remaining sediments may be sieved over 1 mm^2 mesh to extract infauna to be used in stable isotope analyses.

Box Core

- 0.25 m^2 box core (Ocean Instruments, Inc.)

Photo credit: Sarah Hardy 2012

Infaunal invertebrates are collected using a 0.25 m^2 box core (Ocean Instruments, Inc.). A minimum of two good-quality box core samples are required from each station for quantitative community structure analysis and surface sediments for environmental characteristics (e.g., grain size, pigments, organic carbon), and to collect material for the stable isotope food web study. In the event that the box core becomes inoperable, the van Veen grab will be used as a back-up.

If possible, a pinger is attached at ~12 m above the core in order to get a sense of when the bottom is approaching. The box core spade must be "cocked" on deck; once attached to the winch cable under tension, the safety pins may be removed that keep the spade from closing. In shallow water (<150 m) the core is lowered at about 15 m/min to the bottom. A tension read-out on the winch cable is monitored for a sudden drop in tension indicating that the core has hit the bottom. When the tension drops, about 5 m more cable is paid out before the winch is brought to a stop. The core is pulled out slowly at about 10 m/min. Wire tension is again be monitored for a spike indicating that the core has been pulled free from the bottom. Once it is clear of the bottom, it is brought to the surface at about 30 m/min. In deeper water (>150 m) the core is lowered at about 30 m/min until it reaches about 40 m above the bottom. The winch is then stopped for a few minutes to let the box core settle and make sure wire is taut. The bridge should attempt to get as close as possible to zero speed over ground at this point. The core is then be lowered into the bottom at 15 m/min and pulled out as described above.

Upon recovery, each core is inspected through a door in the top of the box. Acceptable cores will not have over-penetrated (evidenced by mud oozing out the top) and will have relatively clear top water and an undisturbed sediment-water interface. If cores are over-penetrating, a slower touch-down speed may help to solve the problem. Once the core is deemed acceptable, the top water should be siphoned off *before* detaching the box and spade from the rest of the assembly. A piece of surgical tubing and/or a turkey baster can be used to siphon the water directly onto a sieve so that any suspended organisms can be retained. Then the box and spade can be lowered onto the rolling cart, moved out of the way, and secured while awaiting processing. A spare spade and box are available so that a second deployment can begin right away. If the ship has drifted off station during recovery, it should be repositioned at the station coordinates before a second deployment occurs.

Quantitative cores are sectioned in 0-1 cm and 1-5 cm layers. A plastic ruler is slid down the side of the box and used as a marker so that the top 1 cm can be carefully scraped off with a paint scraper. The mud is placed into a large bucket and filtered seawater added to begin breaking up the clumps before sieving. Top water filtrate should be combined with the top 1 cm layer of mud. The sectioning procedure will then be repeated for the 1-5 cm layer being placed into a second bucket. Deeper sections of the core are washed on a coarse (1 mm) sieve to obtain larger, deep-burrowing organisms. The box should then be thoroughly washed out and readied for re-deployment.

Sediment layers for quantitative analysis are elutriated and carefully washed on 500 μm mesh. Elutriating involves filling the bucket containing the sample with filtered seawater and gently stirring using a gloved hand to break up large chunks. Muddy water can then be gently poured on the sieve and the steps repeated as needed. An aquarium filter containing a cellulose filter is attached to the seawater hose for use during box core washing to avoid adding zooplankton or other debris from raw seawater into the sample. The hose should be allowed to run at low to medium pressure; a pressure spray-nozzle should NOT be used to wash the box core samples. As much of the sediment as is reasonable should be removed from the sample before washing the residue into the appropriate sized plastic jar using a wash bottle filled with filtered seawater. Jars are filled to about 80% full with filtered seawater, and then preserved with 37% buffered formaldehyde. A paper label is added to each jar indicating the sample number, collection site, date, and cruise ID. Samples are gently agitated after formaldehyde is added in order to make sure preservative fully penetrates the sample. Lids are sealed with electrical tape and stored for return to the home institute.

Non-quantitative cores (for sediment samples and stable isotopes) are subsampled for various analyses. Note that it is less crucial that these cores have completely undisturbed sediment-water interfaces. If a core of marginal quality is recovered it could be allocated for non-quantitative sampling. The surface sediment samples are scraped off using a small spoon and placed into a series of small plastic bags and/or vials. The remaining sediments, down to ~5 cm, are scraped into a bucket and sieved on a 1 mm mesh. Sieved material should be kept cool (e.g., secured on deck in a bucket with seawater added) so that live organisms can be sorted on the microscope when time permits. Organisms are frozen for stable isotope and genetic analyses.

Isaacs-Kidd midwater trawl (IKMT)

- Mouth dimensions: 1.5 m wide x 1.8 m high
- Mesh: 3 mm stretch

Recommended components for IKMT:

  - Two nets, one frame, one bridle, and two codends

Photo credit: Kate Wedemeyer 2011

Pelagic fishes are collected using an Isaacs-Kidd Midwater Trawl (IKMT) with 3 mm mesh throughout the body and codend. The IKMT mouth is 1.5 m wide by 1.8 m high, with an effective fishing area of 2.137 m^2 when fished at 45º angle. A rigid diving vane keeps the mouth of the net open during towing and exerts a depressing force to stabilize the net vertically. A Star-Oddi Centi DST time depth recorder (TDR) is attached to the top of the IKMT frame and will provide a post-haul record of fishing depth. A "lazy line" fastened at the mouth of the codend facilitates hooking up to the snatch block to lift the lower net and catch onboard. The IKMT is deployed from the stern and towed with the current at a speed of 4 kts over ground in a double oblique tow. During the haul, the towing cable is continuously released or retrieved at the rate of approximately 30 m/min; rate will be modified to maintain the target 45º wire angle. The fishing goal is to examine the water column from the surface to 10 m above the seafloor, or to 200 m at deeper sites. One photograph is taken of the entire IKMT catch, and a second photograph may be taken to indicate type & quantity of fishes. Catch-per-unit-effort (CPUE) of IKMT hauls is calculated as (# fish x 1000) / (haul distance in m x 2.137 m^2 net opening) and reported as # fish per 1000 m^3.

Aluette midwater trawl (Aluette or AMT)

- Dimensions: mouth is 8 m wide x 7 m high, trawl length is 18 m
- Mesh: 42 mm Dyneema® at the mouth; 35 mm high-density polyethylene at the intermediary; 12 mm codend liner
- Bolshline footrope weighted with chain
- Deep water floats on headrope (rated to 500 m)
- Door to tow line bridle, 5/16” Dyneema® Amsteel, 12,000 lbs. test
- Door to trawl bridles, 4 pieces of 25 m 3/8” braided Polytron
- 2 dihedral and vented steel Hendricksson doors, 36 x 16”, 70 lbs. each
- Three weight plates per door
- Time depth recorder (TDR)
- SIMRAD real-time depth sensor
- For hauls deeper than 100 m
  - 2 weights, each approximately 25 lbs. and hanging 5–7 m below the bridle
  - Bottom bridle hook up for tom weight
  - Additional floats on headrope and bullet floats on bridle
  - 2 additional weight plates for bottom of each trawl doors; n=5 total weight plates available per door

Midwater Aluette Trawl and Hendricksson Doors. Photo credit: *www.fishtrawls.com*

Pelagic fishes are collected in open water using an Aluette midwater trawl, which is a proprietary design by Innovative Net Systems (www.fishtrawls.com). This trawl is designed to sample schooling or isolated fishes and to quickly change depth in response to vessel speed variations. The Aluette can be rigged for surface fishing at 0–2 meters or can be deployed to 400–500 m. The mouth is 8 m wide and 7 m high; while fishing the mouth opening is variable and the mouth of the codend is about 0.66 m. Mesh is 42 mm Dyneema® at the mouth, 35 mm high-density polyethylene at the intermediary, and 12 mm at the codend liner. The net has a multiple Bolshline style footrope through which various weights of chains can be threaded. The codend is detachable, allowing for use of smaller or larger mesh. The 12 mm codend liner used for this survey is best for catching fishes <150 mm in length. A time depth recorder (TDR or DST-tilt) will be attached to the footrope to provide a post-haul record of maximum fishing depth. If possible, a SIMRAD depth sensor should attached above the codend for real-time depth feedback on the net. Alternatively, if possible, a pair of SIMRAD sensors may be attached to each door to monitor depth and spread.

The Aluette is deployed and retrieved from the stern while the vessel is under way. It is towed with the current at a speed of 3.5–4 kts over ground. If the net is performing poorly or dropping too slowly, then vessel speed should be reduced. During the haul, the towing cable is continuously released or retrieved at the rate of approximately 30 m/min until the target depth is reached, at which time the net depth will be adjusted using the vessel's speed. Slowing the speed makes the net drop and speeding up lifts the net. A winch is desirable for hauling doors to the surface, at which point the bridles and net will be retrieved by hand by two or more strong people. It may be fished on station from the surface to 10 m above the sea floor or to 500 m maximum depth. It is recommended that this net be fished opportunistically when the vessel depth sounder or hydroacoustics (when available) show potential for capturing a large group of pelagic fish.

Fishes, and potentially invertebrates, are removed from the codend. After removal of the catch, the net is inspected and cleaned of jellyfishes and all shackles will be tightened in preparation of the next deployment. Invertebrate specimens (e.g., jellyfishes, krill) may be removed for food web analysis prior to preservation of the remaining sample in 10% formalin. Because mouth dimensions are variable during fishing, an estimate of catch-per-unit-effort (CPUE) of Aluette hauls will be standardized to 1000 m haul, which is calculated as (# fish / haul distance in m from deployment to retrieval).

Shallow fishing: Attach towing bridle to the door at the "shallow" tow bracket. Use light weight chain in the footrope. Use 3 weight plates on each door.
Deep fishing: The Aluette will be rigged with additional floats and weights for deep fishing. The bridle is attached to the "deep" tow bracket. A 25 lb. tom weight is added to each of the bottom bridles that lead from the door to the footrope. A heavier chain may be threaded into the Bolshline footrope.

Benthic beam trawls (PSBT-A, CBT)

- Modified plumb staff beam trawl (PSBT-A)
  - 4.7 m headrope, 4.6 m footrope, 7 mm mesh in body, 4 mm mesh as codend liner
    - Trawl design modified from Gunderson & Ellis (1986) by Abookire and Rose (2005) to improve bottom trawling in uneven complex habitats. Further modified by Norcross field team to be stronger and fish in deep water.
    - Beam, 10 ft. (3.05 m) length with reinforced center
    - Additional chain below footrope with 10.2 cm steel rollers; different bridle to avoid obstructions; and include the addition of footrope rollers; an extra bridle for additional support when encountering obstacles.
    - Floats attached to beam: 9" hard floats of 1800 m working depth. One float on each side for ≤500 m depth; 2 floats per side for deeper hauls. When deployed with SIMRAD depth sensor, add 1 float at bridle swivel to offset SIMRAD weight.
    - Tip weights, 40 lbs. each. One weight per side for ≤350 m depth, 2 weights per side >355 m
    - Headrope flotation – n=11 YN 1215 deep-sea trawl floats of 4.75” diameter, 1# buoyancy, 1280 m working depth
    - Addition in 2013 of Spectra line in bridles and head and footropes

Recommended components for modified plumb staff beam traawl (PSBT-A):

- one net and Spectra bridle for every 10 stations
- one reinforced beam for every 5 stations
- 40 lb tipweights
  - use one weight on each side when fishing to 350 m
  - add one extra weight on each side at 500 m, and again at 750 m
  - suggest bringing twice as many weights as nets

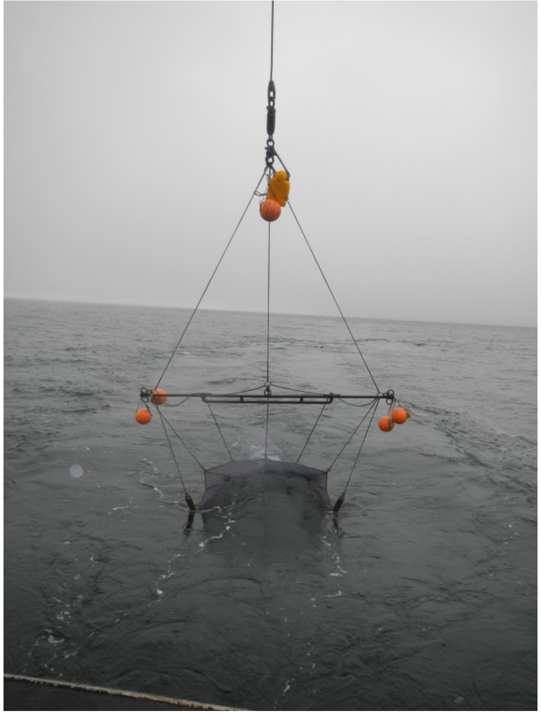


Photo credit: UAF Fisheries Oceanography Laboratory, UAF 2013

Demersal fishes and invertebrates are collected with a 10 ft. (3.05 m) modified plumb staff beam trawl (PSBT-A). Guide lines are added where needed to deploy or retrieve safely, e.g., attached at the tip weights, codend tie, and a 'lazy line' that provides a hauling point from the beam to just above the codend. A rigid 3 m pipe forward of the net holds the mouth open for an effective swath of 2.26 m, allowing for accurate quantifications of trawl effort by area swept or by duration of tow. The vertical opening of the net is approximately 1.2 m. A time-depth recorder (TDR) is attached to the net headrope.

The PSBT-A is deployed from the stern. The towing cable is deployed at 30 m/min with a ratio of 2.5–5 m of towing cable to 1 m of water depth. Haul distance is calculated between the positions of the vessel when scope is fully deployed and when the haul back begins. Haul duration is approximately 3–15 minutes depending on the substrate and the real-time display on the SIMRAD depth sensor. The PSBT-A is towed with the current while the vessel is moving at 1–1.5 kts speed over ground. Upon retrieval of the net, the catch is determined to be either qualitative or quantitative. A haul is considered qualitative, not quantitative, if the net was damaged during the tow sufficiently to lead to loss of catch or to alter the net dimensions, overfull codend occurred, high proportion of pelagic rather than demersal animals collected, or problems occurred with launching and retrieving the net. If a haul is determined to be qualitative, a second PSBT-A haul may be conducted for that station. The catch is brought on board and a digital photograph is taken with a label indicating the station name. Sediment type observed in the catch is recorded (rocks, shell hash, mud etc.). Muddy catches are dumped into 3 mm mesh sieves and sprayed with a hose to remove mud before sorting the catch. The approximate volume and sediment type of each tow is recorded and the entire catch will be sorted to remove fishes. Generally 100% of the catch is sorted for fishes. If the catch is large enough that fish or invertebrate subsampling is required, the haul is mixed to provide an unbiased, representative subsample. CPUE of PSBT-A catch is calculated as (# fish x 1000) / (haul distance in m x 2.26 m net swath) and reported as # fish per 1000 m^2.

Canadian DFO Benthic trawl (CBT)

- Net: 4.2 m headrope, 4.2 m footrope, 10 mm mesh in body, 6 mm mesh as codend liner

Photo credit: UAF Fisheries Oceanography Laboratory, UAF 2013

Comparison tows are conducted at all stations with the Canadian benthic trawl (CBT) to compare catch composition with the Norcross/UAF PSBT-A. The CBT is deployed from the stern. The towing cable is deployed at 30 m/min with a ratio of 2.5–5 m of towing cable to 1 m of water depth. Haul distance is calculated between the positions of the vessel when scope is fully deployed and when the haul back begins. Haul duration is approximately 3–15 minutes depending on the substrate. The CBT is towed with the current while the vessel is moving at approximately 2 kts speed over ground. Upon retrieval of the net, the catch is determined to be either qualitative or quantitative. A haul will be considered qualitative, not quantitative, if the net was damaged during the tow sufficiently to lead to loss of catch or to alter the net dimensions, overfull codend occurred, high proportion of pelagic rather than demersal animals collected, or problems occurred with launching and retrieving the net. If a haul is determined to be only qualitative, a second CBT haul may be conducted for that station. The catch is brought on board. A digital photograph of the catch will be taken with a label indicating the station name. Sediment type observed in the catch is recorded (rocks, shell hash, mud, etc.). Muddy catches are dumped into 3 mm mesh sieves and sprayed with a hose to remove mud before sorting the catch. The approximate volume and sediment type of each tow is recorded and the entire catch is sorted to remove fishes. Generally 100% of the catch is sorted for fishes. If the catch is large enough that fish or invertebrate subsampling is required, the haul is mixed to provide an unbiased, representative subsample.

Otter trawl (OT)

- 9.1 m Otter Trawl (OT)
    - Bridles: 27.4 m bridles
    - Doors: 61 cm x122 cm doors with steel shoes
    - Mesh: body- 38 mm stretch, codend liner- 19 mm stretch

Recommended components for OT:

- one net for every 20 stations
- one bridle for every 15 stations
- at least 2 pairs of doors
- extra bellies and net repair parts

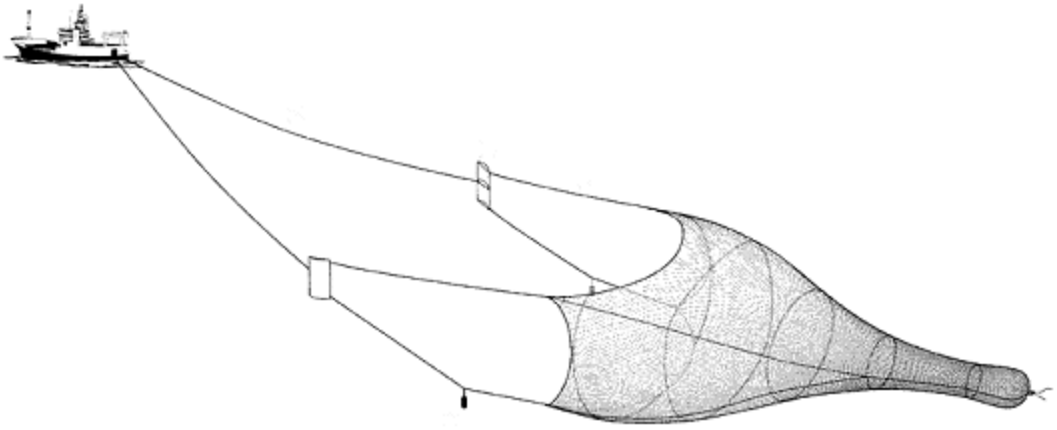


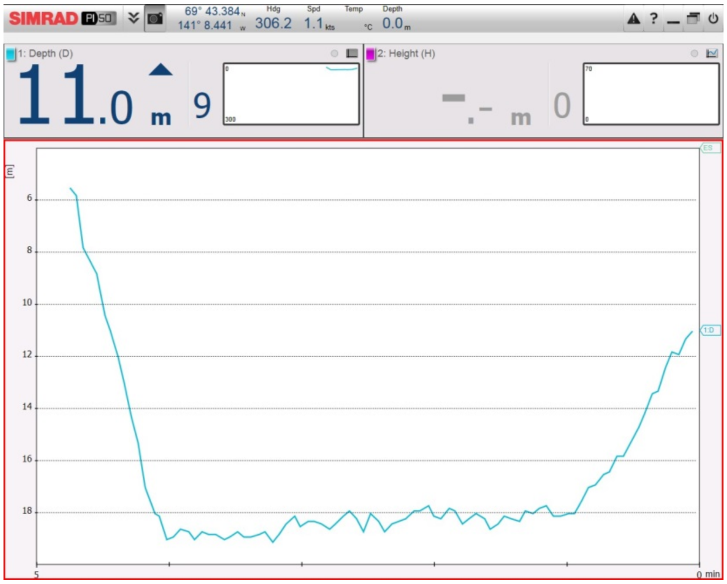
Image credit: http://njscuba.net/artifacts/ship_fishing.html

The otter trawl is deployed from the stern and towed at a speed of 2 kts on the bottom for approximately 10 minutes. As with the PSBT-A, upon retrieval of the net, the catch is determined to be either qualitative or quantitative. If the trawl is determined to be qualitative, a second tow may take place. A digital photograph of the catch is taken together with a label indicating the station name. Sediment type observed in the catch is recorded (rocks, shell hash, mud, etc.) and approximate volume of the catch is estimated. Generally, 100% of the catch is sorted for fishes. If the catch is large enough that fish or invertebrate subsampling is required, the haul is mixed to provide an unbiased, representative subsample.

SIMRAD depth and height sensors

Photo credit: Bluhm/Iken, SFOS, UAF 2013

Using SIMRAD depth and height sensors allows us to have real-time feedback on the behavior of the nets. It is a valuable tool to help determine when the bottom nets had settled on the bottom and are fishing. We also use them to determine height above the bottom for the net bridles, thereby preventing inadvertently hitting the bottom with the pelagic nets. The image below shows "good bottom contact" for an approximately three minute benthic trawl. Depending on the model, the SIMRAD attaches to the wire (depth only) or the bridle (height or depth + height combined). During gear deployment, scientists should be using the real time feedback to watch the net settle, and should be in constant contact with winch operator. We recommend using SIMRAD depth and height sensors whenever possible on all cruises.



Processing of fishes captured in all trawls

Fishes are euthanized according to approved UAF International Care and Use Committee protocol by placing the fish in a 130 mg/liter solution of tricaine methanesulfonate (MS-222) in freshwater until gill movement ceases. IACUC approval must be confirmed every year. Fish identification keys and descriptive information (e.g., Matarese et al. 1989 and Mecklenburg et al. 2002) are used for identification. Fishes are sorted into species and weighed as a group. Approximate total length (within 10 mm bin) is measured.

Whole specimens and tissue samples are collected and used to build a geo-referenced voucher collection for the University of Alaska Museum (UAM). When available, up to 12 whole specimens with associated tissues and an additional 18 tissue samples (with no voucher) are collected for each species from predetermined areas of interest. Any quantities of specimens and tissues below this target sample size are also useful additions to the research collection. For tissue collections, a small section of fin (~1 cm^2) is cut and placed in a marked vial with tissue preservative (EDTA/DMSO/NaCl). Paired fins from the right side of the fish are the preferred tissue source. A tag is attached to the fish to associate the specimen and corresponding tissue vial number. After tissue sampling, the whole fish is immersed in a 4% formaldehyde buffered solution for a period of 7 to 10 days along with a sampling label with collecting locality identifiers. At the end of the cruise, the formaldehyde is drained and the specimens shipped back to Fairbanks for preservation and accession in the museum archives and databases. All specimens and tissue samples are accessioned in the UAM fish collection. Collection information and associated media files are archived in the collection's electronic catalog. Specimens and tissue are archived in the museum's collections. Each fish collected for this request is assigned a unique identification number.

After voucher samples have been taken in the field, all remaining fishes are retained and transported to the UAF Fisheries Oceanography Laboratory in Fairbanks, AK for further processing. After at-sea length and weight processing, fishes are packaged by species into groups of 5–10 individuals in a Ziploc bag filled with seawater with a label containing station and haul information. The first 20 individuals from each 10 mm length bin for each haul are marked for precise measurement of length and weight; other fishes are returned to the UAF Fisheries Oceanography Lab and archived for potential additional analyses (e.g., otoliths, stomach contents, and stable isotope analysis). Larval fishes are preserved in 70% ethanol to preserve otoliths for daily growth increments or examining trace elements. Muscle tissue or fin clips may be collected from some species for genetic analysis.

Processing of epibenthic invertebrates captured in trawls

Epibenthic invertebrates are collected from the benthic fishing trawls. Quantitative measurements (abundance, biomass) are done from the PSBT-A and CBT at each station. After the benthic trawl has been brought on deck by the ship crew and opened, a digital photograph with a label with the station number for reference is taken. The sediment type is recorded (rocks, shell hash, mud, etc.). If the catch is too large to fully sort and subsampling is required, the haul is mixed for an unbiased, representative subsample. This is accomplished by transferring handfuls of trawl content to a series of buckets or tubs in a circular manner so that each tub receives portions from all sections of the trawl for best mixing. Subsample factor is noted. We plan to sort at least one 20 L container at each station in most cases, depending on the size of the dominant organisms. The subsample of the catch is rinsed using seawater in 2 mm sieves to remove mud. All epibenthic organisms are sorted to lowest possible taxon identifiable in the field. Individuals are counted and total wet mass per taxon determined using spring scales or digital hanging scales at the accuracy of ~1 g (for weights 1–100 g) and ~5 g accuracy for weights >100 g. Voucher specimens are preserved in 10% buffered formalin, and occasionally, some specimens may be vouchered in molecular-grade ethanol for later genetic analysis.

Should snow crab occur in the trawls, all of them are kept from each trawl (unless n>200). They are counted and weighed individually using digital hanging scales or spring scales. We record gender, shell condition, clutch fullness and color (for females only), carapace width, chela height (for males only) of all crabs in each haul, or subsample if snow crab densities are extremely high (which is unlikely in the region). We keep samples of crabs for egg counts, sperm reserves (10–20 per site) and stomach content analysis (20–30 per site, size-structured). Depending on the objective, crabs are frozen or preserved in formalin. Once the subsample has been counted and weighed, vouchers been taken, samples been taken for stable isotope studies (see below) and other purposes, the haul is discarded overboard.

Representative benthic invertebrates for food web structure are collected from the trawls (epifauna). Common invertebrate taxa covering a range of taxonomic groups and feeding guilds are collected as representatives of the benthic food web at each station. Taxa are collected in replicates of three. Epifauna taxa are sampled after the counting and weighing for quantitative assessment is finished (see above). Small portions of muscle tissue, body wall, or whole animals (if too small for dissection) are taken and stored frozen at -20 °C until further processing. Voucher samples for benthic organism isotope samples are taken. In case of the epifauna, most food web samples will correspond to vouchers taken for quantitative haul assessments.

Requests for Collaboration

The UAF Fisheries Oceanography Laboratory receives many requests for samples from our field collections. All requests must be clearly defined at least three months prior to the cruise to allow time to plan for materials to accommodate the request. Each request is considered and prioritized by the principle investigator and the project officer. Examples of common requests include:

- Andres Lopez, UAM- request to be processed in the field
    - Retain N=30 fin clips for genetic analysis of each species captured from predetermined locations
    - N=12 of these samples will be obtained from fish retained as vouchers
- Sandra Talbot, USGS- request to be processed in the field
    - Retain 1 large and 1 small Arctic Cod (*Boreogadus saida*) from 20 m and 1000 m benthic trawl at each transect for genetic analysis. Fish will be preserved in RNALater™ (to be provided to Edenfield prior to cruise) and frozen.
- Sandra Talbot, USGS- request to be processed in the UAF Fisheries Oceanography Lab
    - Retain N=30 Arctic Cod from a variety of sizes from 20 m and 1000 m at each transect. Freeze in seawater. Fish will be individually measured, weighed, and otoliths removed. The remainder of the fish carcass will be refrozen immediately for genetic analysis.
- Lara Horstmann-Dehn, UAF- request to be processed in laboratory
    - Retain N=5 frozen fish from each species captured for stable isotope analysis and UAF Fatty Acid library

Literature Cited

Abookire AA, Rose CS (2005) Modifications to a plumb staff beam trawl for sampling uneven, complex habitats. Fisheries Research 71 (2005) 247–254.

Frost KJ, Lowry LF (1983) Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort Seas, 1976–77. NOAA Technical Report NMFS SSRF-764

Gunderson DR, Ellis IE (1986) Development of a plumb staff beam trawl for sampling demersal fauna. Fish Res 4:35–41.

Logerwell E, Rand K, Weingartner TJ (2011) Oceanographic characteristics of the habitat of benthic fish and invertebrates in the Beaufort Sea. Polar Biol 34:783–1796.

Matarese AC, Kendall Jr. AW, Blood DM, and Vinter BM (1989) Laboratory guide to early life history of Northeast Pacific fishes. NOAA Technical Report NMFS 80, Seattle, WA. 652 p.

Mecklenburg CW, Mecklenburg TA, and Thorsteinson LK (2002) Fishes of Alaska. American Fisheries Society, Bethesda, MD. 1037 p.

Norcross BL, Edenfield LE (2012) Central Beaufort Sea Fish Monitoring. 2011 Annual report provided to Bureau of Ocean Energy Management.

Pickart, RS Spall MA, Moore GWK, Weingartner TJ, Woodgate RA, Aagaard K, Shimada K and others (2011) Upwelling in the Alaskan Beaufort Sea: Atmospheric forcing and local versus non-local response Progress in Oceanography 88:78–100.

Rand KM, Logerwell EA (2011) The first demersal trawl survey of benthic fish and invertebrates in the Beaufort Sea since the late 1970s. Polar Biol 34:475–488.

Thorsteinson LK, Jarvela LE, Hale DA (1991) Arctic fish habitat use investigations: nearshore studies in the Alaskan Beaufort Sea, summer 1990. Annual Report, September 1991OCS Study MMS 92-0011. Anchorage, AK. 78 pp.

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix C

Environmental Data–CTD and Substrate Tables

Author
Brenda Norcross

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Appendix C Table 1. Conductivity, temperature and density at water surface and deepest measurement in Beaufort Sea survey 2012–2014. Temperature record from temperature depth recorder (TDR) fastened to the trawl is noted where collected deeper than CTD. Station name indicates transect name and station depth. Stations are ordered west to east and inshore to offshore. Asterisk (*) indicates deepest CTD measurement is distant from the sea floor.

				Latitude	Longitude	Station Target	Surface			Deepest CTD Data				Deepest TDR Data	
Station	Gear	Date	Time	(°N)	(°W)	Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)
2012															
B2-20	CTD-13	29-Sep-12	4:00	71.08	-151.10	20	3.59	27.22	21.74	17	3.26	29.52	23.60		
B2-50	CTD-12	29-Sep-12	1:05	71.18	-151.10	50	3.94	26.68	21.28	43	0.83	32.23	25.95		
B2-100	CTD-11	28-Sep-12	14:11	71.32	-151.10	100	4.06	26.48	21.11	91	-1.08	32.71	26.42		
B2-200	CTD-10	28-Sep-12	11:21	71.34	-151.10	200	4.16	26.48	21.10	190	-0.10	34.50	27.84		
B2-350	CTD-9	27-Sep-12	19:35	71.41	-151.10	350	4.13	26.12	20.82	323	0.48	34.77	28.03		
B2-500	CTD-8	27-Sep-12	14:02	71.43	-151.10	500	4.34	26.29	20.93	474	0.54	34.83	28.07		
B2-1000	CTD-7	26-Sep-12	13:19	71.45	-151.10	1000	4.26	26.22	20.89	* 499	0.52	34.83	28.08	--	--
BX-200	CTD-15	29-Sep-12	22:13	71.29	-150.68	200	3.92	26.49	21.13	206	0.42	34.75	28.01		
BX-350	CTD-16	29-Sep-12	22:52	71.30	-150.65	350	3.94	26.49	21.13	332	0.54	34.82	28.06		
BX-500	CTD-17	30-Sep-12	8:21	71.31	-150.67	500	3.68	26.53	21.18	477	0.53	34.83	28.07		
BX-1000	CTD-18	30-Sep-12	17:00	71.42	-150.70	1000	4.09	26.39	21.04	* 491	0.57	34.85	28.09	--	--
B1-20	CTD-1	21-Sep-12	17:12	70.73	-150.10	20	3.39	27.70	22.14	17	3.13	28.78	23.03		
B1-50	CTD-2	22-Sep-12	4:25	71.15	-150.10	50	4.73	26.32	20.92	46	0.64	32.28	26.00		
B1-100	CTD-3	22-Sep-12	17:34	71.21	-150.15	100	4.59	26.44	21.04	99	-1.12	32.88	26.57		
B1-200	CTD-4	23-Sep-12	22:07	71.23	-150.09	200	4.52	26.51	21.10	192	0.07	34.54	27.86		
"	CTD-14	29-Sep-12	12:48	71.23	-150.10	200	4.07	26.54	21.15	190	0.04	34.60	27.92		
B1-350	--					350	--	--	--	--	--	--	--	--	--
B1-500	CTD-5	24-Sep-12	23:59	71.26	-150.26	500	4.49	26.37	20.99	501	0.53	34.85	28.09		
B1-1000	CTD-6	25-Sep-12	5:16	71.29	-150.09	1000	4.48	26.26	20.90	* 500	0.48	34.85	28.09	--	--
2013															
A6-20-13	CTD-1	13-Aug-13	17:14	70.43	-146.11	20	7.12	23.07	18.11	29	-1.07	30.98	25.02		
A6-37-13	CTD-2	14-Aug-13	1:20	70.55	-146.10	37	6.39	22.86	18.02	34	-1.09	30.96	25.00		
A6-50	CTD-3	14-Aug-13	8:57	70.68	-146.09	50	6.67	22.25	17.51	48	-1.25	31.22	25.22		
A6-100	CTD-4	14-Aug-13	14:59	70.82	-146.06	100	6.06	22.60	17.85	94	-1.50	32.54	26.30		
A6-200	CTD-5	14-Aug-13	23:39	70.89	-146.08	200	6.13	22.34	17.64	189	-1.28	33.87	27.37		
A6-350	CTD-6	15-Aug-13	12:01	70.93	-146.07	350	6.31	22.90	18.07	315	0.45	34.75	28.01		
A6-500	CTD-7	15-Aug-13	19:49	70.97	-146.13	500	6.76	22.89	18.01	491	0.63	34.83	28.07		
A6-750	CTD-8	16-Aug-13	8:41	70.97	-146.03	750	6.80	22.77	17.91	* 590	0.57	34.84	28.08	--	--
A6-1000	CTD-9	17-Aug-13	18:09	71.02	-146.13	1000	6.11	23.17	18.29	* 594	0.47	34.85	28.10	--	--

Appendix C Table 1. Conductivity, temperature and density, continued.

							Surface			Deepest CTD Data				Deepest TDR Data	
Station	Gear	Date	Time	Latitude (°N)	Longitude (°W)	Station Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)
2013															
A2-10-13	CTD-18	20-Aug-13	19:06	69.92	-142.23	10	3.84	25.56	20.40	8	-0.07	30.71	24.76		
"	CTD-19	20-Aug-13	19:58	69.96	-142.20	10	3.59	26.36	21.05	16	-0.29	31.11	25.09		
A2-37	CTD-15.1	20-Aug-13	10:53	70.30	-142.14	37	7.23	15.14	11.85	45	-1.14	31.89	25.76		
A2-40-13	CTD-16	20-Aug-13	12:29	70.12	-142.26	40	6.49	18.33	14.43	37	-0.85	31.68	25.58		
A2-100	CTD-14	20-Aug-13	7:01	70.49	-141.94	100	7.47	17.31	13.54	86	-1.46	32.61	26.35		
A2-200	CTD-15	20-Aug-13	7:31	70.50	-141.91	200	7.42	17.23	13.48	196	-0.74	34.27	27.68		
A2-350	CTD-13	19-Aug-13	14:31	70.54	-141.95	350	8.98	13.57	10.44	* 167	-1.26	33.65	27.20	321	0.633
A2-500	CTD-12	19-Aug-13	6:37	70.57	-141.97	500	8.95	13.87	10.68	496	0.51	34.85	28.09		
A2-750	CTD-11	18-Aug-13	22:39	70.62	-141.95	750	8.66	15.18	11.74	* 597	0.45	34.86	28.10	--	--
A2-1000	CTD-10	18-Aug-13	7:53	70.63	-142.07	1050	8.61	15.53	12.02	* 595	0.44	34.86	28.10	--	--
A1-10-13	CTD-20	21-Aug-13	1:01	69.72	-141.14	20	3.20	26.77	21.41	16	-0.63	31.00	25.02		
A1-32	CTD-21	21-Aug-13	4:01	69.83	-141.10	32	2.55	26.54	21.27	26	-0.79	31.33	25.30		
"	CTD-22	21-Aug-13	5:11	69.92	-141.09	32	3.96	24.75	19.74	38	-1.10	32.01	25.86		
A1-50	CTD-23	21-Aug-13	6:22	70.04	-141.08	50	1.95	24.74	19.85	47	-1.32	32.14	25.97		
A1-55	CTD-24.1	22-Aug-13	7:11	70.31	-141.10	55	7.10	15.68	12.29	48	-1.19	31.71	25.61		
A1-100	CTD-25	22-Aug-13	9:44	70.34	-141.12	100	6.85	14.98	11.76	103	-1.51	32.66	26.39		
A1-200	--					200	--	--	--	--	--	--	--	186	0.772
A1-350	CTD-27	23-Aug-13	6:08	70.41	-141.05	350	6.85	14.96	11.74	327	0.62	34.82	28.06		
A1-500	CTD-26	23-Aug-13	3:33	70.47	-141.02	500	6.92	14.81	11.62	489	0.43	34.86	28.10		
A1-750	CTD-28	23-Aug-13	11:38	70.53	-141.04	750	6.79	14.99	11.77	595	0.36	34.86	28.11		
A1-1000	CTD-29	23-Aug-13	19:01	70.60	-141.04	1000	6.72	14.78	11.62	* 594	0.42	34.86	28.10	--	-0.011
TBS-29	CTD-40	26-Aug-13	13:47	69.74	-140.35	29	5.54	17.80	14.10	24	-0.97	30.43	24.57		
TBS-35	CTD-39	26-Aug-13	11:57	69.84	-140.39	35	5.72	16.10	12.74	28	-0.71	30.98	25.01		
TBS-50	CTD-36.1	26-Aug-13	7:00	70.16	-140.40	50	5.59	14.64	11.59	42	-1.18	31.72	25.63		
TBS-51	CTD-38	26-Aug-13	10:59	69.96	-140.40	51	5.21	15.01	11.91	41	-1.23	31.91	25.78		
TBS-52	CTD-36	26-Aug-13	6:26	70.18	-140.36	52	5.72	14.59	11.54	45	-1.20	31.70	25.61		
TBS-56	CTD-37	26-Aug-13	10:10	70.05	-140.41	56	5.20	15.07	11.95	50	-1.29	32.10	25.93		
TBS-100	CTD-35	26-Aug-13	1:14	70.24	-140.26	100	5.83	14.53	11.49	98	-1.44	32.51	26.28		
TBS-200	CTD-34	25-Aug-13	18:39	70.27	-140.30	200	5.63	14.51	11.49	190	-0.86	34.14	27.58		

Appendix C Table 1. Conductivity, temperature and density, continued.

				Latitude	Longitude	Station Depth	Surface			Deepest CTD Data				Deepest TDR Data	
Station	Gear	Date	Time	(°N)	(°W)	(m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)
2013															
TBS-350	CTD-33	25-Aug-13	12:47	70.34	-140.39	350	5.80	14.28	11.29	336	0.59	34.82	28.06		
TBS-500	CTD-32	25-Aug-13	4:14	70.42	-140.36	500	6.21	14.09	11.11	485	0.47	34.85	28.09		
TBS-750	CTD-31	24-Aug-13	19:44	70.56	-140.45	750	6.45	14.51	11.42	* 594	0.42	34.86	28.10	741	0.151
TBS-1000	CTD-30	24-Aug-13	7:17	70.60	-140.37	1000	6.23	14.22	11.21	596	0.45	34.85	28.10		
EXP-1000	--					1000	--	--	--	--	--	--	--	--	--
MAC-50	CTD-45	27-Aug-13	14:08	69.46	-137.66	50	7.17	11.96	9.35	42	-1.21	31.51	25.45		
MAC-57	CTD-44	27-Aug-13	13:17	69.52	-137.78	57	6.96	12.58	9.86	49	-1.26	31.94	25.80		
MAC-100	CTD-43	27-Aug-13	9:12	69.63	-137.97	100	6.91	12.80	10.04	94	-1.40	32.46	26.23		
MAC-161	CTD-42	27-Aug-13	3:40	69.74	-138.17	161	6.50	13.07	10.28	150	-1.25	33.67	27.22		
MAC-200	CTD-41	26-Aug-13	19:46	69.83	-138.40	200	6.88	12.65	9.92	186	-0.91	34.05	27.51		
MAC-500	CTD-60.1	31-Aug-13	9:47	70.29	-139.13	500	5.94	15.26	12.06	* 51	-1.17	31.19	25.19	482	0.433
MAC-750	CTD-59	31-Aug-13	2:43	70.44	-139.52	750	6.40	14.45	11.38	* 596	0.41	34.85	28.10	--	--
"	CTD-60	31-Aug-13	4:43	70.30	-139.26	750	5.91	15.99	12.63	* 493	0.46	34.85	28.09	--	--
MAC-1000	CTD-58	30-Aug-13	16:32	70.59	-139.78	1000	5.99	14.61	11.54	* 594	0.45	34.85	28.10	--	--
"	CTD-58.1	31-Aug-13	1:40	70.56	-139.64	1000	5.74	15.31	12.11	51	-1.25	32.00	25.85		
GRY-20	CTD-46	27-Aug-13	19:20	69.70	-136.67	20	6.86	13.43	10.53	14	-0.45	29.24	23.59		
GRY-30	CTD-47	27-Aug-13	22:44	69.79	-136.96	30	7.43	12.12	9.46	27	-1.23	30.62	24.72		
GRY-50	CTD-48	28-Aug-13	0:38	69.88	-137.22	50	6.91	13.36	10.48	45	-1.20	31.74	25.64		
GRY-68	CTD-49	28-Aug-13	4:29	69.95	-137.48	68	6.81	13.95	10.95	* 40	-1.16	31.62	25.54		
"	CTD-49.1	28-Aug-13	4:45	69.95	-137.50	68	6.78	14.02	11.01	61	-1.30	32.13	25.96		
GRY-80	CTD-50	28-Aug-13	6:21	70.02	-137.66	80	6.74	14.47	11.37	74	-1.36	32.32	26.11		
GRY-100	CTD-51	28-Aug-13	7:12	70.09	-137.77	100	6.33	14.73	11.61	90	-1.47	32.69	26.42		
GRY-200	CTD-53	29-Aug-13	4:49	70.14	-137.98	200	5.90	14.66	11.58	189	-0.31	34.45	27.81		
GRY-350	CTD-52	29-Aug-13	2:45	70.25	-138.36	350	5.80	14.48	11.44	326	0.57	34.81	28.05		
GRY-500	CTD-54	29-Aug-13	8:09	70.30	-138.49	500	5.79	14.69	11.62	488	0.48	34.85	28.09		
"	CTD-54.1	29-Aug-13	14:30	70.29	-138.53	500	6.28	14.39	11.34	* 22	-1.30	29.78	24.05		
GRY-598	CTD-55	29-Aug-13	15:19	70.36	-138.74	598	6.25	14.22	11.21	567	0.44	34.85	28.10		
GRY-750	CTD-56	29-Aug-13	17:33	70.44	-138.95	750	5.91	14.66	11.58	* 554	0.46	34.85	28.09	723	0.221
GRY-1000	CTD-57	30-Aug-13	3:08	70.52	-139.23	1000	5.81	15.28	12.08	* 596	0.42	34.85	28.10	--	--

Appendix C Table 1. Conductivity, temperature and density, continued.

							Surface			Deepest CTD Data				Deepest TDR Data	
Station	Gear	Date	Time	Latitude (°N)	Longitude (°W)	Station Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)
2014															
A6-20-14	CTD-1	19-Aug-14	19:37	70.27	-146.09	20	0.87	31.44	25.31	21	-0.49	31.68	25.57		
A6-37-14	CTD-2	19-Aug-14	21:40	70.45	-146.10	37	1.35	30.74	24.72	34	-1.40	32.09	25.93		
A6-50	CTD-3	20-Aug-14	1:19	70.65	-146.09	50	1.72	30.72	24.68	47	-1.39	32.20	26.02		
A6-100	CTD-4	20-Aug-14	5:06	70.82	-146.03	100	3.49	29.66	23.69	96	-1.46	32.65	26.39		
A6-200	CTD-50	31-Aug-14	19:32	70.89	-146.09	200	4.91	27.00	21.45	188	-1.39	33.22	26.85		
A6-350	CTD-51	31-Aug-14	22:02	70.92	-145.99	350	5.10	26.83	21.29	* 276	0.43	34.73	27.99	--	--
A6-500	CTD-49	31-Aug-14	16:31	70.94	-146.04	500	4.92	27.03	21.48	525	0.42	34.85	28.10		
A6-750	CTD-48	31-Aug-14	13:11	70.99	-146.09	750	4.80	27.27	21.67	754	0.09	34.87	28.13		
A6-1000	CTD-47	31-Aug-14	4:17	71.03	-146.13	1000	5.11	27.06	21.48	1207	-0.23	34.90	28.17		
A6-1500	--					1500	--	--	--	--	--	--	--	--	--
A5-20	CTD-8	21-Aug-14	0:16	70.12	-145.11	20	2.96	31.32	25.07	18	-0.47	31.79	25.65		
A5-35	CTD-7	20-Aug-14	21:13	70.33	-145.11	35	1.51	30.57	24.58	30	-1.27	31.92	25.79		
A5-50	CTD-6	20-Aug-14	18:58	70.54	-145.08	50	2.35	29.86	23.95	46	-1.43	32.42	26.20		
A5-100	CTD-5	20-Aug-14	15:41	70.72	-145.09	100	1.37	30.04	24.15	98	-1.44	32.65	26.39		
A5-200	CTD-42	30-Aug-14	10:55	70.76	-145.10	200	5.80	26.24	20.76	199	-0.94	33.86	27.36		
A5-350	CTD-43	30-Aug-14	13:29	70.84	-145.05	350	6.05	25.90	20.46	343	0.62	34.82	28.06		
A5-500	CTD-44	30-Aug-14	16:50	70.94	-145.11	500	6.02	25.78	20.37	473	0.51	34.85	28.09		
"	CTD-44.1	30-Aug-14	17:43	70.94	-145.10	500	6.00	25.54	20.18	* 3	6.03	26.03	20.57		
A5-750	CTD-45	30-Aug-14	19:09	70.96	-145.07	750	6.05	25.88	20.45	726	0.09	34.87	28.13		
A5-1000	CTD-46	30-Aug-14	23:45	70.99	-145.02	1000	6.13	25.31	19.99	987	-0.08	34.88	28.15		
A4-20	CTD-9	21-Aug-14	4:33	70.20	-144.10	20	1.97	31.23	25.07	18	-0.78	31.92	25.78		
A4-35	CTD-10	21-Aug-14	7:15	70.29	-144.08	35	0.60	31.14	25.09	31	-0.81	31.94	25.79		
A4-50	CTD-11	21-Aug-14	10:27	70.45	-144.09	50	1.91	30.09	24.16	45	-0.90	31.91	25.77		
A4-100	CTD-12	21-Aug-14	14:26	70.58	-144.14	100	1.61	30.24	24.30	95	-1.42	32.61	26.35		
A2-10-13	--					10	--	--	--	--	--	--	--	13	1.34
A2-20	CTD-22	24-Aug-14	11:53	69.98	-142.21	20	2.58	30.99	24.84	19	-0.07	31.60	25.49		
A2-30	CTD-21	24-Aug-14	10:08	70.02	-142.18	30	2.21	30.29	24.30	26	-0.33	31.61	25.50		
A2-40-13	CTD-20	24-Aug-14	7:35	70.13	-142.30	40	3.26	30.15	24.11	37	-0.84	31.81	25.68		
A2-50	CTD-19	24-Aug-14	0:32	70.30	-142.14	50	2.78	30.28	24.25	48	-1.31	32.32	26.11		

Appendix C Table 1. Conductivity, temperature and density, continued.

							Surface			Deepest CTD Data				Deepest TDR Data	
Station	Gear	Date	Time	Latitude (°N)	Longitude (°W)	Station Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)	Salinity	Sigma-t	Depth (m)	Temp (C°)
2014															
A2-50	CTD-19.1	24-Aug-14	4:33	70.30	-142.14	50	2.34	30.43	24.40	49	-1.28	32.28	26.08		
"	CTD-19.1	24-Aug-14	4:33	70.30	-142.14	50	2.34	30.43	24.40	49	-1.28	32.28	26.08		
"	CTD-19.2	24-Aug-14	5:44	70.29	-142.14	50	2.59	30.37	24.33	47	-1.28	32.27	26.07		
"	CTD-19.3	24-Aug-14	5:54	70.29	-142.14	50	3.07	30.27	24.22	48	-1.29	32.28	26.08		
A2-100	CTD-18	23-Aug-14	20:05	70.48	-141.92	100	2.91	29.86	23.90	98	-1.44	32.74	26.46		
A2-200	CTD-17	23-Aug-14	13:26	70.50	-141.90	200	3.37	29.58	23.64	194	-0.18	34.45	27.81		
A2-350	CTD-16	23-Aug-14	9:04	70.54	-142.08	350	3.72	29.53	23.57	336	0.62	34.81	28.05		
A2-500	CTD-15	23-Aug-14	0:39	70.56	-142.03	500	4.64	28.38	22.57	474	0.60	34.83	28.07		
A2-750	CTD-14	22-Aug-14	18:31	70.62	-141.95	750	5.04	27.93	22.17	723	0.19	34.86	28.12		
A2-1000	CTD-13	22-Aug-14	5:32	70.63	-142.05	1000	5.89	26.88	21.25	984	-0.02	34.88	28.14		
A1-10-13	--					10	--	--	--		--	--	--	--	--
A1-20	CTD-24	24-Aug-14	18:26	69.72	-141.14	20	1.86	32.06	25.74	19	0.33	32.27	26.01		
A1-32	CTD-25	24-Aug-14	21:36	69.83	-141.10	32	3.50	31.53	25.19	28	0.19	32.20	25.96		
A1-43	CTD-26	24-Aug-14	22:46	69.94	-141.09	43	1.59	30.83	24.78	39	-1.17	32.18	26.00		
A1-50	CTD-27	24-Aug-14	23:48	70.03	-141.05	50	2.60	30.78	24.67	45	-1.24	32.22	26.03		
A1-52	CTD-28	25-Aug-14	3:44	70.20	-141.07	52	2.23	30.68	24.61	45	-1.22	32.26	26.07		
A1-100	CTD-29	25-Aug-14	5:51	70.33	-141.05	100	5.96	28.13	22.24	88	-1.35	32.52	26.27		
A1-200	CTD-30	25-Aug-14	10:48	70.37	-141.19	200	4.39	28.71	22.86	189	-1.06	33.72	27.24		
A1-350	CTD-31	25-Aug-14	18:50	70.41	-141.04	350	4.65	28.89	22.98	336	0.61	34.80	28.04		
A1-500	CTD-32	26-Aug-14	2:37	70.47	-141.02	500	6.49	26.73	21.07	530	0.42	34.85	28.10		
A1-750	CTD-33	26-Aug-14	11:47	70.53	-141.04	750	5.95	27.28	21.57	720	0.20	34.86	28.12		
A1-1000	CTD-34	26-Aug-14	18:39	70.61	-141.03	1000	6.93	25.44	20.00	984	-0.12	34.89	28.16		
TBS-50	CTD-41	28-Aug-14	17:59	70.15	-140.37	50	5.29	29.48	23.38	45	-1.32	32.37	26.15		
TBS-100	CTD-40	28-Aug-14	15:22	70.25	-140.30	100	6.51	25.80	20.33	98	-1.41	32.48	26.24		
TBS-200	CTD-39	28-Aug-14	12:00	70.27	-140.30	200	5.81	27.23	21.54	190	-1.23	33.48	27.06		
TBS-350	CTD-38	28-Aug-14	7:59	70.34	-140.39	350	5.41	28.62	22.69	335	0.62	34.81	28.05		
TBS-500	CTD-37	28-Aug-14	3:22	70.41	-140.35	500	6.98	26.32	20.69	479	0.50	34.84	28.09		
TBS-750	CTD-36	28-Aug-14	0:50	70.56	-140.45	750	8.59	22.14	17.21	735	0.12	34.87	28.13		
TBS-1000	CTD-35	27-Aug-14	14:19	70.60	-140.40	1000	8.30	22.13	17.23	975	-0.10	34.88	28.15		

Appendix C Table 2. Sediment characteristics of the sea floor in the Beaufort Sea 2012–2014. Station name indicates transect name and station depth. Stations are ordered west to east and inshore to offshore. Sediment collections by box core in 2013 are assigned as TB Station names although they were collected by BREA. The BREA station DWT-1200 is included because of its great depth and location in the vicinity of TB samples, although it is not on a TB transect.

					Sediment Characteristics									
Station	Alternate Station	Latitude (°N)	Longitude (°W)	Gear	Phi Description	Chl-a (µg/g sed dry wt)	Phaeo-pigment	Porosity (% water by wt)	%Gravel	%Sand	%Mud (silt + clay)	%Silt	%Clay	Mean Phi
2012														
B2-50		71.17	-151.10	Box Core A	Fine silt	4.46	6.48	47.8	0.0	15.7	84.3	38.9	44.1	6.89
"		71.17	-151.10	Box Core B	Medium silt	3.12	5.65	44.3	0.2	19.5	80.3	39.5	39.8	6.60
B1-20		70.74	-150.08	Van Veen	Coarse silt	2.42	1.97	30.6	0.2	50.0	49.8	22.9	26.4	5.03
B1-50		71.15	-150.10	Box Core	Very coarse silt	3.07	6.32	37.8	3.5	42.8	53.7	23.0	29.8	4.94
B1-200		71.23	-150.08	Box Core A	Very coarse silt	3.45	6.41	42.8	11.1	34.3	54.6	23.0	29.0	4.57
"		71.23	-150.08	Box Core B	Very find sand	6.13	7.56	42.5	13.2	36.7	50.1	20.1	25.5	4.00
"		71.23	-150.08	Box Core C	Very coarse silt	5.71	10.05	41.4	9.8	41.3	48.9	20.9	27.1	4.83
B1-350		71.25	-150.10	Box Core	Fine silt	27.84	28.83	52.9	0.0	10.9	89.1	39.2	44.4	7.13
B1-500		71.25	-150.08	Box Core A	Fine silt	10.33	17.89	60.5	0.0	10.7	89.3	35.8	45.9	7.23
B1-500		71.25	-150.08	Box Core B	Fine silt	12.79	17.33	59.2	0.0	9.3	90.7	37.6	51.9	7.37
B1-1000		71.28	-150.08	Box Core	Medium silt	13.73	22.42	61.5	0.0	17.0	83.0	34.2	47.5	6.97
2013														
A6-20-13		70.43	-146.11	Van Veen	Fine Sand	6.55	6.54	22.8	38.6	40.3	21.1	7.9	13.1	2.22
A6-37-13		70.55	-146.10	Van Veen	Very Fine Sand	9.54	8.81	32.4	29.5	40.6	29.9	11.1	18.5	3.03
A6-50		70.68	-146.09	Van Veen	Very Fine Sand	3.64	3.73	32.4	37.8	32.4	29.7	10.6	19.1	3.03
A6-100		70.82	-146.06	Van Veen	Coarse Silt	4.81	9.84	50.1	0.0	47.2	52.8	20.5	31.5	5.20
A6-200		70.89	-146.08	Van Veen	Medium Silt	5.91	13.54	55.9	0.0	22.8	77.2	30.5	46.5	6.65
A2-10-13		69.92	-142.23	Van Veen	Fine Sand	1.47	2.63	19.8	3.8	93.2	3.0	1.7	1.1	2.14
A2-40-13		70.12	-142.26	Van Veen	Coarse Silt	4.88	9.31	40.1	0.5	45.0	54.5	23.4	31.1	5.26
A2-100		70.49	-141.94	Van Veen	Medium Sand	1.14	3.38	21.0	0.1	92.3	7.5	3.3	4.2	1.80
A2-200		70.50	-141.90	Van Veen	Fine Silt	0.36	0.87	30.3	0.0	4.5	95.5	47.2	37.6	7.13
A2-1000				TRAWL	Fine Sand	--	--	84.0	0.0	93.9	6.1	3.5	2.6	2.25
A1-20		69.72	-141.14	Van Veen	Fine Sand	2.50	2.38	24.6	18.7	49.8	31.5	17.7	13.0	2.83
A1-50		70.04	-141.08	Van Veen	Medium Silt	6.43	9.43	39.6	7.1	17.3	75.7	21.9	53.8	6.48
A1-75	A1-BREA-02	70.33	-141.12	Box Core	--	3.21	6.88	--	--	--	--	--	--	--
A1-100		70.34	-141.12	Van Veen	Very Coarse Silt	1.78	3.57	33.5	6.0	41.4	52.6	25.9	26.4	4.79
A1-350	A1-BREA-04	70.40	-141.05	Box Core	--	4.47	10.07	--	--	--	--	--	--	--
A1-750	A1-BREA-06	70.53	-141.02	Box Core	--	1.85	6.58	--	--	--	--	--	--	--
TBS-50		70.16	-140.40	Van Veen	Fine Sand	7.07	8.82	24.2	46.5	26.2	27.2	8.0	18.3	2.51
TBS-100		70.24	-140.26	Van Veen	Medium Silt	4.06	8.45	55.1	0.1	32.4	67.5	20.5	46.6	6.36
TBS-200		70.27	-140.30	Van Veen	Coarse Silt	3.26	10.18	49.5	2.5	42.0	55.5	16.2	38.6	5.31
TBS-350	TBS-BREA-04	70.33	-140.37	Box Core	--	3.65	10.05	--	--	--	--	--	--	--
MAC-50		69.46	-137.66	Van Veen	Medium Silt	7.09	9.63	52.7	0.0	32.2	67.8	16.3	50.6	6.70
MAC-100		69.63	-137.97	Van Veen	Medium Silt	8.49	12.70	52.6	0.0	25.8	74.2	24.1	49.3	6.74
MAC-200		69.83	-138.40	Van Veen	Coarse Silt	6.60	14.95	58.1	0.0	41.7	58.3	14.6	43.5	5.86

Appendix C Table 2. Sediment characteristics of the sea floor, continued.

					Sediment Characteristics									
Station	Alternate Station	Latitude (°N)	Longitude (°W)	Gear	Phi Description	Chl-a (µg/g sed dry wt)	Phaeo-pigment	Porosity (% water by wt)	%Gravel	%Sand	%Mud (silt + clay)	%Silt	%Clay	Mean Phi
2013														
GRY-20		69.70	-136.67	Van Veen	Fine Silt	2.73	2.99	40.9	0.0	0.3	99.7	34.4	64.0	7.89
GRY-50		69.88	-137.22	Van Veen	Fine Silt	3.61	5.03	56.6	0.0	13.3	86.7	20.7	64.5	7.46
GRY-75	GRY-BREA-02	70.00	-137.67	Box Core	--	5.56	10.14	--	--	--	--	--	--	--
GRY-200		70.14	-137.98	Van Veen	Medium Silt	4.34	9.38	48.8	0.3	35.5	64.1	18.1	45.9	6.05
GRY-350	GRY-BREA-04	70.25	-138.37	Box Core	--	4.00	9.01	--	--	--	--	--	--	--
GRY-750	GRY-BREA-06	70.43	-138.98	Box Core	--	1.61	5.21	--	--	--	--	--	--	--
DWT-1200	DWT-BREA-01	70.58	-138.32	Box Core	--	1.74	6.67	--	--	--	--	--	--	--
2014														
A6-20-14		70.27	-146.09	Van Veen	Fine Silt	5.45	2.58	30.2	0.1	7.7	92.2	47.4	37.9	7.00
A6-37-14		70.45	-146.10	Van Veen	Coarse Silt	5.87	6.15	41.8	0.5	35.7	63.8	26.6	36.8	5.84
A6-50		70.65	-146.09	Van Veen	Coarse Silt	6.71	10.32	38.3	13.7	29.3	57.0	20.8	35.8	5.17
A6-100		70.82	-146.03	Van Veen	Medium Silt	6.59	11.27	58.1	0.0	33.0	67.0	25.5	40.7	6.37
A5-20		70.12	-145.11	Van Veen	Coarse Silt	9.23	8.81	33.8	0.0	44.1	55.9	33.8	21.4	5.28
A5-35		70.33	-145.11	Van Veen	Fine Sand	5.57	5.88	27.4	11.1	64.4	24.5	8.6	15.6	2.94
A5-50		70.55	-145.08	Van Veen	Very Fine Sand	3.22	4.08	34.5	14.3	45.6	40.1	14.0	25.7	3.55
A5-100		70.71	-145.07	Van Veen	Coarse Sand	1.35	2.80	23.0	57.6	24.9	17.5	6.2	11.2	0.79
A5-200		70.55	-145.09	Van Veen	Fine Silt	4.64	13.49	54.4	0.0	14.0	86.0	32.7	52.2	7.22
A5-350		70.84	-145.06	Van Veen	Fine Silt	3.04	8.83	61.5	0.0	4.8	95.2	33.9	60.1	7.68
A4-20		70.20	-144.10	Van Veen	Medium Sand	2.90	1.48	20.3	0.6	98.0	1.4	--	--	1.89
A4-35		70.29	-144.07	Van Veen	Very Coarse Silt	2.80	1.79	34.3	4.2	44.5	51.3	19.8	30.9	4.82
A4-50		70.46	-144.08	Van Veen	Fine Sand	2.86	4.85	30.2	32.9	35.8	31.3	10.9	20.2	2.98
A4-100		70.58	-144.15	Van Veen	Coarse Silt	7.00	13.13	53.0	1.5	41.8	56.7	19.3	36.4	5.48
A2-20		69.98	-142.22	Van Veen	Fine Sand	7.11	5.81	25.5	26.3	48.4	25.3	14.0	11.0	2.56
A2-50		70.30	-142.14	Van Veen	Very Coarse Silt	8.24	12.35	48.1	3.6	47.9	48.5	16.5	31.5	4.86
A2-100		70.48	-141.93	Van Veen	Very Coarse Silt	2.80	5.23	32.5	1.6	61.0	37.4	12.3	24.6	4.13
A2-200		70.50	-141.90	Van Veen	Fine Silt	0.88		37.7	0.2	6.0	93.8	40.8	52.4	7.46
A2-350		70.54	-142.08	Van Veen	Medium Silt	7.58	15.37	64.3	0.0	24.9	75.1	26.3	48.1	6.87
A1-20		69.72	-141.14	Van Veen	Medium Sand	75.90	17.98	24.3	40.6	36.6	22.8	12.8	9.8	1.69
A1-50		70.03	-141.03	Van Veen	Fine Silt	7.48	8.46	35.7	0.3	14.4	85.4	27.9	57.2	7.27
A1-100		70.33	-141.06	Van Veen	Medium Silt	3.26	5.23	40.7	0.2	20.7	79.1	34.6	44.0	6.70
A1-200		70.37	-141.15	Van Veen	Fine Silt	3.99	9.65	54.2	0.0	15.7	84.3	29.3	54.2	7.17
A1-350		70.41	-141.03	Van Veen	Fine Silt	5.79	10.43	57.8	0.0	4.2	95.8	30.4	65.5	7.82
TBS-50		70.15	-140.37	Van Veen	Fine Sand	5.93	10.48	28.7	45.8	26.6	27.6	7.6	19.7	2.46
TBS-100		70.25	-140.30	Van Veen	Medium Sand	2.97	6.26	28.1	61.2	9.1	29.6	11.2	18.4	1.90
TBS-200		70.27	-140.31	Van Veen	Fine Silt	4.50	12.14	65.7	0.9	9.6	89.5	27.4	62.1	7.53
TBS-350		70.34	-140.39	Van Veen	Fine Silt	2.60	7.94	62.6	0.0	15.3	84.7	26.6	58.1	7.25

Appendix C Table 2. Sediment characteristics of the sea floor, continued.

		Sediment Characteristics							
Station	Alternate Station	Sorting	Kurtosis	Skewness	δ_{15}N (‰)	δ_{13}C (‰)	C/N	TOC (mg/g dry sed)	mg lipid/ g sediment
2012									
B2-50		2.32	0.69	Very Coarse Skewed	4.75	-25.02	9.45	20.341	0.121
"		2.49	0.71	Coarse Skewed	4.27	-25.17	9.83	8.202	0.197
B1-20		2.73	0.56	Very Fine Skewed	3.39	-26.31	20.06	4.059	0.112
B1-50		3.42	0.67	Symmetrical	7.14	-25.00	9.58	8.630	0.122
B1-200		3.81	0.70	Symmetrical	6.36	-23.23	9.37	8.217	0.091
"		3.99	0.64	Symmetrical	5.99	-24.41	9.14	12.178	0.144
"		3.41	0.80	Fine Skewed	4.38	-24.36	11.15	6.528	0.099
B1-350		2.31	0.82	Very Coarse Skewed	4.88	-24.78	9.56	19.206	0.164
B1-500		2.28	0.79	Very Coarse Skewed	5.37	-24.56	9.05	24.120	0.257
B1-500		2.17	0.79	Very Coarse Skewed	5.28	-24.68	10.48	28.282	0.207
B1-1000		2.43	0.72	Very Coarse Skewed	5.56	-24.35	8.92	20.167	0.166
2013									
A6-20-13		3.59	1.02	Very Fine Skewed	5.69	-21.57	10.78	7.59	--
A6-37-13		4.03	0.66	Very Fine Skewed	4.62	-21.50	9.45	10.30	--
A6-50		4.07	0.65	Very Fine Skewed	2.74	-15.26	12.50	9.47	--
A6-100		2.95	0.61	Fine Skewed	6.59	-24.58	8.45	7.18	--
A6-200		2.74	0.71	Very Coarse Skewed	3.96	-24.53	8.16	13.05	--
A2-10-13		0.95	1.38	Coarse Skewed	5.14	-22.63	7.34	1.37	--
A2-40-13		2.98	0.59	Fine Skewed	9.09	-25.39	9.53	11.93	--
A2-100		1.28	3.13	Very Fine Skewed	8.00	-24.74	8.35	6.60	--
A2-200		1.97	0.72	Coarse Skewed	3.80	-25.56	10.07	11.70	--
A2-1000		1.11	1.29	Very Fine Skewed	--	--	--	--	--
A1-20		3.71	0.84	Fine Skewed	3.12	-25.10	9.10	4.20	--
A1-50		3.51	0.91	Very Coarse Skewed	2.12	-25.22	8.42	10.94	--
A1-75	A1-BREA-02	--	--	--	4.82	-23.94	8.98	15.82	--
A1-100		3.50	0.71	Symmetrical	6.47	-21.69	9.49	9.83	--
A1-350	A1-BREA-04	--	--	--	9.25	-24.20	6.95	15.79	--
A1-750	A1-BREA-06	--	--	--	8.98	-24.28	7.61	13.43	--
TBS-50		4.06	0.74	Very Fine Skewed	5.93	--	--	--	--
TBS-100		2.96	0.60	Very Coarse Skewed	9.08	-24.90	7.73	11.22	--
TBS-200		3.32	0.58	Symmetrical	4.66	-23.91	8.28	8.76	--
TBS-350	TBS-BREA-04	--	--	--	4.82	-25.01	8.17	15.60	--
MAC-50		2.80	0.55	Very Coarse Skewed	6.16	-26.10	8.24	14.23	--
MAC-100		2.72	0.61	Very Coarse Skewed	1.26	-25.88	8.68	13.28	--
MAC-200		3.04	0.55	Coarse Skewed	6.34	-25.39	7.86	13.43	--

Appendix C Table 2. Sediment characteristics of the sea floor, continued.

		Sediment Characteristics							
Station	Alternate Station	Sorting	Kurtosis	Skewness	δ_{15}N (‰)	δ_{13}C (‰)	C/N	TOC (mg/g dry sed)	mg lipid/ g sediment
2013									
GRY-20		1.73	0.91	Very Coarse Skewed	4.96	-26.01	10.60	15.64	--
GRY-50		2.36	0.99	Very Coarse Skewed	5.55	-25.99	8.52	14.81	--
GRY-75	GRY-BREA-02	--	--	--	3.30	-26.32	8.32	15.82	--
GRY-200		3.16	0.55	Very Coarse Skewed	5.24	-25.69	8.37	10.58	--
GRY-350	GRY-BREA-04	--	--	--	9.22	-24.89	6.97	14.20	--
GRY-750	GRY-BREA-06	--	--	--	5.71	-24.65	7.14	14.80	--
DWT-1200	DWT-BREA-01	--	--	--	7.14	-24.52	6.88	15.54	--
2014									
A6-20-14		2.15	0.78	Coarse Skewed	3.74	-25.39	9.75	15.62	--
A6-37-14		2.90	0.57	Symmetrical	4.73	-25.14	8.73	11.90	--
A6-50		3.66	0.72	Coarse Skewed	5.37	-25.32	8.14	20.91	--
A6-100		2.54	0.57	Coarse Skewed	5.38	-24.72	8.39	15.23	--
A5-20		2.57	0.70	Very Fine Skewed	3.04	-23.71	11.71	7.37	--
A5-35		3.68	1.23	Very Fine Skewed	4.52	-25.41	8.62	14.38	--
A5-50		4.02	0.60	Fine Skewed	4.84	-17.60	12.54	10.90	--
A5-100		3.18	1.50	Very Fine Skewed	4.81	-15.14	13.81	10.75	--
A5-200		2.30	0.74	Very Coarse Skewed	5.43	-24.70	8.53	15.10	--
A5-350		1.92	0.84	Very Coarse Skewed	5.77	-24.69	8.36	17.00	--
A4-20		0.71	0.87	Symmetrical	3.44	-14.20	15.31	1.10	--
A4-35		3.48	0.68	Fine Skewed	3.79	-21.42	12.80	12.38	--
A4-50		4.08	0.61	Very Fine Skewed	4.23	-15.89	13.98	15.44	--
A4-100		3.07	0.58	Symmetrical	5.57	-25.81	8.52	19.08	--
A2-20		3.55	0.85	Fine Skewed	4.14	-21.01	10.82	11.50	--
A2-50		3.23	0.64	Very Fine Skewed	4.43	-25.15	8.22	13.41	--
A2-100		3.20	0.58	Very Fine Skewed	3.15	-22.03	9.71	6.23	--
A2-200		2.05	0.80	Very Coarse Skewed	2.90	-25.78	10.18	12.40	--
A2-350		2.45	0.56	Very Coarse Skewed	4.83	-25.01	8.35	15.74	--
A1-20		3.44	0.89	Very Fine Skewed	6.15	-26.31	8.81	21.15	--
A1-50		2.47	0.86	Very Coarse Skewed	4.57	-25.29	9.25	12.60	--
A1-100		2.55	0.69	Very Coarse Skewed	4.71	-25.25	8.02	17.04	--
A1-200		2.52	0.83	Very Coarse Skewed	4.59	-25.43	8.64	15.58	--
A1-350		1.85	0.94	Very Coarse Skewed	4.83	-25.10	8.35	15.91	--
TBS-50		4.10	0.69	Very Fine Skewed	4.99	-25.64	7.56	18.92	--
TBS-100		4.08	0.64	Very Fine Skewed	4.27	-22.82	9.74	14.77	--
TBS-200		2.16	0.88	Very Coarse Skewed	4.69	-25.32	8.23	16.75	--
TBS-350		2.41	0.80	Very Coarse Skewed	5.02	-25.29	8.23	16.78	--

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix D

Epibenthic Fauna

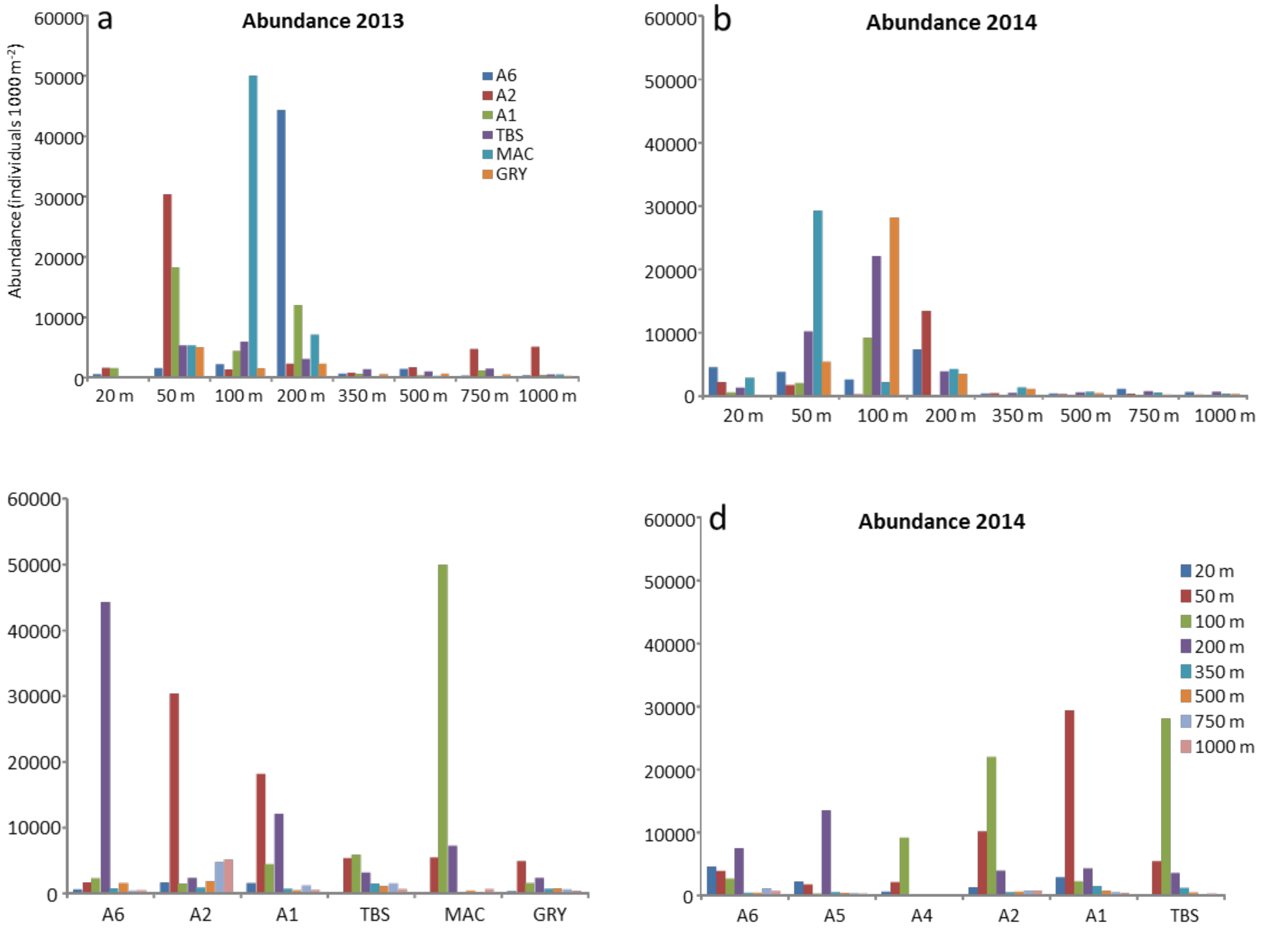
Authors
Katrin Iken
Bodil Bluhm

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

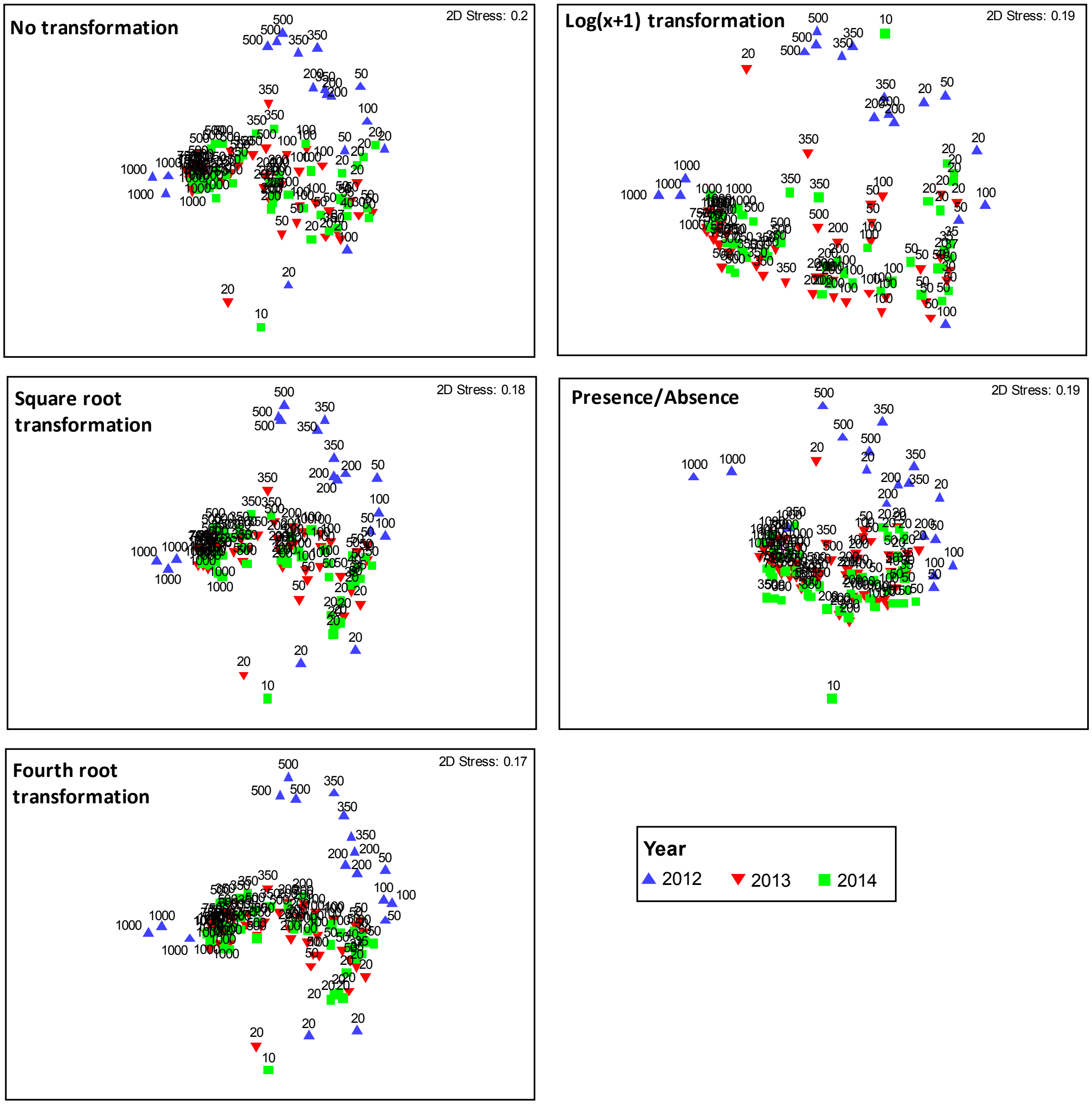
FINAL REPORT
December 2017

LIST OF FIGURES

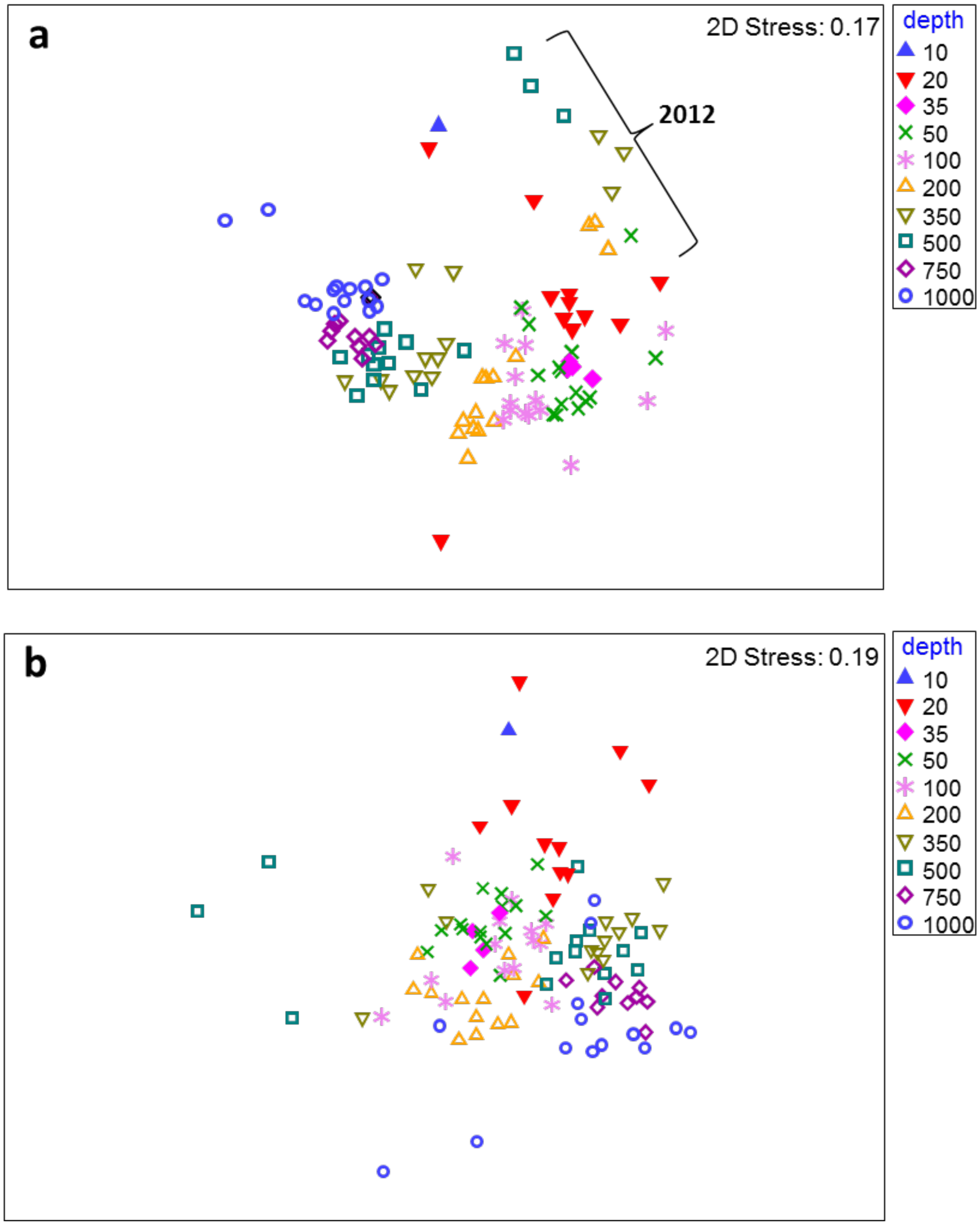
LIST OF TABLES



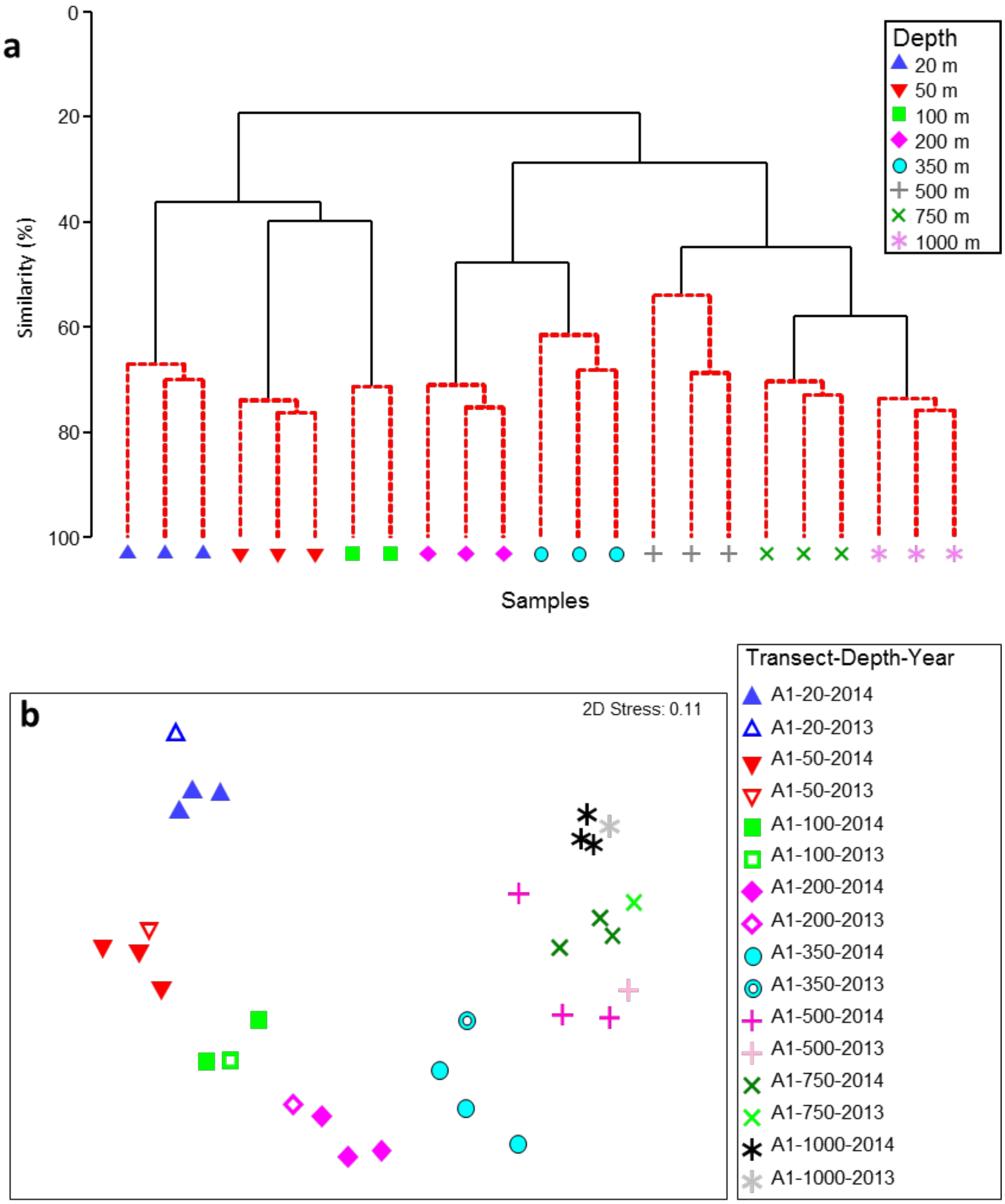
Appendix D Figure 1. Epibenthic abundance (individuals 1000 m-2) distribution in 2013 (a and c) and 2014 (b and d) arranged by depth strata (a and b) and by transect lines (c and d). Transects in panels c and d are arranged in longitudinal order from west to east: : A6 -146°W, A5 - 145°W, A4 - 144°W, A2 - 142°W, A1 - 141°W, TBS - 140°W, MAC- 139°W, GRY - 138°W.



Appendix D Figure 2. Community structure ordination based on relative abundance for all transects and depths sampled in 2012, 2013, and 2014, based on various transformations. All nMDS ordinations are based on Bray-Curtis similarity matrices. Numbers in nMDS plots refer to depth, colored symbols refer to years.

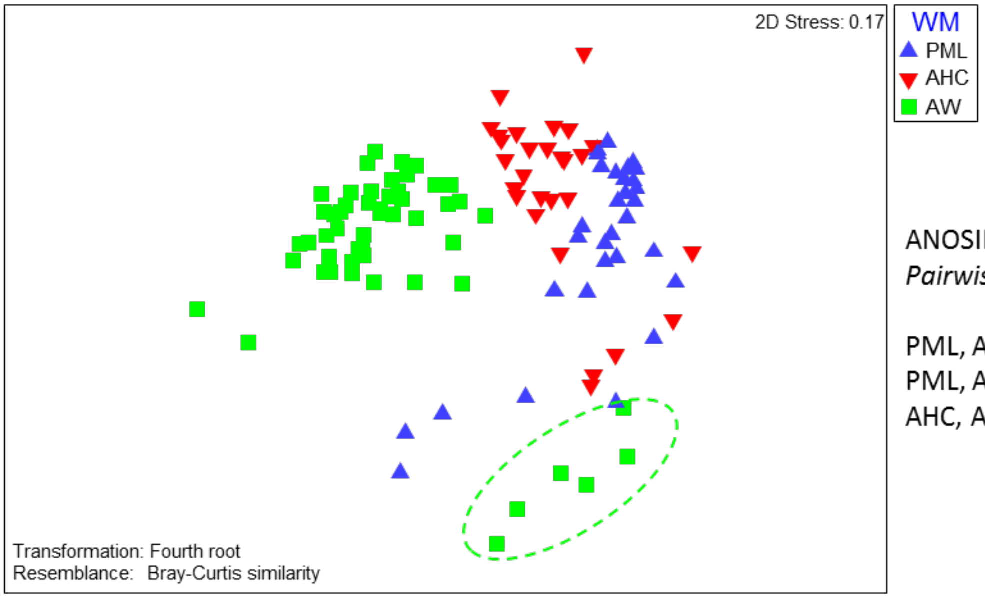


Appendix D Figure 3. Community structure ordination (nMDS) based on (a) relative abundance identified to the lowest taxonomic level (species or genus for most taxa, occasionally higher levels for difficult groups), and (b) relative abundance identified to a higher taxonomic level (mostly class level, phylum for some difficult groups). All nMDS ordinations are based on Bray-Curtis similarity matrices. Colored symbols refer to depth; a distinct station group from 2012 sampling is indicated in panel a.



Appendix D Figure 4: Community structure of repeat trawls along depth strata of transect A1 (141°W) sampled in 2014 and comparison with transect sampled in 2013; all analyses based on fourth-root transformed community abundance data and use Bray-Curtis similarity matrices.

- Clusters for 2014 repeat sampling. Red lines indicate non-significant differences among samples based on the SIMPROF test within the hierarchical cluster analysis.
- Multidimensional scaling plots include 2014 repeat sampling (filled / dark symbols) at depth strata along transect A1 (141°W) as well as the same stations sampled in 2013 (open / light symbols).



ANOSIM statistic R_{gobal}: 0.531

Pairwise Tests

	R
PML, AHC	0.267
PML, AW	0.637
AHC, AW	0.539

Appendix D Figure 5. Epibenthic community similarity based on abundance grouped by water masses (WM): PML – Polar Mixed Layer, AHC – Arctic Halocline, AW – Atlantic Water. Dashed ellipse circles stations in the Atlantic Water at 200-500 m along the B-transects sampled in 2012 (151-150°W) that are distinct from all other transect stations within the Atlantic Water. All data were fourth-root transformed and MDS plots are based on a Bray-Curtis similarity matrix. ANOSIM test statistics are given for overall test and for pairwise comparisons between water masses.

Appendix D Table 1. Mean biomass (± standard deviation) (g wet weight 1000 m^{-2}) for taxa on the shelf and slope in 2013 and 2014.

	Phylum/	2013 - shelf		2014 - shelf		2013 - slope		2014 - slope	
Taxon	**Class**	**mean**	**± SD**	**mean**	**± SD**	**mean**	**± SD**	**mean**	**± SD**
PORIFERA									
Polymastia sp.	Porifera	71	355	31	77	10	36	18	71
Porifera	Porifera	131	689	45	92	3	16	1	3
CNIDARIA									
Allantactis parasitica	Anthozoa	86	200	59	141	91	180	53	91
Amphianthus sp.	Anthozoa	0	0	0	0	0	0	0	0
Anthosactis janmayeni	Anthozoa	3	14	1	2	8	31	0	0
Anthozoa	Anthozoa	317	1749	123	346	13	51	13	32
Gersemia rubiformis	Anthozoa	13	33	25	125	7	20	8	20
Hormathia nodosa	Anthozoa	11	38	3	9	28	145	0	0
Stomphia sp.	Anthozoa	145	493	14	47	1	11	1	4
Umbellula sp.	Anthozoa	0	0	0	0	0	0	0	2
Zoanthidea	Anthozoa	0	0	0	0	6	10	4	8
Lafoeina maxima	Hydrozoa	1	3	1	7	0	0	0	0
Tubularia sp.	Hydrozoa	0	0	0	0	0	0	0	0
Hydrozoa	Hydrozoa	2	5	6	21	0	1	0	0
ANNELIDA									
Brada sp.	Polychaeta	1	4	3	9	0	0	0	0
Lumbrineridae	Polychaeta	0	0	1	3	0	0	0	1
Melaenis loveni	Polychaeta	1	2	0	3	0	1	0	0
Nephtys sp.	Polychaeta	7	16	10	39	11	29	1	2
Nereis zonata	Polychaeta	3	7	15	32	2	11	22	71
Nothria conchylega	Polychaeta	4	12	5	13	4	12	1	4
Phyllodoce groenlandica	Polychaeta	2	4	1	2	0	1	1	3
Polychaeta	Polychaeta	22	65	11	24	22	81	2	6
Polynoidae	Polychaeta	10	20	15	22	6	14	2	3
Polyphysia crassa	Polychaeta	0	0	0	0	0	0	0	1
Spinther sp.	Polychaeta	0	0	0	0	0	0	0	0
Notostomum laeve	Hirudinea	0	0	0	2	2	11	2	6
MOLLUSCA									
Musculus sp.	Bivalvia	0	1	0	1	0	0	0	0
Similipecten greenlandicus	Bivalvia	115	175	208	274	0	1	10	56
Admete spp.	Gastropoda	3	8	1	3	1	3	0	1
Amicula vestita	Gastropoda	0	0	0	2	0	0	0	0
Anomalosipho verkruezeni	Gastropoda	2	5	1	3	0	2	0	2
Beringius behringi	Gastropoda	4	19	0	0	0	0	8	46
Boreotrophon spp.	Gastropoda	2	8	5	10	0	2	0	1
Buccinum spp.	Gastropoda	8	13	20	49	14	43	5	16
Colus spp.	Gastropoda	59	126	47	103	60	104	41	70
Cryptonatica affinis	Gastropoda	2	7	1	3	0	0	0	0
Curtitoma sp.	Gastropoda	2	4	0	0	0	1	0	1
Cylichna spp.	Gastropoda	5	14	1	3	1	2	0	0
Gastropoda	Gastropoda	1	2	2	5	0	1	0	1
Lepeta caeca	Gastropoda	0	1	0	0	0	0	0	0
Limneria undata	Gastropoda	0	0	0	1	0	0	0	0
Lunatia pallida	Gastropoda	4	15	2	10	1	5	0	0
Margarites spp.	Gastropoda	59	203	144	313	0	1	0	1
Mohnia sp.	Gastropoda	0	0	0	0	1	6	0	0
Neptunea ventricosa	Gastropoda	2	14	9	31	3	23	0	0
Obestoma sp.	Gastropoda	0	0	1	2	0	0	0	0
Oenopota sp.	Gastropoda	1	2	1	2	0	1	0	1
Opisthobranchia	Gastropoda	1	3	4	7	0	1	0	1
Philine sp.	Gastropoda	1	3	14	37	0	1	0	1
Plicifusus kroeyeri	Gastropoda	1	4	2	7	0	0	0	0
Propebela spp.	Gastropoda	1	4	0	1	0	1	0	0

Appendix D Table 1. Continued.

Taxon	Phylum/ Class	2013 - shelf mean	2013 - shelf ± SD	2014 - shelf mean	2014 - shelf ± SD	2013 - slope mean	2013 - slope ± SD	2014 - slope mean	2014 - slope ± SD
PORIFERA									
Polymastia sp.	Porifera	71	355	31	77	10	36	18	71
Porifera	Porifera	131	689	45	92	3	16	1	3
CNIDARIA									
Allantactis parasitica	Anthozoa	86	200	59	141	91	180	53	91
Amphianthus sp.	Anthozoa	0	0	0	0	0	0	0	0
Anthosactis janmayeni	Anthozoa	3	14	1	2	8	31	0	0
Anthozoa	Anthozoa	317	1749	123	346	13	51	13	32
Gersemia rubiformis	Anthozoa	13	33	25	125	7	20	8	20
Hormathia nodosa	Anthozoa	11	38	3	9	28	145	0	0
Stomphia sp.	Anthozoa	145	493	14	47	1	11	1	4
Umbellula sp.	Anthozoa	0	0	0	0	0	0	0	2
Zoanthidea	Anthozoa	0	0	0	0	6	10	4	8
Lafoeina maxima	Hydrozoa	1	3	1	7	0	0	0	0
Tubularia sp.	Hydrozoa	0	0	0	0	0	0	0	0
Hydrozoa	Hydrozoa	2	5	6	21	0	1	0	0
ANNELIDA									
Brada sp.	Polychaeta	1	4	3	9	0	0	0	0
Lumbrineridae	Polychaeta	0	0	1	3	0	0	0	1
Melaenis loveni	Polychaeta	1	2	0	3	0	1	0	0
Nephtys sp.	Polychaeta	7	16	10	39	11	29	1	2
Nereis zonata	Polychaeta	3	7	15	32	2	11	22	71
Nothria conchylega	Polychaeta	4	12	5	13	4	12	1	4
Phyllodoce groenlandica	Polychaeta	2	4	1	2	0	1	1	3
Polychaeta	Polychaeta	22	65	11	24	22	81	2	6
Polynoidae	Polychaeta	10	20	15	22	6	14	2	3
Polyphysia crassa	Polychaeta	0	0	0	0	0	0	0	1
Spinther sp.	Polychaeta	0	0	0	0	0	0	0	0
Notostomum laeve	Hirudinea	0	0	0	2	2	11	2	6
MOLLUSCA									
Musculus sp.	Bivalvia	0	1	0	1	0	0	0	0
Similipecten greenlandicus	Bivalvia	115	175	208	274	0	1	10	56
Admete spp.	Gastropoda	3	8	1	3	1	3	0	1
Amicula vestita	Gastropoda	0	0	0	2	0	0	0	0
Anomalosipho verkruezeni	Gastropoda	2	5	1	3	0	2	0	2
Beringius behringi	Gastropoda	4	19	0	0	0	0	8	46
Boreotrophon spp.	Gastropoda	2	8	5	10	0	2	0	1
Buccinum spp.	Gastropoda	8	13	20	49	14	43	5	16
Colus spp.	Gastropoda	59	126	47	103	60	104	41	70
Cryptonatica affinis	Gastropoda	2	7	1	3	0	0	0	0
Curtitoma sp.	Gastropoda	2	4	0	0	0	1	0	1
Cylichna spp.	Gastropoda	5	14	1	3	1	2	0	0
Gastropoda	Gastropoda	1	2	2	5	0	1	0	1
Lepeta caeca	Gastropoda	0	1	0	0	0	0	0	0
Limneria undata	Gastropoda	0	0	0	1	0	0	0	0
Lunatia pallida	Gastropoda	4	15	2	10	1	5	0	0
Margarites spp.	Gastropoda	59	203	144	313	0	1	0	1
Mohnia sp.	Gastropoda	0	0	0	0	1	6	0	0
Neptunea ventricosa	Gastropoda	2	14	9	31	3	23	0	0
Obestoma sp.	Gastropoda	0	0	1	2	0	0	0	0
Oenopota sp.	Gastropoda	1	2	1	2	0	1	0	1
Opisthobranchia	Gastropoda	1	3	4	7	0	1	0	1
Philine sp.	Gastropoda	1	3	14	37	0	1	0	1
Plicifusus kroeyeri	Gastropoda	1	4	2	7	0	0	0	0
Propebela spp.	Gastropoda	1	4	0	1	0	1	0	0

Appendix D Table 1. Continued.

Taxon	Phylum/Class	2013 - shelf		2014 - shelf		2013 - slope		2014 - slope	
		mean	± SD	mean	± SD	mean	± SD	mean	± SD
Pyrulofusus deformis	Gastropoda	8	39	6	24	0	3	0	0
Retifusus roseus	Gastropoda	1	2	0	0	0	0	0	1
Tachyrhynchus erosus	Gastropoda	5	16	9	33	0	0	0	0
Trichotropis sp.	Gastropoda	0	1	0	2	0	0	0	0
Velutina velutina	Gastropoda	0	2	2	5	0	1	0	0
Siphonodentalium lobatum	Scaphopoda	0	0	0	0	8	22	2	2
Bathypolypus/Benthoctopus	Cephalopoda	1	3	0	2	24	70	9	28
CRUSTACEA									
Gooseneck barnacles	Cirripedia	0	0	0	0	2	16	1	3
Tanaidacea	Tanaidacea	1	3	0	2	0	1	1	1
Diastylis spp.	Cumacea	53	111	156	315	2	4	1	1
Gnathia sp.	Isopoda	0	0	0	0	1	4	0	0
Isopoda	Isopoda	2	6	2	6	1	3	0	0
Saduria spp.	Isopoda	88	261	21	79	35	183	5	7
Synidotea bicuspida	Isopoda	75	236	134	299	0	0	0	1
Pycnogonida	Pycnogonida	18	37	15	20	6	18	4	7
Acanthostepheia beringiensis	Amphipoda	5	16	5	13	1	4	0	2
Amathillopsis spinigera	Amphipoda	0	0	0	0	1	4	1	2
Amphipoda	Amphipoda	7	13	10	18	3	5	2	4
Anonyx sp.	Amphipoda	26	56	39	60	2	7	2	6
Apherusa sp.	Amphipoda	0	0	0	0	0	0	0	0
Arrhis phyllonyx	Amphipoda	2	5	10	23	1	3	0	1
Atylus spp.	Amphipoda	19	69	62	173	0	0	0	0
Epimeria loricata	Amphipoda	0	0	0	0	0	1	0	1
Eurythenes gryllus	Amphipoda	0	0	0	0	0	0	0	1
Eusirus sp.	Amphipoda	0	1	0	1	3	10	1	2
Gammaridae	Amphipoda	0	0	0	2	3	26	0	0
Gammarus wilkitzkii	Amphipoda	0	1	0	0	0	0	0	0
Hippomedon sp.	Amphipoda	0	1	20	96	0	1	0	0
Ischyrocerus sp.	Amphipoda	0	1	1	5	0	0	0	0
Lembos arcticus	Amphipoda	0	0	0	1	0	0	0	0
Melita sp.	Amphipoda	0	1	1	3	0	0	0	0
Onisimus sp.	Amphipoda	1	2	1	4	0	1	0	0
Paramphithoe cuspidata	Amphipoda	0	1	1	2	0	0	0	0
Paroediceros lynceus	Amphipoda	1	3	6	18	0	1	0	0
Protomedia sp.	Amphipoda	0	0	0	0	0	0	0	0
Rhachotropis sp.	Amphipoda	0	1	2	6	1	2	0	0
Stegocephalus sp.	Amphipoda	5	8	10	25	1	2	1	2
Stephobruzelia sp.	Amphipoda	0	0	0	0	0	0	0	0
Weyprechtia heuglini	Amphipoda	0	0	0	2	0	0	0	0
Argis sp.	Decapoda	40	72	2	7	30	87	9	39
Bythocaris spp.	Decapoda	0	0	0	0	10	21	11	19
Chionoecetes opilio	Decapoda	0	0	77	414	161	1208	0	0
Eualus spp.	Decapoda	60	68	59	66	79	128	31	56
Hyas coarctatus	Decapoda	4	22	0	1	0	0	0	0
Lebbeus spp.	Decapoda	0	0	7	18	2	10	17	48
Pagurus sp.	Decapoda	0	2	6	20	0	2	0	1
Pandalus sp.	Decapoda	0	0	0	0	0	0	0	0
Sabinea septemcarinata	Decapoda	131	129	80	65	13	30	7	14
Sclerocrangon ferox	Decapoda	0	0	0	0	26	64	4	8
Spirontocaris sp.	Decapoda	11	27	6	13	0	0	0	0
ECHINODERMATA									
Florometra sp.	Crinoidea	585	1386	170	361	96	178	22	42
Strongylocentrotus pallidus	Echinoidea	232	685	94	176	1	9	0	0
Elpidia sp.	Holothuroidea	0	0	0	0	0	0	0	0

Appendix D Table 1. Continued.

Taxon	**Phylum/ Class**	**2013 - shelf mean**	**± SD**	**2014 - shelf mean**	**± SD**	**2013 - slope mean**	**± SD**	**2014 - slope mean**	**± SD**
Holothuroidea	Holothuroidea	3	8	0	0	0	2	0	0
Kolga sp.	Holothuroidea	0	0	0	0	0	0	0	1
Molpadia borealis	Holothuroidea	0	0	0	0	105	257	42	131
Myriotrochus rinkii	Holothuroidea	12	52	21	41	0	0	0	0
Ocnus glacialis	Holothuroidea	14	55	15	38	0	0	0	0
Psolus peronii	Holothuroidea	929	3573	933	1684	0	0	0	0
Amphiodia craterodmeta	Ophiuroidea	0	1	0	0	0	0	0	0
Gorgonocephalus sp.	Ophiuroidea	144	370	38	142	104	453	57	208
Ophiacantha bidentata	Ophiuroidea	87	229	149	402	192	380	92	144
Ophiocten sericeum	Ophiuroidea	451	945	588	820	154	575	59	149
Ophiopholis aculeata	Ophiuroidea	1	6	0	0	0	0	0	0
Ophiopleura borealis	Ophiuroidea	0	0	0	0	897	1773	213	349
Ophioscolex glacialis	Ophiuroidea	0	0	0	0	3	11	11	29
Ophiura robusta	Ophiuroidea	2	7	1	3	0	0	0	0
Ophiuroidea	Ophiuroidea	0	0	0	0	0	3	0	0
Bathybiaster vexillifer	Asteroidea	0	0	0	0	151	262	47	66
Crossaster papposus	Asteroidea	77	197	58	78	0	0	2	12
Ctenodiscus crispatus	Asteroidea	39	106	21	114	57	286	18	62
Hymenaster pellucidus	Asteroidea	2	8	3	16	9	21	3	7
Icasterias panopla	Asteroidea	118	304	102	365	85	159	34	48
Leptasterias spp.	Asteroidea	57	134	70	99	1	3	0	0
Lophaster furcifer	Asteroidea	50	272	22	118	12	58	3	16
Pontaster tenuispinus	Asteroidea	89	319	62	249	297	385	136	151
Pteraster spp.	Asteroidea	31	100	49	125	0	0	0	0
Rhegaster tumidus	Asteroidea	5	27	7	30	23	114	1	4
Urasterias linckii	Asteroidea	521	960	198	399	24	128	0	0
ASCIDIACEA									
Ascidia spp.	Ascidiacea	3	17	0	0	34	184	5	28
Ascidiacea	Ascidiacea	0	1	10	48	0	1	1	3
Chelyosoma sp.	Ascidiacea	0	0	0	1	0	0	0	0
Pelonaia corrugata	Ascidiacea	0	0	0	0	0	0	0	0
Styela rustica	Ascidiacea	0	2	0	0	0	0	0	0
BRYOZOA									
Alcyonidium spp.	Bryozoa	6	15	6	11	0	1	0	0
Eucratea loricata	Bryozoa	0	1	0	0	0	1	0	0
Heteropora sp.	Bryozoa	1	3	4	16	0	0	0	0
Bryozoa	Bryozoa	3	8	13	28	0	0	0	0
OTHERS									
Brachiopoda	Brachiopoda	1	4	2	7	0	0	0	0
Platyhelmintes	Platyhelmintes	0	1	2	8	0	1	0	0
Hemingia arctica	Echiura	2	9	0	0	1	5	0	0
Nemertea	Nemertea	8	18	20	81	1	1	0	1
Phascolion strombus	Sipuncula	0	0	0	1	0	1	2	6
Priapulus caudatus	Priapula	0	0	0	0	1	5	1	3
TOTAL	**all taxa**	**7908**	9529	**4285**	4142	**2959**	2658	**1094**	1035

Appendix D Table 2: SIMPER results for epifauna (based on relative biomass including all sampling years) for shelf and slope groups; 70% similarity cut-off.

Depth Group shelf (20-100 m) (n=37)
Average similarity: 36.38 %

Taxon	***Av. Rel. Biom.***	***Indiv. Contrib. %***	***Cum. Contrib. %***
Ophiocten sericeum	1.56	9.65	9.65
Similipecten greenlandicus	1.21	7.15	16.80
Sabinea septemcarinata	1.14	7.05	23.85
Anonyx sp.	0.89	5.14	28.99
Diastylis goodsiri/scorpioides	0.86	4.57	33.56
Pycnogonida	0.67	4.30	37.85
Polynoidae	0.69	3.91	41.76
Florometra sp.	0.87	3.08	44.85
Leptasterias groenlandica	0.62	2.66	47.51
Psolus peronii	0.93	2.62	50.13
Crossaster papposus	0.64	2.25	52.37
Amphipoda	0.47	2.12	54.49
Nemertea	0.45	1.98	56.47
Eualus gaimardii sp.	0.61	1.82	58.29
Ophiacantha bidentata	0.60	1.73	60.02
Diastylis sp.	0.43	1.72	61.73
Strongylocentrotus pallidus	0.59	1.69	63.42
Urasterias linckii	0.74	1.61	65.03
Eualus sp.	0.49	1.56	66.59
Margarites costalis	0.50	1.47	68.06
Bryozoa	0.42	1.47	69.53
Synidotea bicuspida	0.52	1.40	70.92

Depth Group slope (200-1000 m) (n=54)
Average similarity: 42.08 %

Taxon	***Av. Rel. Biom.***	***Indiv. Contrib. %***	***Cum. Contrib. %***
Pontaster tenuispinus	1.80	14.36	14.36
Ophiopleura borealis	1.74	10.51	24.87
Bathybiaster vexillifer	1.22	7.05	31.92
Colus sabinii	0.93	5.14	37.06
Allantactis parasitica	0.92	4.34	41.40
Ophiocten sericeum	0.85	4.20	45.59
Icasterias panopla	0.87	3.53	49.13
Saduria sabini	0.69	3.53	52.65
Pycnogonida	0.63	3.52	56.18
Nephtys sp.	0.58	3.42	59.59
Ophiacantha bidentata	0.83	2.78	62.37
Siphonodentalium lobatum	0.53	2.62	65.00
Molpadia borealis	0.66	2.14	67.14
Diastylis sp.	0.37	1.92	69.06
Zoanthidea	0.48	1.72	70.78

Appendix D Table 3: Dissimilarity between shelf and slope habitats for epifauna (based on relative biomass including all three sampling years) from SIMPER (similarity percentage) analysis; 70% dissimilarity cut-off.

Groups shelf & slope
Average dissimilarity = 79.00

Taxon	***Group shelf Av. Rel. Biom.***	***Group slope Av. Rel. Biom.***	***Individual Contrib. %***	***Cumulative Contrib. %***
Ophiopleura borealis	0.00	1.74	3.80	3.80
Pontaster tenuispinus	0.27	1.80	3.33	7.13
Bathybiaster vexillifer	0.00	1.22	2.66	9.79
Similipecten greenlandicus	1.21	0.08	2.42	12.21
Ophiocten sericeum	1.56	0.85	2.01	14.21
Psolus peronii	0.93	0.00	1.98	16.20
Florometra sp.	0.87	0.56	1.88	18.08
Icasterias panopla	0.26	0.87	1.86	19.94
Sabinea septemcarinata	1.14	0.37	1.81	21.76
Allantactis parasitica	0.41	0.92	1.81	23.56
Ophiacantha bidentata	0.60	0.83	1.79	25.35
Colus sabinii	0.33	0.93	1.75	27.11
Saduria sabini	0.33	0.69	1.60	28.71
Anonyx sp.	0.89	0.19	1.57	30.28
Urasterias linckii	0.74	0.06	1.51	31.79
Diastylis goodsiri/scorpioides	0.86	0.16	1.50	33.29
Eualus gaimardii sp.	0.61	0.32	1.48	34.76
Molpadia borealis	0.00	0.66	1.44	36.21
Eualus sp.	0.49	0.52	1.44	37.64
Anthozoa	0.45	0.50	1.32	38.96
Crossaster papposus	0.64	0.03	1.28	40.24
Strongylocentrotus pallidus	0.59	0.02	1.26	41.50
Leptasterias groenlandica	0.62	0.03	1.24	42.74
Siphonodentalium lobatum	0.00	0.53	1.17	43.91
Bythocaris sp.	0.00	0.54	1.14	45.05
Nephtys sp.	0.35	0.58	1.09	46.14
Zoanthidea	0.02	0.48	1.07	47.21
Gorgonocephalus sp.	0.34	0.28	1.04	48.25
Synidotea bicuspida	0.52	0.01	1.03	49.28
Polynoidae	0.69	0.38	1.02	50.30
Ctenodiscus crispatus	0.20	0.35	1.01	51.31
Margarites costalis	0.50	0.01	0.99	52.29
Hymenaster pellucidus	0.09	0.43	0.93	53.22
Acanthostepheia behringiensis	0.38	0.08	0.92	54.14
Polychaeta	0.27	0.39	0.92	55.06
Gersemia rubiformis	0.35	0.28	0.91	55.96
Amphipoda	0.47	0.40	0.88	56.85
Pteraster obscurus	0.45	0.00	0.86	57.71
Bryozoa	0.42	0.02	0.85	58.56
Lebbeus polaris	0.12	0.34	0.83	59.39
Nemertea	0.45	0.20	0.82	60.21
Eusirus sp.	0.09	0.38	0.82	61.03

Appendix D Table 3. Continued.

Groups shelf & slope
Average dissimilarity = 79.00

Taxon	*Group shelf Av. Rel. Biom.*	*Group slope Av. Rel. Biom.*	*Individual Contrib. %*	*Cumulative Contrib. %*
Pycnogonida	0.67	0.63	0.81	61.83
Porifera	0.36	0.12	0.80	62.64
Arrhis sp.	0.35	0.31	0.80	63.43
Spirontocaris sp.	0.37	0.00	0.79	64.23
Argis sp.	0.28	0.19	0.79	65.02
Stegocephalus sp.	0.35	0.36	0.78	65.80
Diastylis sp.	0.43	0.37	0.74	66.54
Nereis zonata	0.31	0.17	0.73	67.27
Colus pubescens	0.06	0.33	0.73	68.00
Alcyonidium gelatinosum	0.36	0.05	0.71	68.71
Sclerocrangon ferox	0.00	0.34	0.70	69.41
Saduria entomon	0.24	0.00	0.69	70.10

Appendix D Table 4. SIMPER (similarity percentage analysis) results for epifauna relative biomass between slope habitats in 2012 versus in 2013/2014; 70% dissimilarity cut-off.

Groups 2013-2014-slope & 2012-slope

Average dissimilarity = 85.17%

Species	***2013-2014 slope Av. Rel. Biom.***	***2012 slope Av. Rel. Biom.***	***Individual Contrib. %***	***Cumulative Contrib. %***
Pontaster tenuispinus	1.80	0.00	5.00	5.00
Ctenodiscus crispatus	0.35	1.87	4.75	9.75
Ophiopleura borealis	1.74	0.62	4.33	14.08
Bathybiaster vexillifer	1.22	0.77	3.02	17.10
Ophiura sarsii	0.00	1.08	2.64	19.73
Allantactis parasitica	0.92	0.00	2.46	22.20
Icasterias panopla	0.87	0.00	2.32	24.52
Colus sabinii	0.93	0.13	2.31	26.83
Molpadia borealis	0.66	0.22	2.21	29.04
Ophiacantha bidentata	0.83	0.23	2.14	31.18
Saduria sabini	0.69	0.36	2.05	33.23
Chionoecetes opilio	0.05	0.63	1.91	35.14
Eualus sp.	0.52	0.50	1.89	37.03
Ophiocten sericeum	0.85	0.29	1.89	38.93
Tachyrhynchus erosus	0.02	0.64	1.70	40.62
Anthozoa	0.50	0.30	1.69	42.31
Nephtys sp.	0.58	0.00	1.67	43.98
Eualus gaimardii sp.	0.32	0.44	1.57	45.55
Bythocaris sp.	0.54	0.11	1.56	47.11
Siphonodentalium lobatum	0.53	0.00	1.54	48.65
Pycnogonida	0.63	0.14	1.53	50.18
Florometra sp.	0.56	0.11	1.48	51.66
Zoanthidea	0.48	0.00	1.41	53.08
Sabinea septemcarinata	0.37	0.27	1.19	54.26
Hymenaster pellucidus	0.43	0.00	1.15	55.42
Amphipoda	0.40	0.10	1.09	56.51
Eusirus sp.	0.38	0.03	1.07	57.58
Cryptonatica affinis	0.06	0.42	1.04	58.62
Polychaeta	0.39	0.00	1.04	59.67
Buccinum scalariforme	0.11	0.37	1.04	60.70
Diastylis sp.	0.37	0.00	1.01	61.72
Sclerocrangon ferox	0.34	0.06	0.98	62.70
Polynoidae	0.38	0.23	0.96	63.66
Stegocephalus sp.	0.36	0.02	0.96	64.61
Arrhis sp.	0.31	0.15	0.95	65.57
Hemingia arctica	0.05	0.29	0.92	66.49
Lebbeus polaris	0.34	0.00	0.91	67.40
Pandalus sp.	0.00	0.38	0.90	68.30
Stomphia sp.	0.05	0.31	0.87	69.17
Colus pubescens	0.33	0.00	0.86	70.04

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix E1

Fish Counts by Gear

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL
REPORT
December 2017

Appendix E1 Table 1. Total number of fishes caught by Isaacs-Kidd midwater trawl (IKMT) by year and haul. Fishes are in phylogenetic order by family. Catch effort is bad haul (NQ) or the multiplication factor by which catch is standardized to ind. 1000 m^3.

			Osmeridae	Gadidae	Cottidae					Agonidae	Liparidae			Zoarcidae	Stichaeidae						Pleuronectidae		Misc	
IKMT Haul	Station	Effort	Mallotus catervarius	Boreogadus saida	Gymnocanthus tricuspis	Icelus spp.	Myoxocephalus scorpius	Triglops pingelii	Cottidae unid.	Aspidophoroides olrikii	Liparis fabricii	Liparis gibbus	Liparis spp.	Lycodes reticulatus	Anisarchus medius	Leptoclinus maculatus	Lumpeninae	Lumpenus fabricii	Stichaeus punctatus	Stichaeidae unid.	Limanda proboscidea	Pleuronectidae larva A	Teleost unid.	Total count
2012																								
1	B1-20	4.727876	-	2	1	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	6
2	B1-50	2.361326	-	11	4	-	-	-	-	2	-	-	3	-	-	7	-	-	-	16	-	-	-	43
3	B1-100	2.128486	-	60	-	-	-	-	3	3	-	-	5	-	-	5	-	122	-	-	-	-	-	198
4	B1-200	0.754324	-	4	-	-	-	-	2	4	5	-	2	-	10	-	-	-	2	-	-	-	-	29
5	B1-350	0.668439	-	5	2	-	-	-	-	-	-	-	3	-	-	-	-	1	-	6	-	-	-	17
6	B1-500	0.822873	-	9	-	-	-	-	-	1	1	-	3	-	-	-	-	1	-	-	-	-	-	15
7	B1-1000	0.774275	-	28	1	-	-	-	-	5	-	1	5	-	-	-	-	-	-	21	-	-	-	61
8	B2-1000	0.550489	-	28	-	-	-	-	-	1	-	-	3	-	-	3	-	1	-	-	1	-	-	37
9	B2-500	0.584999	-	40	-	-	-	-	-	4	1	-	3	-	-	-	-	-	-	7	-	-	-	55
10	B2-500	0.663253	-	17	-	-	1	-	-	6	-	-	4	-	-	-	-	6	3	-	-	-	-	37
11	B2-350	0.396181	-	3	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	6
12	B2-200	0.336377	-	25	-	-	-	-	-	1	-	-	4	-	-	-	-	-	-	3	-	-	-	33
13	B2-100	8.094697	-	11	-	-	-	-	-	2	1	-	1	-	-	-	-	-	-	2	-	-	-	17
14	B2-50	0.99627	-	24	9	-	-	1	-	-	-	-	3	-	-	-	-	75	-	-	-	-	-	112
15	B2-20	1.864747	2	12	5	-	-	-	-	-	-	-	-	-	-	-	-	50	2	-	-	1	-	72
16	B1-200	0.331626	-	15	-	-	-	1	-	1	-	-	2	-	1	-	-	-	-	-	-	-	-	20
17	BX-500	0.176802	-	12	4	-	-	-	-	2	-	-	2	-	-	-	-	-	-	7	-	-	-	27
18	BX-1000	2.017941	-	13	-	-	-	-	-	1	1	-	1	-	-	-	-	1	-	5	-	-	-	22
2012 Total			**2**	**319**	**26**	**0**	**2**	**2**	**6**	**34**	**9**	**2**	**45**	**0**	**11**	**15**	**0**	**257**	**7**	**67**	**1**	**2**	**0**	**807**
2013																								
1	A6-20	1.500865	-	4	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			5
2	A6-37	0.914709	-	6	1	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-			12
3	A6-50	0.282157	-	6	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-			8
4	A6-100	0.148014	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			1
5	A6-200	NQ	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-			2
6	A6-200	0.063621	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			2
7	A6-350	0.067562	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			1
8	A6-500	0.068758	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1	2
9	A6-750	0.071386	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			0
10	A6-1000	0.052693	-	4	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			5
11	A2-1000	0.047455	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			0
12	A2-750	0.050946	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			3
13	A2-500	0.045682	-	9	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-			10
14	A2-350	0.057176	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			2
15	A2-200	0.063019	-	3	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-			4
16	A2-100	0.145353	-	3	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-			5
17	A2-40	0.248843	-	15	-	-	-	-	10	1	6	-	-	-	-	-	-	-	-	-	-			32
18	A2-30	0.341622	-	7	-	-	-	1	3	1	-	-	-	-	-	-	-	-	-	-	-		1	13
19	A2-10	0.047555	-	2	-	-	-	-	4	-	-	-	1	-	-	-	-	-	-	2	-			9

			Osmeridae	Gadidae	Cottidae					Agonidae	Liparidae			Zoarcidae	Stichaeidae						Pleuronectidae		Misc	
IKMT Haul	Station	Effort	Mallotus catervarius	Boreogadus saida	Gymnocanthus tricuspis	Icelus spp.	Myoxocephalus scorpius	Triglops pingelii	Cottidae unid.	Aspidophoroides olrikii	Liparis fabricii	Liparis gibbus	Liparis spp.	Lycodes reticulatus	Anisarchus medius	Leptoclinus maculatus	Lumpeninae	Lumpenus fabricii	Stichaeus punctatus	Stichaeidae unid.	Limanda proboscidea	Pleuronectidae larva A	Teleost unid.	Total count
20	A1-20	0.494685	-	2	-	2	-	-	-	-	-	-	4	-	-	-	7	-	-	-	-			15
21	A1-50	0.263672	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-			2
22	A1-32	0.223236	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			3
23	A1-100	0.131148	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1	3
24	A1-200	0.072366	-	11	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			12
25	A1-350	0.046112	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			3
26	A1-500	0.067775	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			6
27	A1-750	0.049777	-	11	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	-			14
28	A1-1000	0.113279	-	3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-			5
29	TBS-1000	0.05229	-	13	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-			14
30	TBS-750	0.063422	-	11	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	1	-			15
31	TBS-500	0.047397	-	49	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			49
32	TBS-350	0.045771	-	8	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-			9
33	TBS-200	0.046775	-	6	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-			8
34	TBS-100	0.1106	-	13	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-			14
35	TBS-50	0.241184	-	55	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	1	-			58
36	TBS-35	0.314762	-	10	-	-	-	-	1	-	4	-	-	-	-	-	-	1	-	-	-			16
37	MAC-200	0.057574	-	23	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-			26
39	MAC-161	0.06209	-	14	1	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-			25
40	MAC-100	0.135209	-	13	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	-	-			16
41	MAC-50	0.252832	-	4	-	-	-	-	3	-	-	-	2	-	-	-	5	-	-	3	-			17
42	GRY-20	0.755159	-	9	-	-	-	-	-	-	-	-	2	-	-	-	3	-	-	-	-			14
43	GRY-50	0.194727	-	13	1	3	-	-	-	-	-	-	10	-	-	-	4	-	-	-	-			31
44	GRY-100	0.141809	-	78	-	-	-	-	4	-	2	-	2	-	-	-	-	-	-	-	-			86
45	GRY-200	0.064887	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			9
46	GRY-350	0.056302	-	8	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-			10
47	GRY-500	0.041589	-	81	2	-	-	-	-	1	-	-	3	-	-	-	2	-	-	-	-			89
48	GRY-750	0.050156	-	18	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-			20
49	GRY-1000	0.048362	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			6
50	EXP-1000	0.021054	-	18	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-			21
51	MAC-1000	0.124592	-	8	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-			9
52	MAC-500	0.043353	-	19	-	-	-	-	2	-	1	-	-	-	-	-	-	1	-	-	-			23
2013 Total			**0**	**596**	**7**	**5**	**0**	**1**	**41**	**8**	**23**	**0**	**45**	**1**	**0**	**0**	**23**	**3**	**0**	**8**	**0**	**0**	**3**	**764**
IKMT All Years Total			**2**	**915**	**33**	**5**	**2**	**3**	**47**	**42**	**32**	**2**	**90**	**1**	**11**	**15**	**23**	**260**	**7**	**67**	**1**	**2**	**3**	**1571**

Appendix E1 Table 2. Total number of fishes caught by Aluette midwater trawl (AMT) by year and haul. Fishes are in phylogenetic order by family. Catches are proportional (%) or bad haul (NQ).

			Gadidae	Agonidae	Liparidae		
AMT Haul	Station	Effort	Boreogadus saida	Aspidophoroides olrikii	Liparis fabricii	Liparis spp.	Total Count
2014							
1	A2-500	NQ	3	-	-	-	3
2	A2-500	%	2	-	-	-	2
3	A2-350	%	13	-	-	-	13
4	A2-350	NQ	-	-	2	-	2
5	A2-200	NQ	-	-	3	1	4
6	A1-200	NQ	-	-	-	-	0
7	A1-350	NQ	2	1	-	-	3
8	A1-500	%	2	-	2	-	4
9	A6-500	%	6	-	-	-	6
10	A6-350	NQ	1	-	-	-	1
11	A6-200	%	1	-	-	-	1
2014 Total			**30**	**1**	**7**	**1**	**39**
AMT All Years Total			**30**	**1**	**7**	**1**	**39**

Appendix E1 Table 3. Total number of fishes caught by modified plumb staff beam trawl (PSBT-A) by year and haul. Fishes are in phylogenetic order by family. Catch effort is proportional (%), bad haul (NQ), or the multiplication factor by which catch is standardized to ind. 1000 m^2.

			Rajidae		Osmeridae	Myctophidae	Gadidae	Cottidae									Hemitripteridae	Psychrolutidae		Agonidae		Cyclopteridae		Liparidae									Zoarcidae																		Stichaeidae						Ammodytidae	Pleuronectidae		
PSBT-A Haul	Station	Effort	Amblyraja hyperborea	Rajidae unid.	Mallotus catervarius	Myctophidae unid.	Boreogadus saida	Artediellus scaber	Gymnocanthus tricuspis	Icelus bicornis	Icelus spatula	Icelus spp.	Myoxocephalus scorpius	Triglops nybelini	Triglops pingelii	Cottidae unid.	Hemitripteridae (unidentified)	Cottunculus microps	Psychrolutidae unid.	Aspidophoroides olrikii	Leptagonus decagonus	Eumicrotremus derjugini	Cyclopteridae unid.	Careproctus lerikimae	Liparis bathyarcticus	Liparis fabricii	Liparis gibbus	Liparis tunicatus	Liparis spp.	Paraliparis bathybius	Paraliparis spp.	Rhodichthys regina	Gymnelus hemifasciatus	Gymnelus viridis	Gymnelus spp. unid.	Lycenchelys kolthoffi	Lycodes adolfi	Lycodes eudipleurostictus	Lycodes frigidus	Lycodes jugoricus	Lycodes mucosus	Lycodes pallidus	Lycodes polaris	Lycodes raridens	Lycodes reticulatus	Lycodes rossi	Lycodes sagittarius	Lycodes seminudus	Lycodes squamiventer	Lycodes spp. unid.	Anisarchus medius	Eumesogrammus praecisus	Leptoclinus maculatus	Lumpenus fabricii	Stichaeus punctatus	Stichaeidae unid.	Ammodytes hexapterus	Reinhardtius hippoglossoides	Pleuronectidae unid.	Total Count
2012																																																												
1	B1-20	%	-	-	-	-	63	-	71	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	2	125	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	1	-	-	274
2	B1-50	%	-	-	-	-	4	5	5	-	17	-	1	-	2	-	-	-	-	2	-	-	-	-	-	1	-	-	7	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	53
3	B1-100	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
4	B1-100	%	-	-	-	-	5	-	-	-	5	-	-	-	-	-	-	-	-	24	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36
5	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
6	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
7	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
10	B1-200	NQ	-	-	-	-	9	-	-	-	1	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16
11	B1-350	NQ	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
12	B1-350	%	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	10
13	B1-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
14	B1-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
15	B1-500	%	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	2	-	-	1	-	-	-	-	-	-	-	6	-	1	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	-	-	1	-	21
16	B1-1000	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
17	B1-1000	%	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	10	-	5	10	-	-	-	-	-	-	-	-	-	34
18	B2-1000	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
19	B2-500	%	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	4	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	3	-	3	-	-	16	-	-	-	-	-	-	-	-	-	42
20	B2-350	%	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	1	-	6
21	B2-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
22	B2-200	%	-	-	-	-	9	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	17
23	B2-100	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
24	B2-100	%	-	-	-	-	1	1	-	-	10	-	-	-	-	-	-	-	-	13	-	1	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31
25	B2-50	%	-	-	-	-	8	-	2	-	1	-	-	-	2	-	-	-	-	2	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	36
26	B2-20	%	-	-	-	-	61	-	74	-	2	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	275	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	10	3	-	-	-	-	428
27	B2-20	%	-	-	5	-	175	-	53	-	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	198	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	64	-	-	-	-	-	501
28	B2-20	%	-	-	-	-	54	5	104	-	2	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	197	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	1	29	-	-	-	397
29	B1-200	%	-	-	-	-	62	-	4	-	1	2	-	1	3	-	-	-	-	10	1	-	-	-	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	93
30	BX-200	%	-	-	-	-	19	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
31	BX-350	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
32	BX-350	%	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
33	BX-500	%	-	-	-	-	6	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-	17	-	-	-	-	-	-	-	-	-	29
34	BX-1000	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2012 Total			**1**	**0**	**5**	**0**	**518**	**11**	**313**	**0**	**41**	**2**	**4**	**1**	**14**	**3**	**1**	**0**	**0**	**58**	**1**	**1**	**0**	**3**	**2**	**9**	**1**	**2**	**832**	**0**	**0**	**0**	**3**	**1**	**0**	**0**	**12**	**1**	**1**	**2**	**1**	**0**	**11**	**0**	**4**	**0**	**17**	**2**	**5**	**47**	**17**	**1**	**0**	**83**	**4**	**29**	**1**	**3**	**0**	**2068**
2013																																																												
1	A6-20	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2	A6-20	1.035647	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
3	A6-37	1.135466	-	-	-	-	1	2	-	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
4	A6-50	2.293688	-	-	-	-	1	2	3	-	4	-	-	-	-	-	-	-	-	4	-	-	2	-	-	-	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
5	A6-100	1.442693	-	-	-	-	-	-	-	-	3	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	10	-	-	-	-	1	21
6	A6-200	2.893269	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
7	A6-350	2.344228	-	-	-	-	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	-	-	-	-	-	-	-	36
8	A6-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9	A6-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
10	A6-750	3.640059	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11	A6-750	0.665139	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3
12	A6-1000	2.803772	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
13	A2-1000	0.610078	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	11
14	A2-750	2.33499	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	6
15	A2-500	1.074065	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	4
16	A2-350	0.907997	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
17	A2-200	1.612489	-	-	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
18	A2-100	3.616285	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
19	A2-40	3.274781	-	-	-	-	-	-	-	-	10	-	-	-	4	-	-	-	-	4	-	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	21
20	A2-10	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
21	A2-10	2.769322	-	-	-	-	-	-	5	-	-	2	-	-	1	6	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	18
22	A1-20	5.171286	-	-	-	-	2	4	3	-	-	-	-	-	2	5	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
23	A1-50	3.190911	-	-	-	-	-	-	-	-	13	-	-	-	2	-	-	-	-	5	-	-	-	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
24	A1-100	2.204217	-	-	-	-	3	-	-	-	3	-	-	-	-	-	-	-	-	8	-	1	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
25	A1-200	2.477243	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
26	A1-350	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
27	A1-350	1.071298	-	-	-	-	4	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	8
28	A1-500	1.592984	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	4
29	A1-750	1.693028	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	4	1	-	-	-	-	-	-	-	-	-	-	-	16
30	A1-1000	0.776516	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	5
31	TBS-1000	0.910977	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	9
32	TBS-750	0.699566	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	19
33	TBS-500	0.962429	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	1	15	-	-	-	-	-	-	-	-	-	-	-	22
34	TBS-350	1.027574	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	4	-	1	-	-	-	-	-	-	-	-	-	12
35	TBS-200	0.635903	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17
36	TBS-100	2.978531	-	-	-	-	-	-	2	-	12	-	-	-	-	-	-	-	-	12	-	1	-	-	1	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	34
37	TBS-50	1.775666	-	-	-	-	6	-	1	-	16	-	-	-	5	-	-	-	-	6	-	-	2	-	-	-	-	-	-	-	-	-	9	2	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
38	MAC-200	1.06392	-	-	-	-	4	-	-	-	1	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
39	MAC-100	2.111486	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	7	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	15
40	MAC-50	2.435099	-	-	-	-	-	-	2	-	2	-	-	-	2	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	7	-	-	-	-	-	29
41	GRY-20	1.793955	-	-	-	-	2	-	6	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14
42	GRY-50	1.387977	-	-	-	-	-	-	2	-	9	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	26
43	GRY-100	1.342108	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
44	GRY-200	2.220034	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
45	GRY-350	1.030782	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-	6	-	-	-	-	-	-	-	-	-	22
46	GRY-500	0.989405	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	-	-	1	3	2	5	-	1	-	-	-	-	-	-	-	-	-	22
47	GRY-750	0.687607	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	20
48	GRY-1000	1.426546	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	9
49	MAC-1000	1.617925	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	9
50	MAC-500	1.141271	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
2013 Total			**0**	**5**	**0**	**0**	**121**	**9**	**24**	**0**	**80**	**2**	**0**	**0**	**37**	**11**	**0**	**5**	**1**	**59**	**1**	**2**	**5**	**3**	**4**	**16**	**1**	**0**	**9**	**0**	**1**	**0**	**19**	**3**	**4**	**0**	**55**	**5**	**0**	**0**	**0**	**6**	**17**	**0**	**4**	**3**	**21**	**40**	**0**	**15**	**28**	**0**	**0**	**18**	**0**	**1**	**0**	**0**	**1**	**636**
2014																																																												
1	A6-20	2.385653	-	-	-	-	1	9	3	-	-	6	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	25
2	A6-20	2.778307	-	-	-	-	1	33	8	18	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	68
3	A6-37	2.005864	-	-	-	-	-	1	5	-	6	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	21
4	A6-50	NQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
5	A6-50	1.384454	-	-	-	-	3	1	3	-	5	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
6	A6-100	1.602729	-	-	-	-	-	-	2	-	3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	10	-	-	-	-	-	-	-	-	18
7	A5-100	3.118603	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
8	A5-100	2.515944	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9

			Rajidae		Osmeridae	Myctophidae	Gadidae	Cottidae									Hemitripteridae	Psychrolutidae		Agonidae		Cyclopteridae		Liparidae									Zoarcidae																		Stichaeidae						Ammodytidae	Pleuronectidae		
PSBT-A Haul	Station	Effort	Amblyraja hyperborea	Rajidae unid.	Mallotus catervarius	Myctophidae unid.	Boreogadus saida	Artediellus scaber	Gymnocanthus tricuspis	Icelus bicornis	Icelus spatula	Icelus spp.	Myoxocephalus scorpius	Triglops nybelini	Triglops pingelii	Cottidae unid.	Hemitripteridae (unidentified)	Cottunculus microps	Psychrolutidae unid.	Aspidophoroides olrikii	Leptagonus decagonus	Eumicrotremus derjugini	Cyclopteridae unid.	Careproctus lerikimae	Liparis bathyarcticus	Liparis fabricii	Liparis gibbus	Liparis tunicatus	Liparis spp.	Paraliparis bathybius	Paraliparis spp.	Rhodichthys regina	Gymnelus hemifasciatus	Gymnelus viridis	Gymnelus spp. unid.	Lycenchelys kolthoffi	Lycodes adolfi	Lycodes eudipleurostictus	Lycodes frigidus	Lycodes jugoricus	Lycodes mucosus	Lycodes pallidus	Lycodes polaris	Lycodes raridens	Lycodes reticulatus	Lycodes rossi	Lycodes sagittarius	Lycodes seminudus	Lycodes squamiventer	Lycodes spp. unid.	Anisarchus medius	Eumesogrammus praecisus	Leptoclinus maculatus	Lumpenus fabricii	Stichaeus punctatus	Stichaeidae unid.	Ammodytes hexapterus	Reinhardtius hippoglossoides	Pleuronectidae unid.	Grand Total
9	A5-50	0.82789	-	-	-	-	2	3	-	22	3	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35
10	A5-35	1.574363	-	-	-	-	1	-	1	-	10	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	23
11	A5-20	2.127862	-	-	-	-	2	10	21	5	2	14	-	-	9	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	71
12	A4-20	1.781867	-	-	-	-	1	-	6	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15
13	A4-20	1.589889	-	-	-	-	2	1	36	-	-	6	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
14	A4-35	1.810177	-	-	-	-	2	-	4	-	13	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	28
15	A4-50	1.780707	-	-	-	-	3	-	-	3	6	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
16	A4-100	2.075602	-	-	-	-	-	-	-	6	3	-	-	-	2	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18
17	A2-1000	0.223393	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	3	-	-	3	-	-	-	-	-	-	-	-	-	15
18	A2-750	0.953646	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	6
19	A2-500	0.918765	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2	-	2	-	-	-	-	-	-	-	-	-	14
20	A2-350	0.704406	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
21	A2-200	0.859142	-	-	-	-	3	-	-	2	-	-	-	5	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	13
22	A2-100	1.368862	-	-	-	-	2	-	-	11	-	1	-	2	1	-	-	-	-	35	-	-	-	-	-	-	-	1	-	-	-	-	3	-	-	-	-	-	-	-	-	-	1	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	61
23	A2-50	3.120812	-	-	-	-	3	-	-	-	6	-	-	-	3	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19
24	A2-40	2.472132	-	-	-	-	-	-	2	-	12	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1	-	-	-	-	22
25	A2-20	1.781682	-	-	-	-	42	2	22	2	-	4	-	-	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	87
26	A2-20	1.774391	-	-	-	-	33	5	23	3	-	12	-	-	23	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	105
27	A2-10	1.932361	-	-	-	-	45	-	16	-	-	2	-	-	3	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	76
28	A2-10	1.905998	-	-	-	-	38	1	42	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	85
29	A1-20	2.3234	-	-	-	-	7	14	10	-	-	21	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	84
30	A1-20	1.81819	-	-	-	-	14	10	4	3	-	15	-	-	9	-	-	-	-	1	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	65
31	A1-20	1.901058	-	-	-	-	23	24	36	3	-	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	125
32	A1-50	2.091611	-	-	-	-	1	-	-	-	8	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	13
33	A1-50	2.171493	-	-	-	-	1	-	1	2	9	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	16
34	A1-50	1.839289	-	-	-	-	1	-	2	-	9	5	-	-	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	23
35	A1-100	NQ	-	-	-	-	-	-	-	7	4	-	-	-	3	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41
36	A1-100	2.674352	-	-	-	-	1	-	-	2	-	-	-	-	2	-	-	-	-	3	-	1	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
37	A1-100	2.746107	-	-	-	-	1	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
38	A1-200	0.752003	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
39	A1-200	1.527653	-	-	-	-	2	-	-	1	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	9
40	A1-200	0.97646	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
41	A1-350	0.865015	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	6
42	A1-350	0.91585	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	7
43	A1-350	1.193997	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	5
44	A1-500	0.988116	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	9
45	A1-500	NQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
46	A1-500	0.636216	-	-	-	-	3	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	3	7	-	-	-	-	-	-	-	-	-	-	-	18
47	A1-750	0.636307	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	-	1	-	-	1	-	-	-	-	7	1	-	2	-	-	-	-	-	-	-	-	-	22
48	A1-750	0.423649	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	1	-	-	-	-	-	-	-	6	2	-	-	-	-	-	-	-	-	-	-	-	15
49	A1-750	0.301991	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	14
50	A1-1000	0.21329	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	2	3	-	-	-	-	-	-	-	-	-	-	-	16
51	A1-1000	0.237111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	6	2	-	-	-	-	-	-	-	-	-	-	-	16
52	A1-1000	NQ	-	-	-	1	6	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	9
53	A1-1000	0.268609	-	-	-	-	10	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	-	-	-	-	5	3	-	-	-	-	-	-	-	-	-	-	-	32
54	TBS-1000	NQ	-	-	-	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8
55	TBS-1000	0.212245	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	16
56	TBS-750	0.263291	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	9
57	TBS-500	0.552908	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	2	-	2	-	-	-	-	-	-	-	-	-	12
58	TBS-350	0.732896	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3
59	TBS-200	0.951174	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
60	TBS-100	2.98711	-	-	-	-	2	-	-	-	2	-	-	-	-	-	-	-	-	17	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	2	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	29
61	TBS-50	1.521903	-	-	-	-	3	-	1	7	1	-	-	-	2	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
62	A1-500	0.74383	-	-	-	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	13
63	A5-1000	0.263271	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	8
64	A5-750	0.272733	1	-	-	-	4	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	14
65	A5-500	0.255062	-	1	-	-	18	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	-	-	-	-	-	-	-	32
66	A5-350	NQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
67	A5-350	0.523021	-	-	-	-	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	1	1	3	3	-	3	-	-	-	-	-	-	-	-	-	41
68	A5-200	0.708763	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	5
69	A6-1000	NQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
70	A6-1000	0.284813	-	-	-	-	10	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	-	21
71	A6-750	NQ	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	1	-	8
72	A6-200	0.735161	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-	-	-	-	4	-	-	-	-	-	8
73	A6-350	0.499383	-	-	-	-	65	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	3	3	-	2	-	-	-	-	-	-	-	-	-	75
74	A6-500	0.365451	-	-	-	-	37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	44
75	A6-750	0.238165	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	16	-	-	-	-	-	-	-	-	-	4	4	-	4	-	-	-	-	-	-	-	-	-	32
76	A6-1500	0.155243	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	-	-	2	-	-	-	-	2	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	16
2014 Total			**1**	**1**	**0**	**3**	**485**	**114**	**251**	**101**	**103**	**131**	**1**	**12**	**107**	**5**	**0**	**8**	**1**	**114**	**1**	**5**	**0**	**2**	**0**	**25**	**1**	**1**	**25**	**2**	**0**	**8**	**29**	**10**	**0**	**1**	**109**	**12**	**3**	**0**	**9**	**3**	**17**	**1**	**2**	**13**	**66**	**57**	**0**	**24**	**12**	**3**	**2**	**27**	**1**	**0**	**1**	**2**	**0**	**1912**
PSBT-A All Years Total			**2**	**6**	**5**	**3**	**1124**	**134**	**588**	**101**	**224**	**135**	**5**	**13**	**158**	**19**	**1**	**13**	**2**	**231**	**3**	**8**	**5**	**8**	**6**	**50**	**3**	**3**	**866**	**2**	**1**	**8**	**51**	**14**	**4**	**1**	**176**	**18**	**4**	**2**	**10**	**9**	**45**	**1**	**10**	**16**	**104**	**99**	**5**	**86**	**57**	**4**	**2**	**128**	**5**	**30**	**2**	**5**	**1**	**4616**

Appendix E1 Table 4. Total number of fishes caught by Canadian Benthic Trawl (CBT) by year and haul. Fishes are in phylogenetic order by family. Catch effort is proportional (%), bad haul (NQ), or the multiplication factor by which catch is standardized to ind. 1000 m^2.

			Rajidae		Osmeridae		Gadidae	Cottidae								Psychrolutidae	Agonidae		Cyclopteridae		Liparidae						Zoarcidae																		Stichaeidae					Pleuronectidae			Misc	
CBT Haul	Station	Effort	Amblyraja hyperborea	Rajidae	Mallotus catervarius	Osmerus dentex	Boreogadus saida	Artediellus scaber	Gymnocanthus tricuspis	Icelus bicornis	Icelus spatula	Myoxocephalus scorpius	Triglops nybelini	Triglops pingelii	Cottidae unid.	Cottunculus microps	Aspidophoroides olrikii	Leptagonus decagonus	Eumicrotremus derjugini	Cyclopteridae unid.	Careproctus lerikimae	Liparis bathyarcticus	Liparis fabricii	Liparis gibbus	Liparis tunicatus	Liparis spp.	Rhodichthys regina	Gymnelus hemifasciatus	Gymnelus viridis	Gymnelus spp. unid.	Lycenchelys kolthoffi	Lycodes adolfi	Lycodes eudipleurostictus	Lycodes jugoricus	Lycodes mucosus	Lycodes pallidus	Lycodes polaris	Lycodes raridens	Lycodes reticulatus	Lycodes rossi	Lycodes sagittarius	Lycodes seminudus	Lycodes squamiventer	Lycodes spp. unid.	Anisarchus medius	Eumesogrammus praecisus	Leptoclinus maculatus	Lumpenus fabricii	Stichaeidae unid.	Hippoglossoides robustus	Pleuronectidae	Reinhardtius hippoglossoides	Teleost unid.	Total Count
2012																																																						
1	B1-20	%	-	-	-	-	6	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
2	B1-20	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3	B1-20	%	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
4	B1-50	%	-	-	-	-	8	7	7	-	32	-	-	9	-	-	4	-	-	-	-	-	1	-	-	25	-	4	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	1	1	-	-	-	-	101
5	B1-100	%	-	-	-	-	2	-	2	-	-	-	-	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
6	B1-200	NQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
7	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8	B1-350	%	-	-	-	-	5	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
9	B1-350	%	-	-	-	-	26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	6	-	-	-	-	-	-	-	-	-	-	4	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	40
10	B1-500	%	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	9	2	-	-	-	-	-	-	-	-	-	-	-	21
11	B1-1000	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
12	B1-1000	%	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	2	-	-	-	-	-	-	-	-	-	-	-	6
13	B2-1000	NQ	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	6	1	-	-	-	-	-	-	-	-	-	-	20
14	B2-500	%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	1	-	6
15	B2-350	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
16	B2-350	%	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	5	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20
17	B2-200	NQ	-	-	-	-	5	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	1	-	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	20
18	B2-200	NQ	-	-	-	-	10	-	-	-	-	-	-	1	-	-	18	-	-	-	-	-	-	1	-	20	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	24	-	-	-	-	76
19	B2-100	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
20	B2-100	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
21	B2-50	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
22	B2-50	NQ	-	-	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	10
23	B2-50	%	-	-	-	-	-	1	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
24	B2-20	%	-	-	-	-	33	-	12	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	11	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	64
25	B2-20	%	-	-	1	-	60	-	79	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	-	-	-	255
26	B2-20	%	-	-	-	1	22	-	3	-	-	1	-	-	64	-	-	-	-	-	-	-	-	-	-	157	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	257
27	B1-200	%	-	-	-	-	8	-	-	-	-	-	-	2	-	-	5	1	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	21
28	BX-200	%	-	-	-	-	31	-	-	-	-	-	-	-	-	-	8	-	-	-	1	-	6	-	-	18	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	68
29	BX-350	%	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
30	BX-500	%	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	1	-	-	-	-	-	-	-	-	-	11
31	BX-1000	NQ	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	1	-	12	9	-	-	-	-	-	-	-	-	-	-	-	28
2012 Total			**5**		**1**	**1**	**233**	**8**	**110**	**0**	**32**	**1**	**0**	**18**	**65**	**0**	**46**	**1**	**0**	**0**	**11**	**2**	**17**	**3**	**0**	**357**	**0**	**4**	**0**	**0**	**0**	**5**	**1**	**2**	**0**	**0**	**19**	**1**	**6**	**1**	**37**	**23**	**1**	**2**	**2**	**1**	**2**	**16**	**32**	**1**	**0**	**1**	**0**	**1068**
2013																																																						
1	A6-20	NQ	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
2	A6-20	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
3	A6-37	0.827038	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
4	A6-50	NQ	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
5	A6-50	2.691102	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
6	A6-100	NQ	-	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	7	-	-	1	-	-	12
7	A6-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
8	A6-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
9	A6-200	3.269767	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9
10	A6-350	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
11	A6-350	4.361914	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
12	A6-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
13	A6-500	2.18967	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	5
14	A6-750	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
15	A6-750	1.856347	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
16	A6-1000	2.587292	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
17	A6-1000	2.373289	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
18	A2-1000	2.808573	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	9
19	A2-750	2.224728	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	8
20	A2-500	1.487083	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	5	-	-	-	-	-	-	-	-	-	-	-	8
21	A2-350	0.841716	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
22	A2-200	2.276933	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
23	A2-100	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
24	A2-100	2.450266	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
25	A2-100	2.514952	-	-	-	-	1	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
26	A2-40	2.515999	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
27	A2-10	1.875435	-	-	-	-	-	-	5	-	-	-	-	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	15
28	A1-20	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
29	A1-20	1.577511	-	-	-	-	1	3	1	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	11
30	A1-50	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
31	A1-50	2.932676	-	-	-	-	1	-	1	-	7	-	-	2	-	-	5	-	-	1	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22
32	A1-100	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
33	A1-100	2.211967	-	-	-	-	-	-	-	-	6	-	-	-	-	-	14	-	-	-	-	-	1	-	1	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26
34	A1-200	1.828621	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
35	A1-350	2.003332	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
36	A1-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	2
37	A1-500	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
38	A1-750	1.056397	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	5
39	A1-1000	0.696789	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	3

			Rajidae		Osmeridae		Gadidae	Cottidae								Psychrolutidae	Agonidae		Cyclopteridae		Liparidae							Zoarcidae																	Stichaeidae					Pleuronectidae			Misc	
CBT Haul	Station	Effort	Amblyraja hyperborea	Rajidae	Mallotus catervarius	Osmerus dentex	Boreogadus saida	Artediellus scaber	Gymnocanthus tricuspis	Icelus bicornis	Icelus spatula	Myoxocephalus scorpius	Triglops nybelini	Triglops pingelii	Cottidae unid.	Cottunculus microps	Aspidophoroides olrikii	Leptagonus decagonus	Eumicrotremus derjugini	Cyclopteridae unid.	Careproctus lerikimae	Liparis bathyarcticus	Liparis fabricii	Liparis gibbus	Liparis tunicatus	Liparis spp.	Rhodichthys regina	Gymnelus hemifasciatus	Gymnelus viridis	Gymnelus spp. unid.	Lycenchelys kolthoffi	Lycodes adolfi	Lycodes eudipleurostictus	Lycodes jugoricus	Lycodes mucosus	Lycodes pallidus	Lycodes polaris	Lycodes raridens	Lycodes reticulatus	Lycodes rossi	Lycodes sagittarius	Lycodes seminudus	Lycodes squamiventer	Lycodes spp. unid.	Anisarchus medius	Eumesogrammus praecisus	Leptoclinus maculatus	Lumpenus fabricii	Stichaeidae unid.	Hippoglossoides robustus	Pleuronectidae	Reinhardtius hippoglossoides	Teleost unid.	Total Count
40	TBS-1000	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	3
41	TBS-1000	0.78488	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
42	TBS-750	1.450346	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
43	TBS-500	0.834096	-	-	-	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	1	-	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	8	-	1	-	-	-	-	-	-	-	2	-	18
44	TBS-350	0.702901	-	-	-	-	12	-	-	-	-	-	-	1	-	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	2	-	-	4	-	-	-	-	1	5	-	2	-	-	-	-	-	-	-	-	-	30
45	TBS-200	0.747852	-	-	-	-	6	-	-	-	-	-	1	-	-	-	-	-	-	-	2	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
46	TBS-100	NQ	-	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	4
47	TBS-100	1.147404	-	-	-	-	2	-	-	-	26	-	-	-	-	-	11	-	1	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	44
48	TBS-50	1.573407	-	-	-	-	4	-	1	-	14	-	-	12	-	-	5	-	-	3	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	43
49	MAC-200	1.083973	-	-	-	-	9	-	-	3	-	-	-	4	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	24
50	MAC-100	1.813109	-	-	-	-	2	-	-	-	5	-	-	1	-	-	7	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	21
51	MAC-50	2.624824	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	6
52	GRY-20	NQ	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	3
53	GRY-20	1.282477	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	3
54	GRY-50	1.318347	-	-	-	-	-	-	1	-	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-	-	-	-	20
55	GRY-100	1.74086	-	-	-	-	-	-	-	-	1	-	-	-	-	-	3	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
56	GRY-200	1.715745	-	-	-	-	17	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	21
57	GRY-350	NQ	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
58	GRY-350	0.83299	-	-	-	-	11	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	2	2	-	1	-	-	-	-	-	-	-	-	-	20
59	GRY-500	1.062197	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	4	-	-	-	-	-	-	-	-	-	10
60	GRY-750	0.859325	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
61	GRY-1000	0.80363	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	4
62	MAC-1000	1.025703	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	2
63	MAC-500	0.787775	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3
64	MAC-500	0.892339	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	6
2013 Total			**0**	**2**	**0**	**0**	**98**	**7**	**12**	**3**	**76**	**0**	**3**	**28**	**6**	**5**	**49**	**0**	**1**	**4**	**8**	**0**	**13**	**2**	**1**	**3**	**1**	**10**	**2**	**4**	**1**	**14**	**8**	**0**	**1**	**6**	**13**	**1**	**1**	**0**	**22**	**34**	**0**	**12**	**20**	**0**	**0**	**13**	**3**	**0**	**1**	**2**	**1**	**491**
CBT All Years Total			**5**	**2**	**1**	**1**	**331**	**15**	**122**	**3**	**108**	**1**	**3**	**46**	**71**	**5**	**95**	**1**	**1**	**4**	**19**	**2**	**30**	**5**	**1**	**360**	**1**	**14**	**2**	**4**	**1**	**19**	**9**	**2**	**1**	**6**	**32**	**2**	**7**	**1**	**59**	**57**	**1**	**14**	**22**	**1**	**2**	**29**	**35**	**1**	**1**	**3**	**1**	**1559**

Appendix E1 Table 5. Total number of fishes caught by otter trawl (OT) by year and haul. Fishes are in phylogenetic order by family. Catch effort is proportional (%) or bad haul (NQ).

			Rajidae		Osmeridae	Gadidae	Cottidae							Psychrolutidae	Agonidae		Cyclopteridae		Liparidae						Zoarcidae												Stichaeidae				Pleuronectidae		
OT Haul	Station	Effort	Amblyraja hyperborea	Rajidae unid.	Osmerus dentex	Boreogadus saida	Artediellus scaber	Cottidae unid.	Gymnocanthus tricuspis	Icelus spatula	Icelus spp.	Myoxocephalus scorpius	Triglops pingelii	Psychrolutes spp.	Aspidophoroides monopterygius	Aspidophoroides olrikii	Eumicrotremus derjugini	Cyclopteridae	Careproctus lerikimae	Liparis bathyarcticus	Liparis fabricii	Liparis gibbus	Liparis tunicatus	Liparis spp.	Gymnelus hemifasciatus	Gymnelus viridis	Lycodes adolfi	Lycodes eudipleurostictus	Lycodes mucosus	Lycodes polaris	Lycodes raridens	Lycodes reticulatus	Lycodes sagittarius	Lycodes seminudus	Lycodes squamiventer	Lycodes spp. unid.	Anisarchus medius	Eumesogrammus praecisus	Leptoclinus maculatus	Lumpenus fabricii	Hippoglossoides robustus	Reinhardtius hippoglossoides	Total Count
2012																																											
1	B1-20	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
2	B1-20	%	-	-	1	333	2	6	53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9	-	-	**432**
3	B1-50	%	-	-	-	20	5	2	22	17	-	1	47	-	-	8	-	-	-	2	-	-	-	23	-	2	-	-	4	6	-	-	-	-	-	-	-	-	-	4	-	-	**163**
4	B1-100	%	-	-	-	12	1	-	-	2	-	-	-	-	-	27	1	-	-	-	-	-	-	24	-	1	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	**70**
5	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	**2**
6	B1-200	NQ	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
7	B1-350	%	-	-	-	38	-	-	-	-	-	-	-	-	-	-	-	-	1	-	5	-	-	1	-	-	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	1	**50**
8	B1-500	%	-	-	-	6	-	-	-	1	-	-	-	-	-	-	-	-	2	-	8	-	-	-	-	-	-	-	-	-	-	5	8	-	-	6	-	-	-	-	-	-	**36**
9	B1-1000	%	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	60	-	-	-	-	-	25	32	-	-	-	-	-	-	-	-	**120**
10	B2-500	%	-	-	-	24	-	-	-	-	-	-	-	-	-	-	-	-	21	-	23	-	-	20	-	-	-	-	-	-	-	-	8	9	1	24	-	-	-	-	-	4	**134**
11	B2-350	%	-	-	-	21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	**29**
12	B2-200	NQ	-	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	**6**
13	B2-200	%	-	-	-	16	-	-	1	2	-	-	4	-	-	5	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1	-	**33**
14	B2-100	NQ	-	-	-	10	-	-	-	-	1	-	-	-	-	6	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**22**
15	B2-100	%	-	-	-	13	-	-	-	-	-	-	-	-	1	12	1	-	-	-	-	-	-	18	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**46**
16	B2-50	%	-	-	-	7	4	-	10	8	-	-	9	-	-	1	-	-	-	-	-	3	-	9	1	-	-	-	-	6	-	1	-	-	-	-	2	-	-	2	-	-	**63**
17	B2-20	%	-	-	-	130	-	-	-	-	-	-	2	-	-	9	-	-	-	-	2	-	-	8	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	**152**
18	B1-200	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
19	BX-200	%	-	-	-	80	-	-	-	-	-	-	1	-	-	2	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	**88**
20	BX-350	%	-	-	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**10**
21	BX-500	%	-	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-	22	-	9	-	-	15	-	-	-	2	-	23	-	2	10	4	-	19	-	-	-	-	-	1	**123**
2012 Total			**2**	**0**	**1**	**738**	**12**	**8**	**86**	**30**	**1**	**1**	**63**	**0**	**1**	**70**	**2**	**0**	**46**	**2**	**55**	**4**	**0**	**162**	**2**	**3**	**60**	**2**	**4**	**36**	**1**	**14**	**51**	**45**	**1**	**50**	**2**	**1**	**1**	**15**	**2**	**7**	**1581**
2013																																											
1	A6-20	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
2	A6-37	%	-	-	-	-	-	-	2	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**7**
3	A6-50	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
4	A6-50	%	-	-	-	1	-	-	-	2	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**5**
5	A6-100	%	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**1**
6	A6-200	NQ	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**
7	A6-350	%	-	-	-	76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	-	-	-	-	**79**
8	A6-500	%	-	1	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	**10**
9	A6-750	%	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-	-	-	2	-	-	-	-	-	3	1	-	1	-	-	-	-	-	-	**9**
10	A6-1000	NQ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**0**
2013 Total			**0**	**1**	**0**	**85**	**0**	**0**	**2**	**5**	**0**	**0**	**3**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**2**	**0**	**0**	**0**	**0**	**0**	**3**	**4**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**113**
OT All Years Total			**2**	**1**	**1**	**823**	**12**	**8**	**88**	**35**	**1**	**1**	**66**	**1**	**1**	**70**	**2**	**1**	**46**	**2**	**56**	**4**	**1**	**162**	**3**	**3**	**62**	**2**	**4**	**36**	**1**	**14**	**54**	**49**	**2**	**51**	**2**	**1**	**1**	**15**	**2**	**8**	**1694**

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix E2

Maps of Pelagic and Demersal Fish Presence

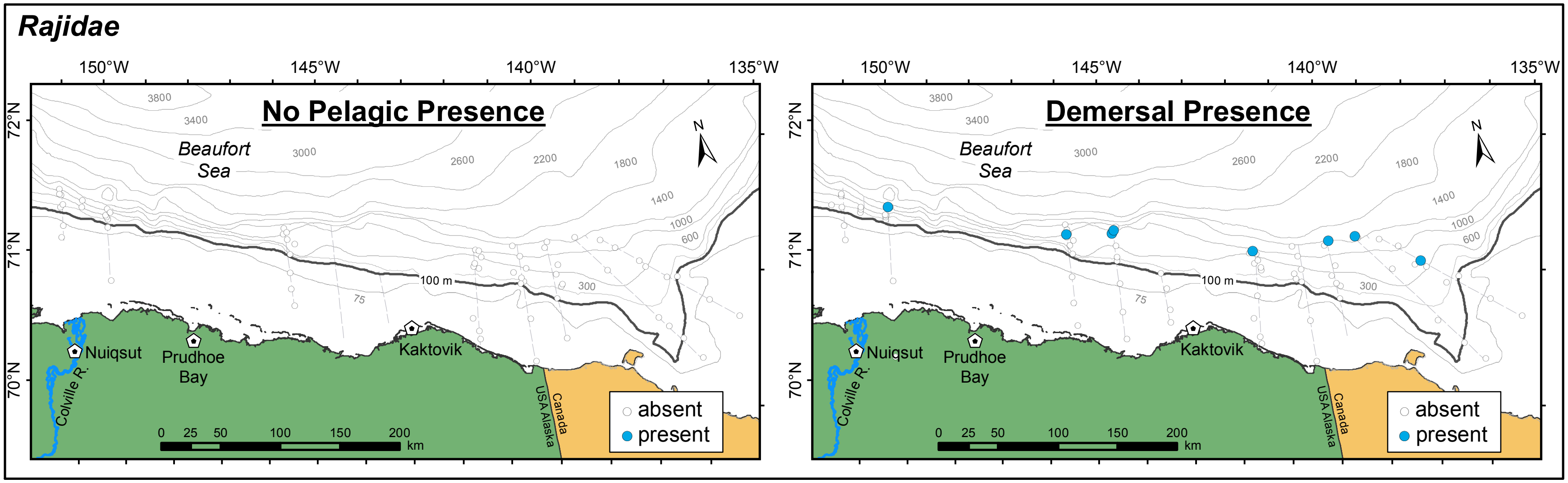
Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

LIST OF FIGURES

Rajidae

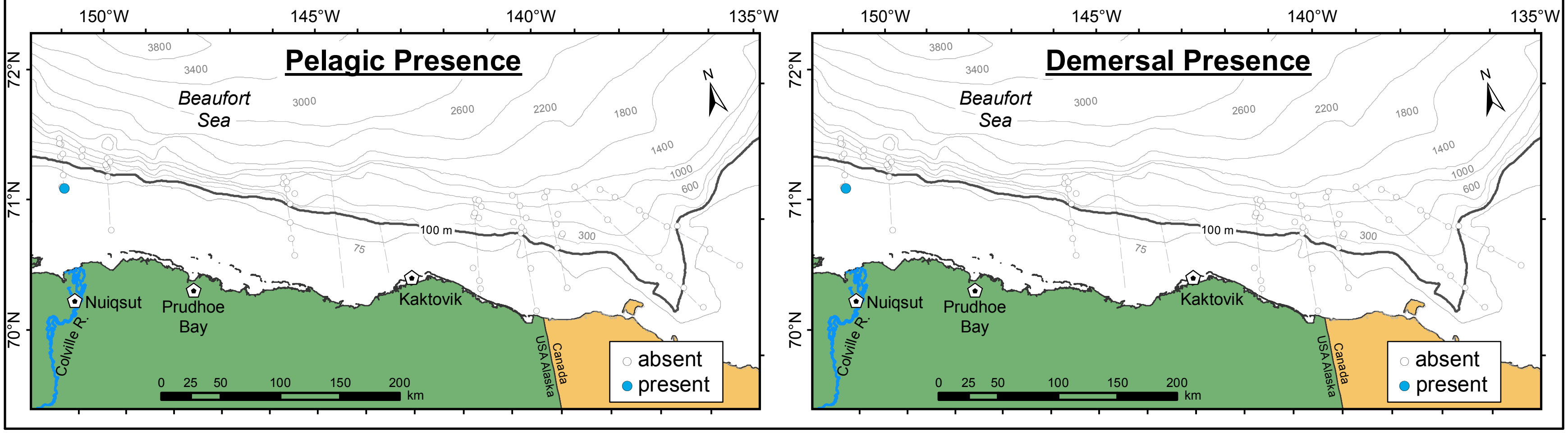
Skates



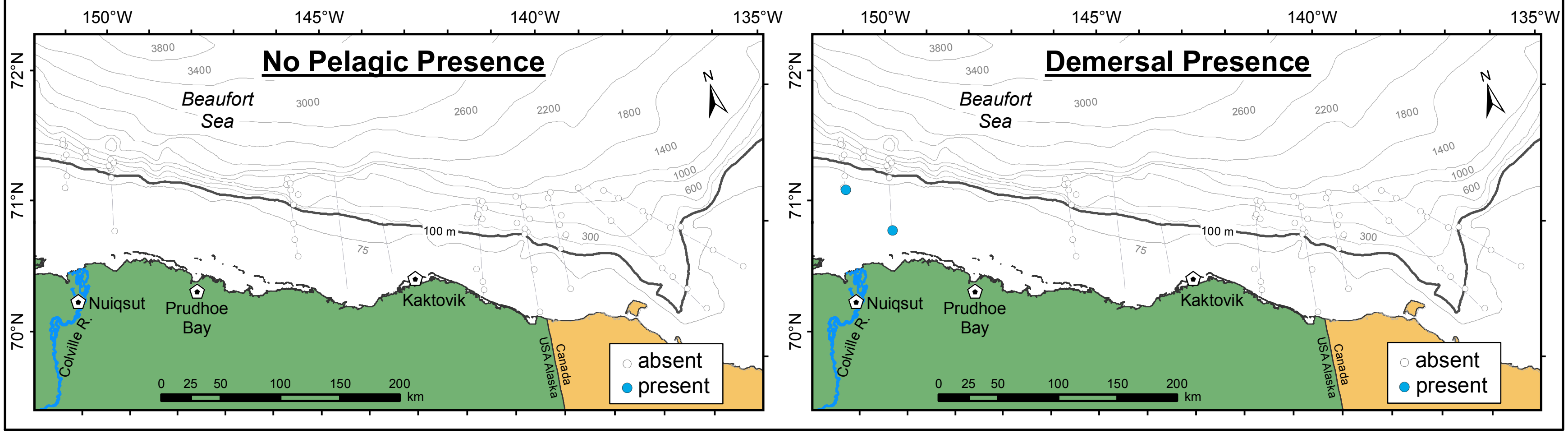
Appendix E2 Figure 1. Presence, Rajidae. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Osmeridae **Smelts**

Mallotus catervarius **Pacific Capelin**

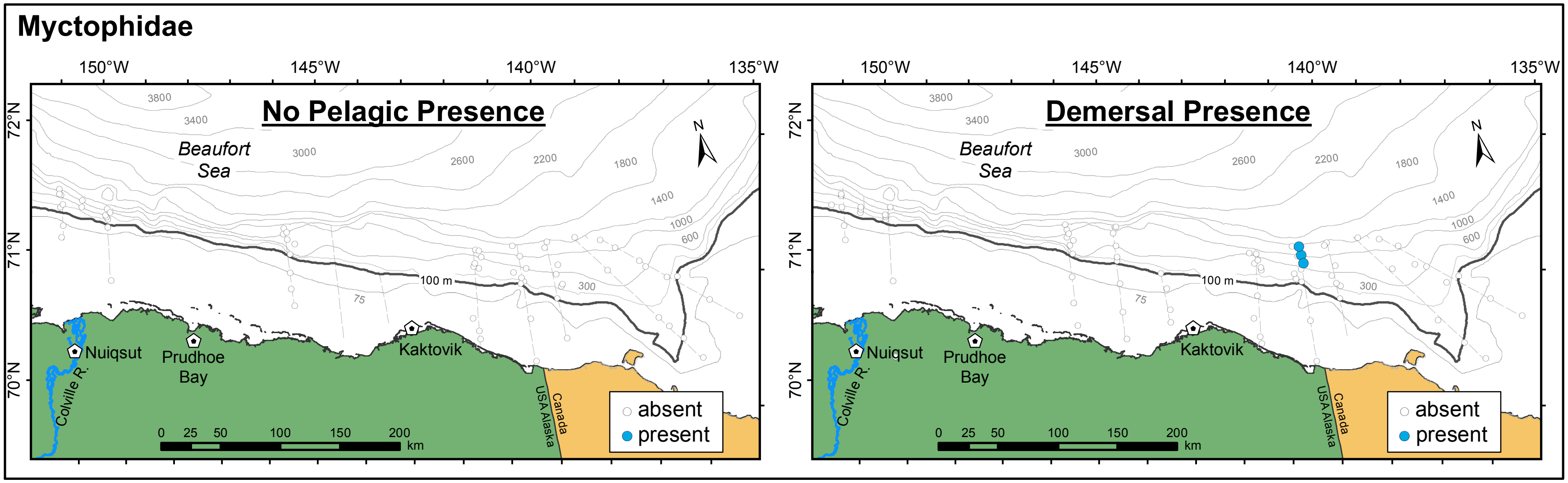


Osmerus dentex **Arctic Smelt**



Appendix E2 Figure 2. Presence, Osmeridae: *Mallotus catervarius* and *Osmerus dentex*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

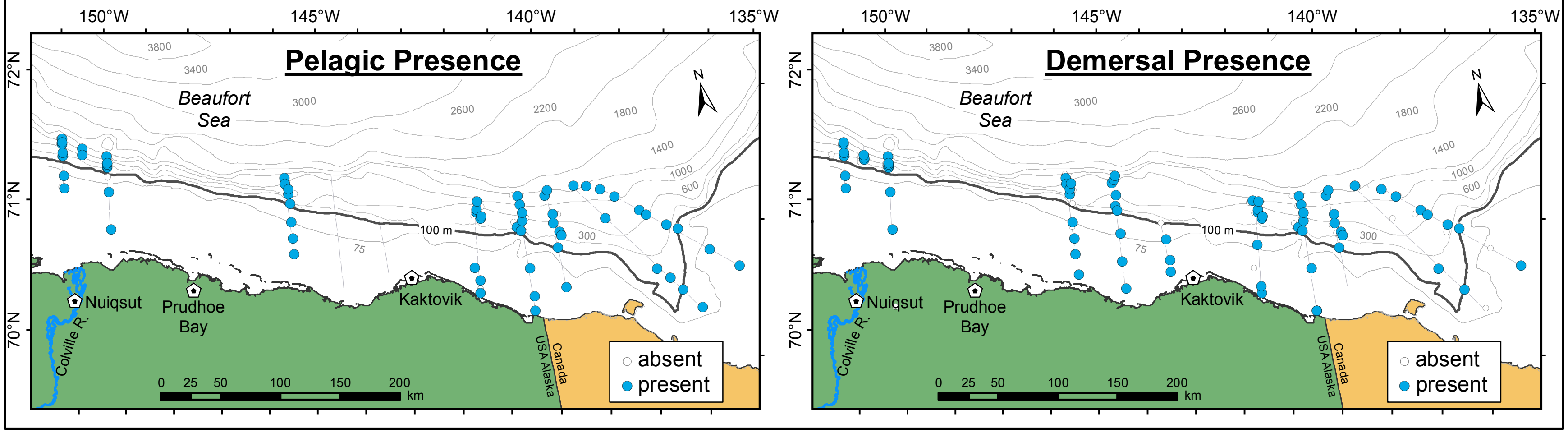
Myctophidae **Lanternfishes**



Appendix E2 Figure 3. Presence, Myctophidae. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Gadidae **Cods**

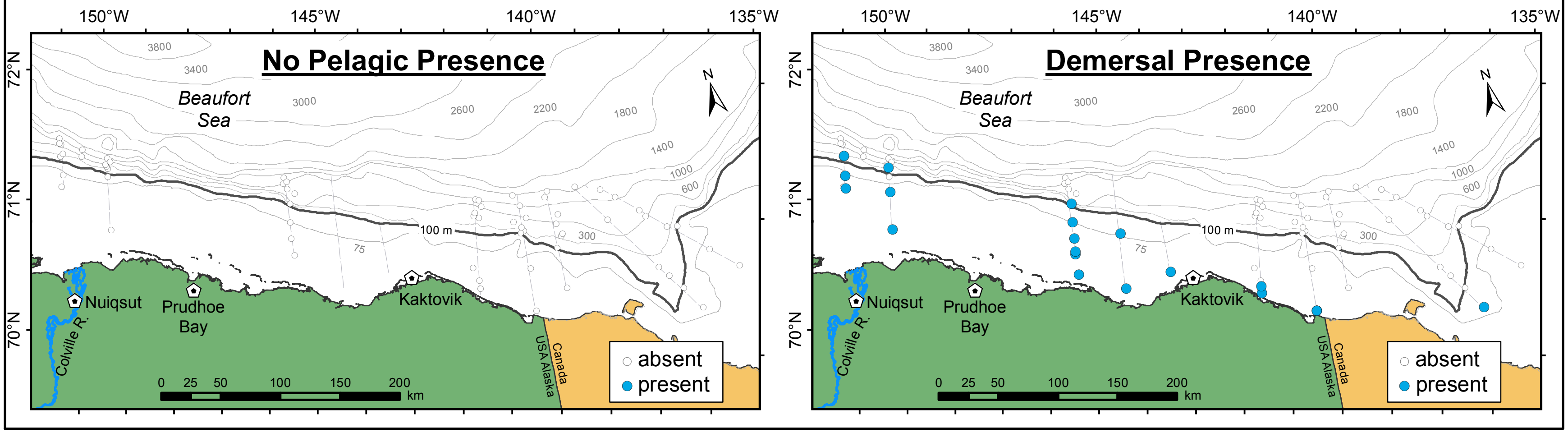
Boreogadus saida **Arctic Cod**



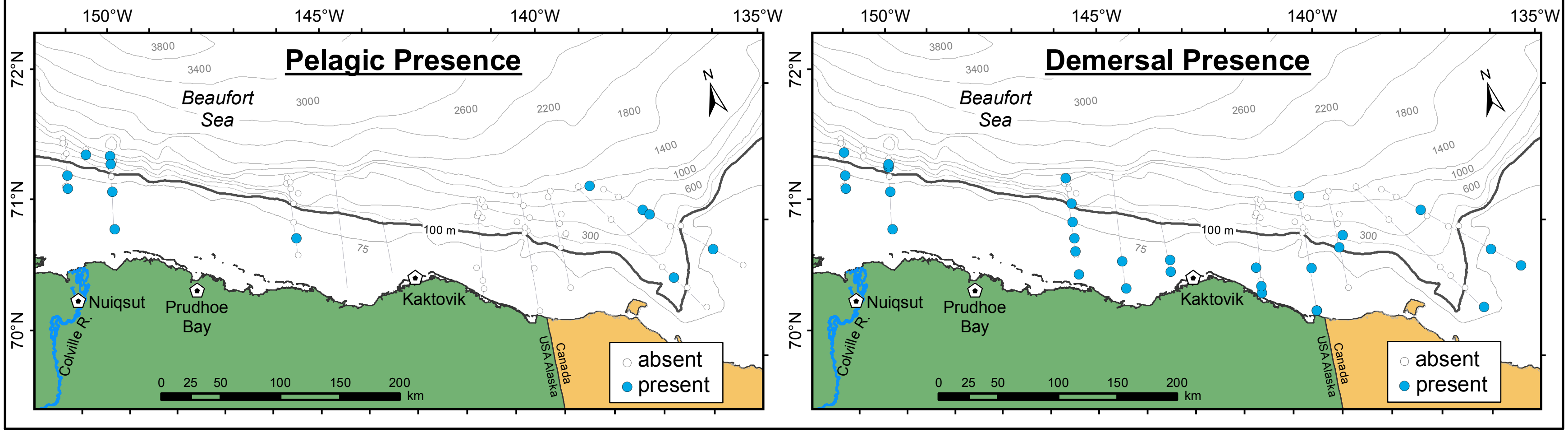
Appendix E2 Figure 4. Presence, Gadidae: *Boreogadus saida*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Cottidae Sculpins

Artediellus scaber Hamecon

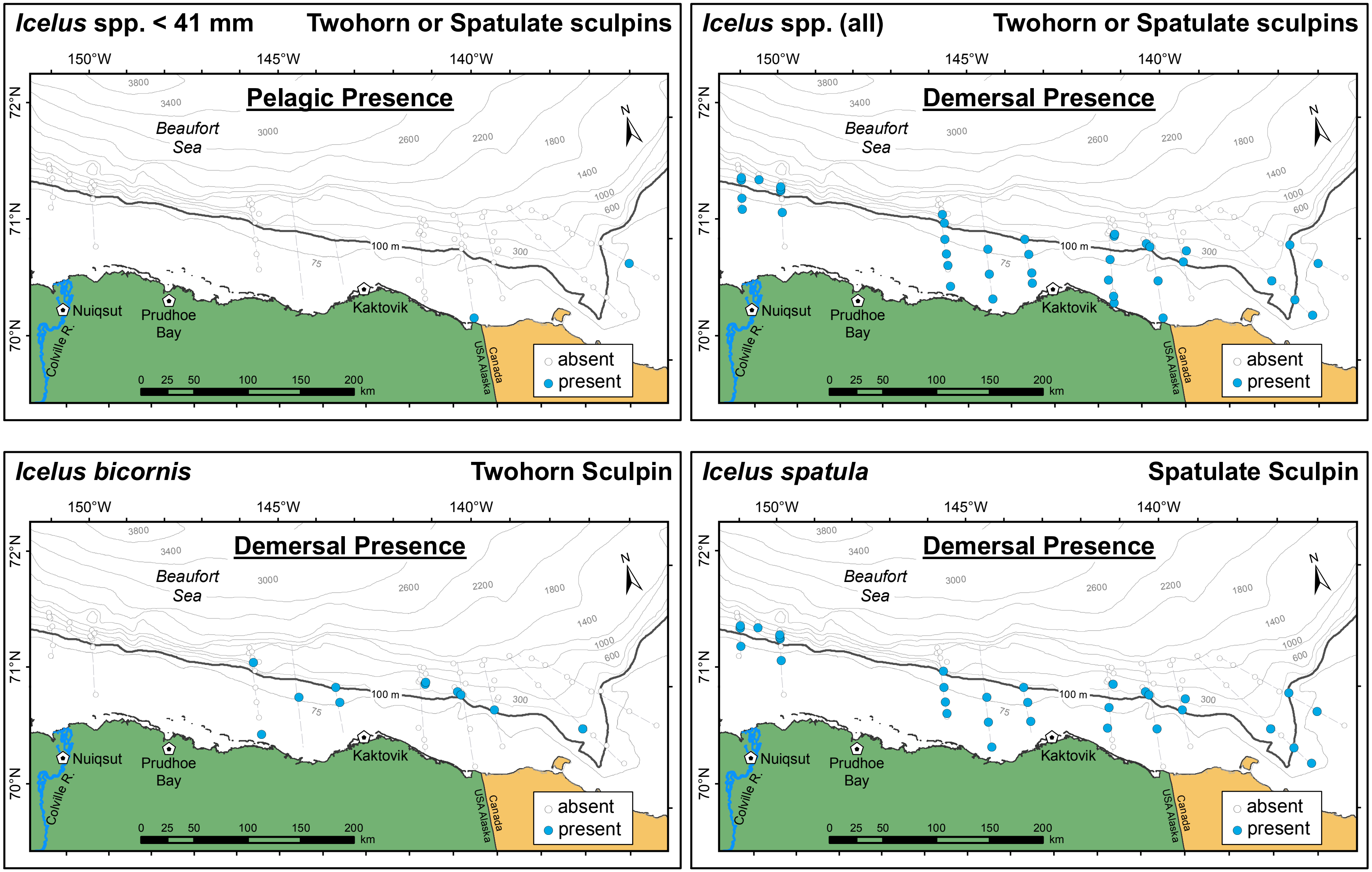


Gymnocanthus tricuspis Arctic Staghorn Sculpin



Appendix E2 Figure 5. Presence, Cottidae: *Artediellus scaber* and *Gymnocanthus tricuspis*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Cottidae Sculpins



***Icelus* spp. < 41 mm Twohorn or Spatulate sculpins**

***Icelus* spp. (all) Twohorn or Spatulate sculpins**

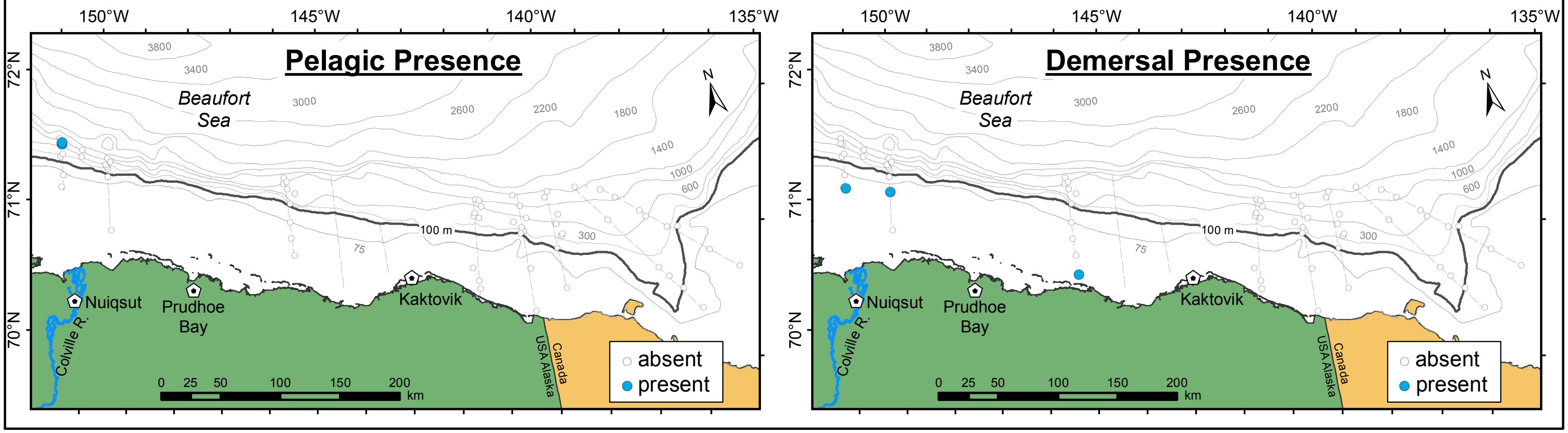
***Icelus bicornis* Twohorn Sculpin**

***Icelus spatula* Spatulate Sculpin**

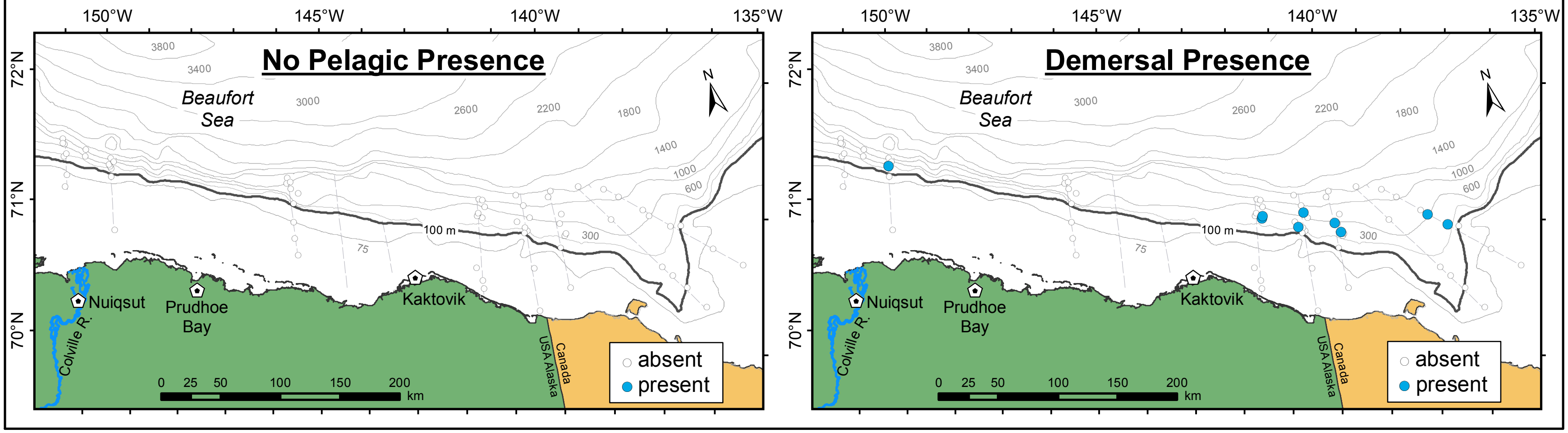
Appendix E2 Figure 6. Presence, Cottidae: *Icelus* spp. <41 mm (all, pelagic), and demersal: *Icelus* spp. (all), *I. bicornis* and *I. spatula*. Beaufort Sea 2012–2014.

Cottidae **Sculpins**

Myoxocephalus scorpius **Shorthorn Sculpin**



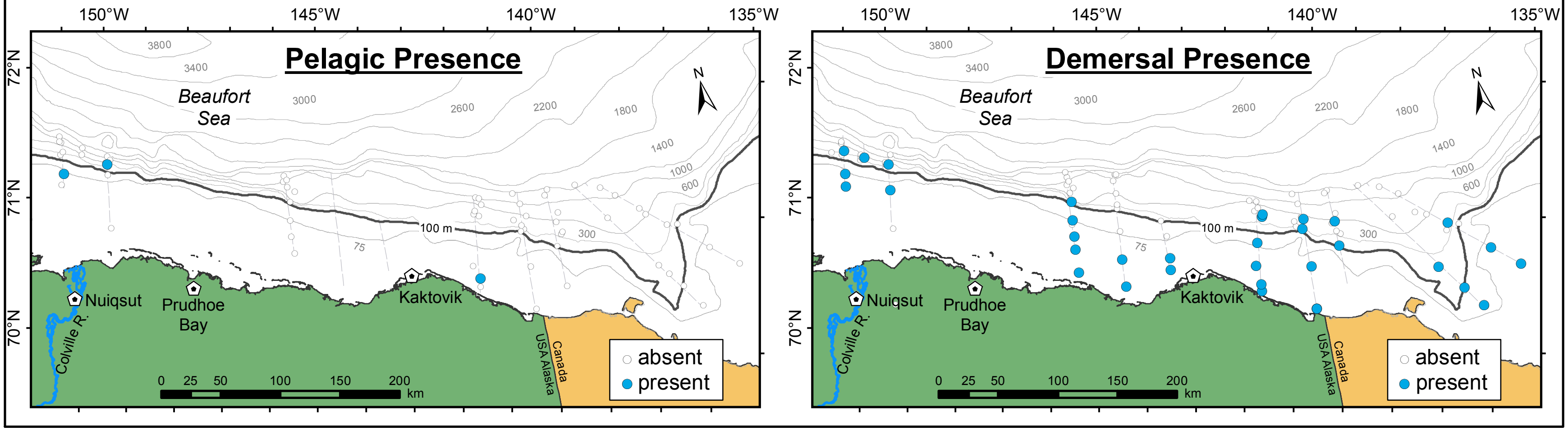
Triglops nybelini **Bigeye Sculpin**



Appendix E2 Figure 7. Presence, Cottidae: *Myoxocephalus scorpius* and *Triglops nybelini*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Cottidae **Sculpins**

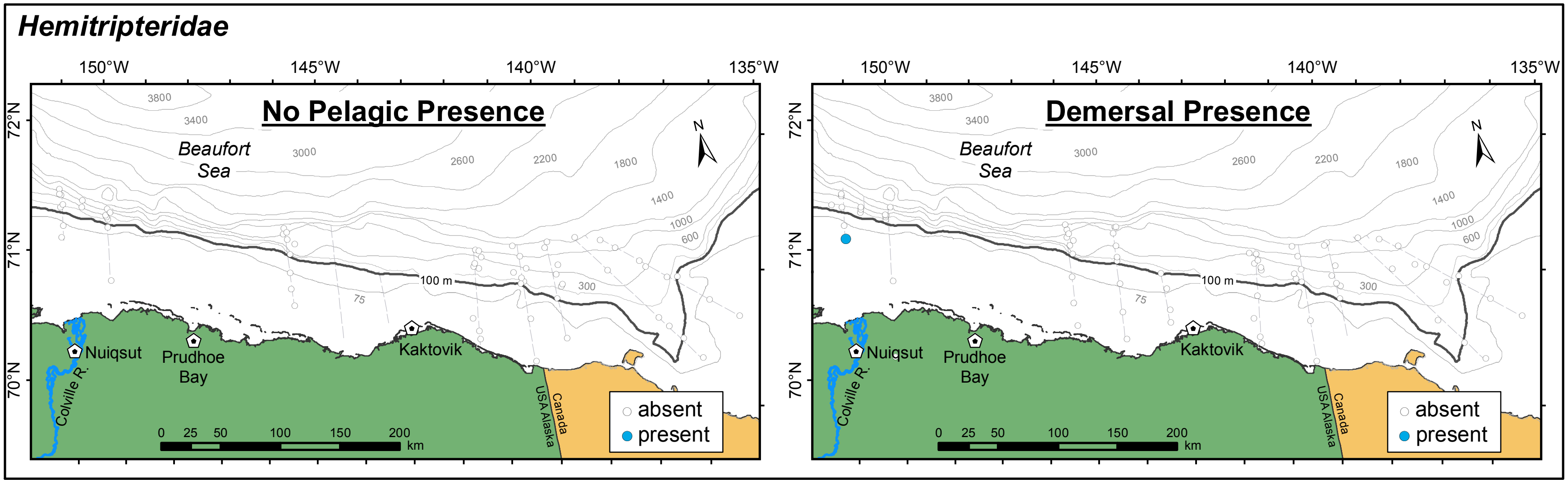
Triglops pingelii **Ribbed Sculpin**



Appendix E2 Figure 8. Presence, Cottidae: *Triglops pingelii*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Hemitripteridae

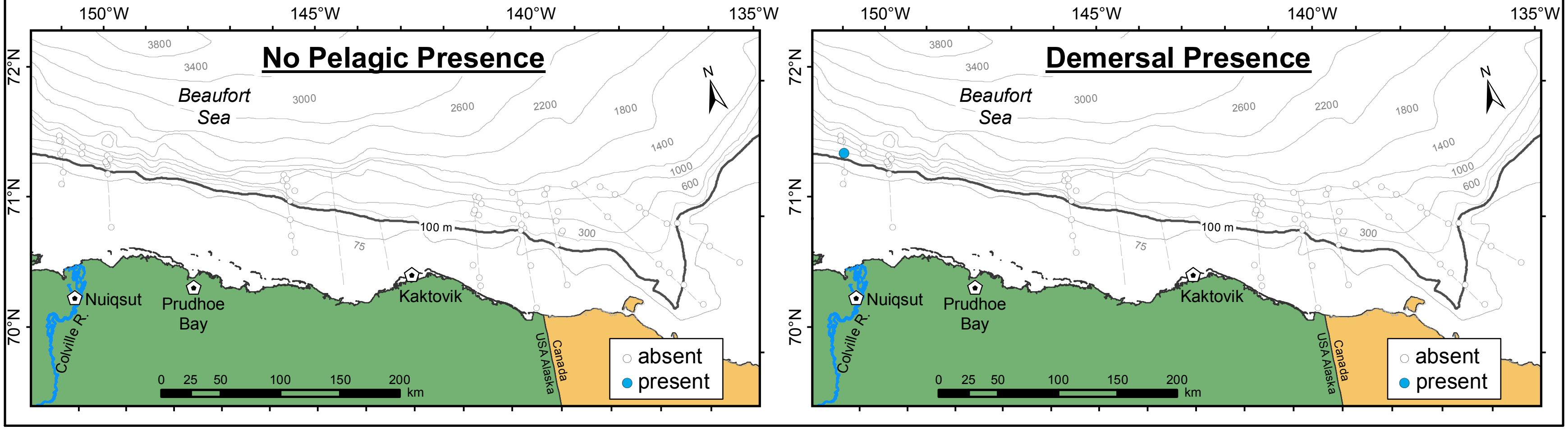
Sailfin sculpins



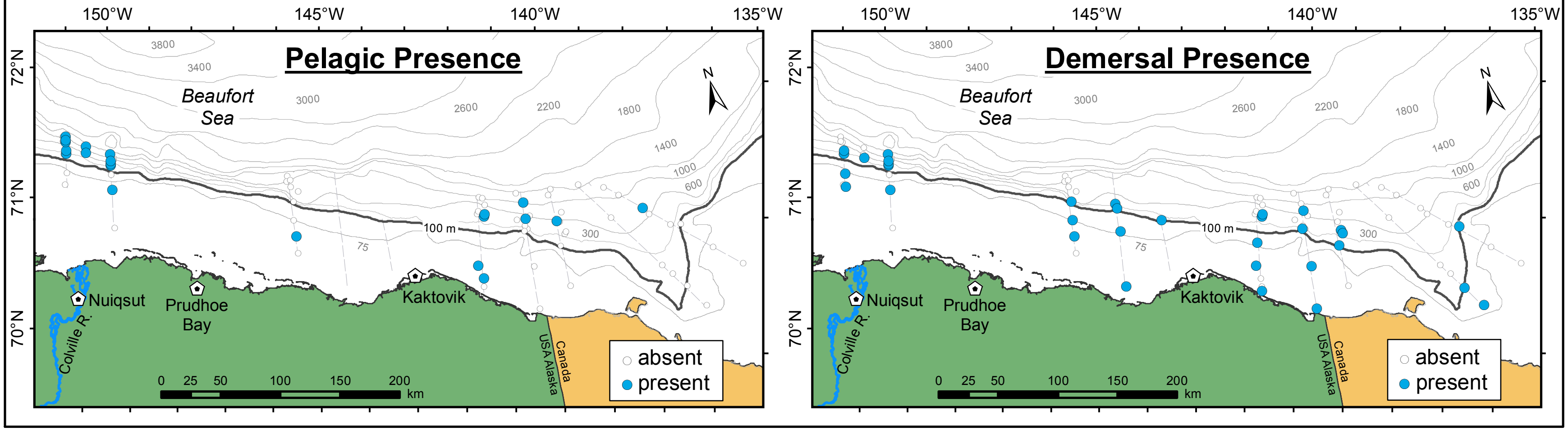
Appendix E2 Figure 9. Presence, Hemitripteridae. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Agonidae **Poachers**

Aspidophoroides monopterygius **Alligatorfish**



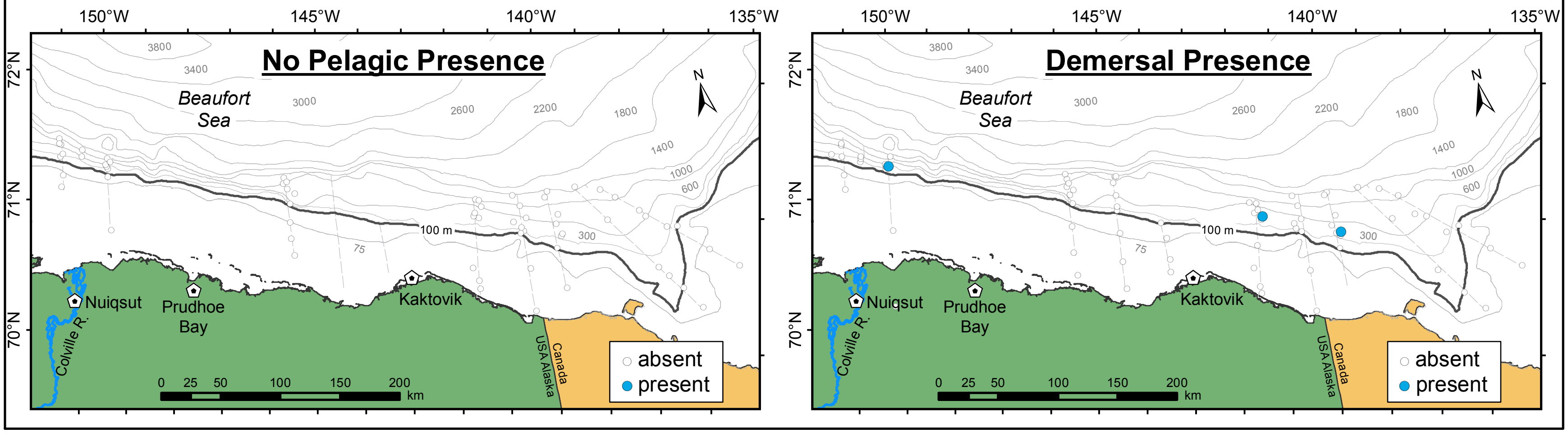
Aspidophoroides olrikii **Arctic Alligatorfish**



Appendix E2 Figure 10. Presence, Agonidae: *Aspidophoroides monopterygius* and *A. olrikii*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Agonidae **Poachers**

Leptagonus decagonus **Atlantic Poacher**



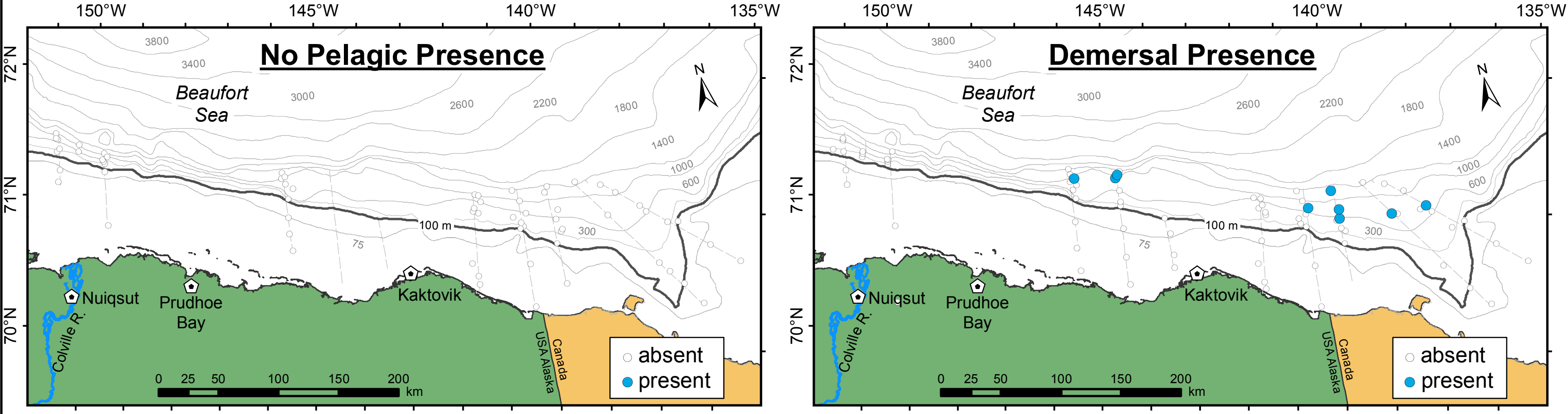
Appendix E2 Figure 11. Presence, Agonidae: *Leptagonus decagonus*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Psychrolutidae

Fathead sculpins

Cottunculus microps

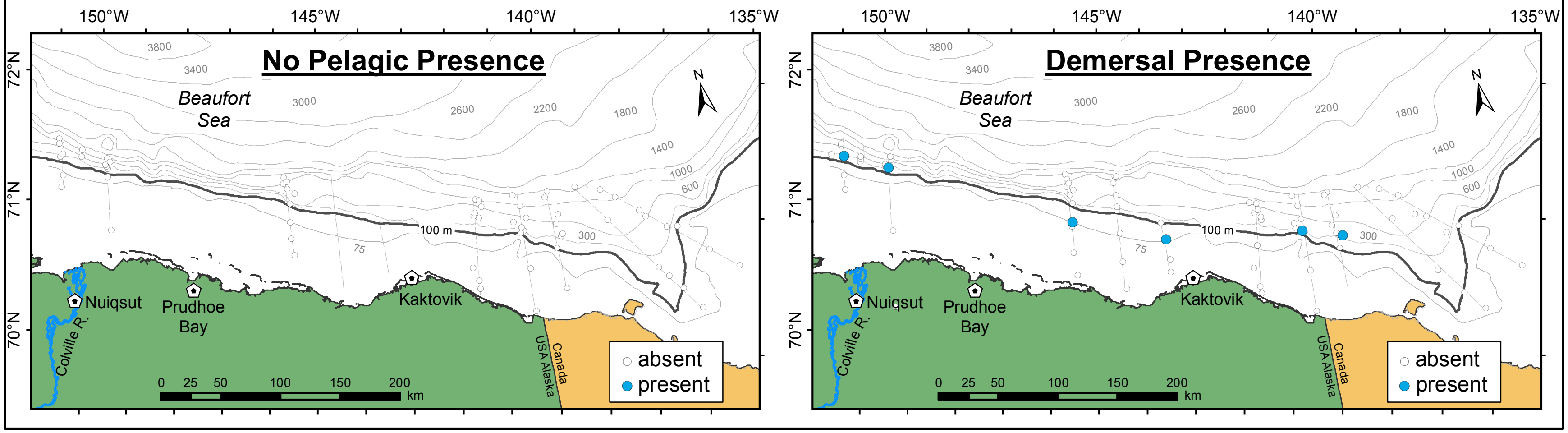
Polar Sculpin



Appendix E2 Figure 12. Presence, Psychrolutidae: *Cottunculus microps*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Cyclopteridae **Lumpfishes**

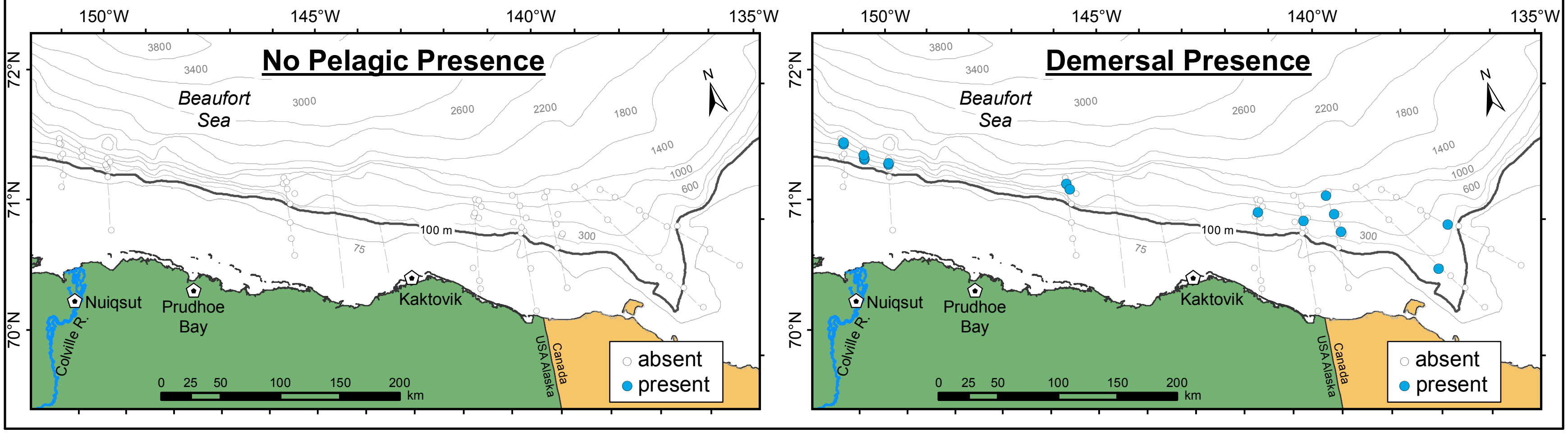
Eumicrotremus derjugini **Leatherfin Lumpsucker**



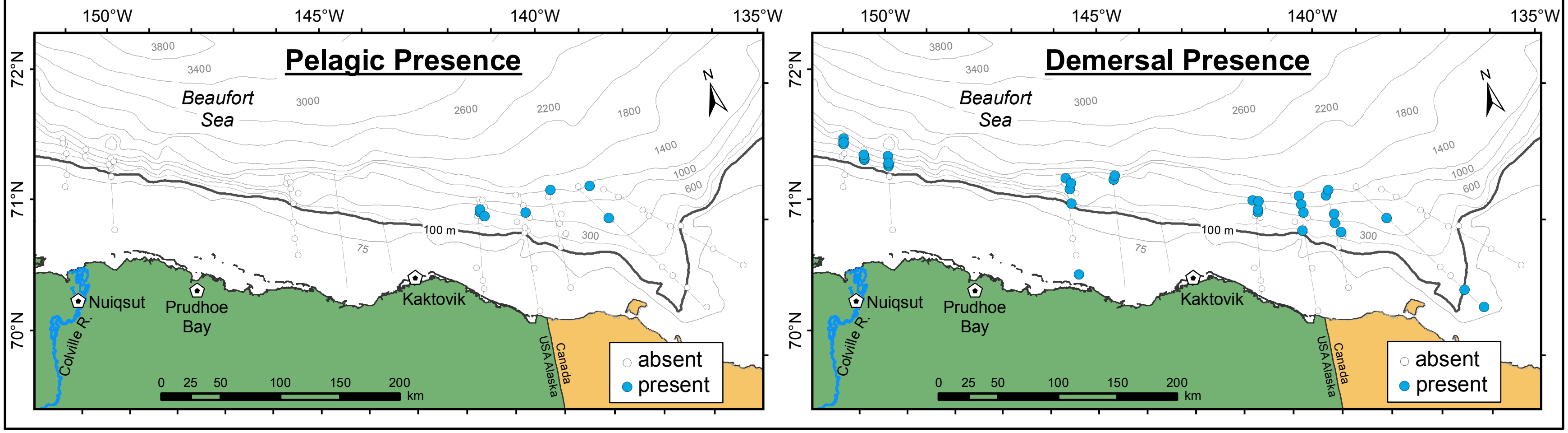
Appendix E2 Figure 13. Presence, Cyclopteridae: *Eumicrotremus derjugini*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Liparidae Snailfishes

Careproctus lerikimae Dusty Snailfish

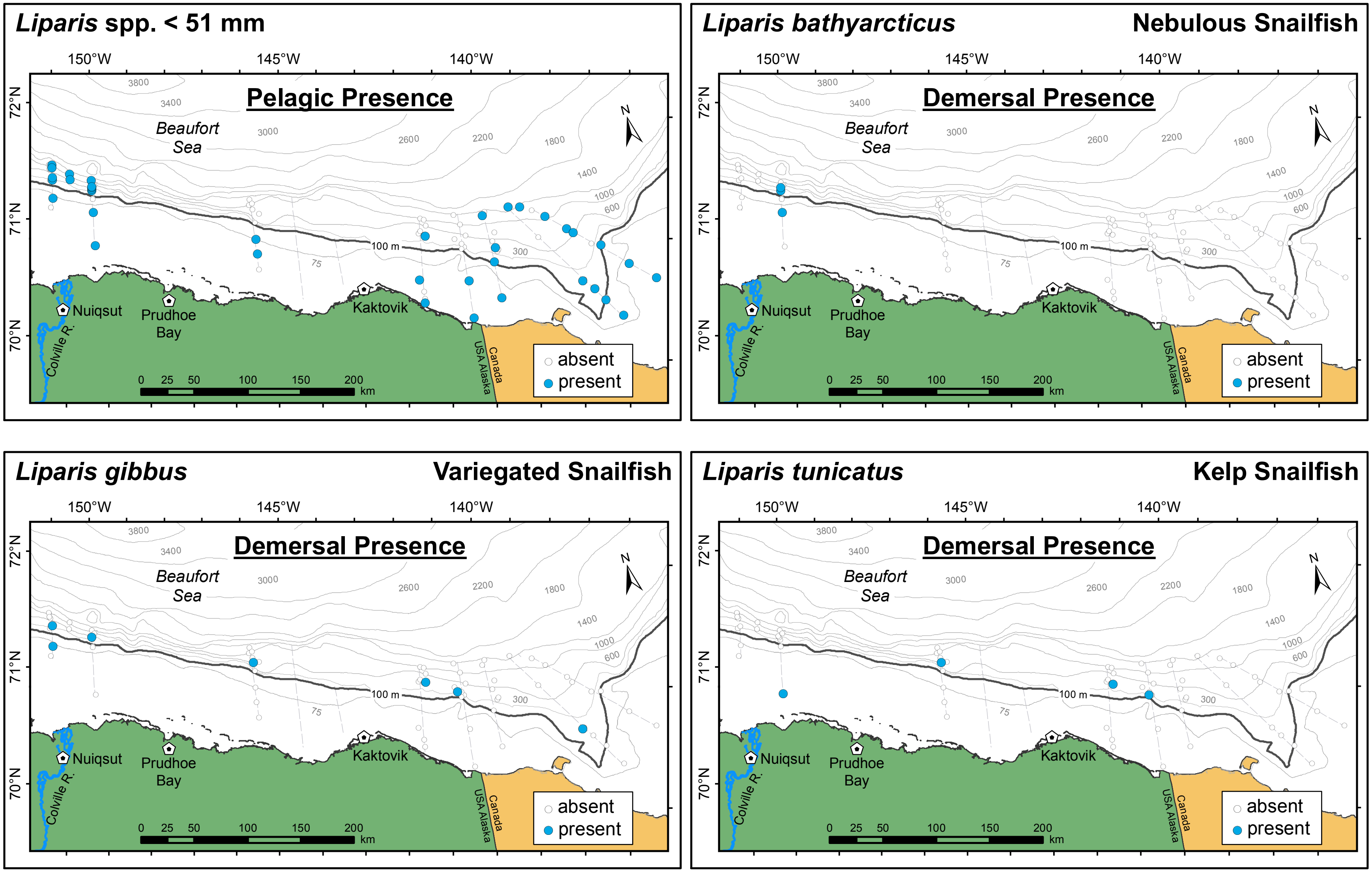


Liparis fabricii Gelatinous Seasnail



Appendix E2 Figure 14. Presence, Liparidae: *Careproctus lerikimae* and *Liparis fabricii*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Liparidae Snailfishes



***Liparis* spp. < 51 mm**

Liparis bathyarcticus **Nebulous Snailfish**

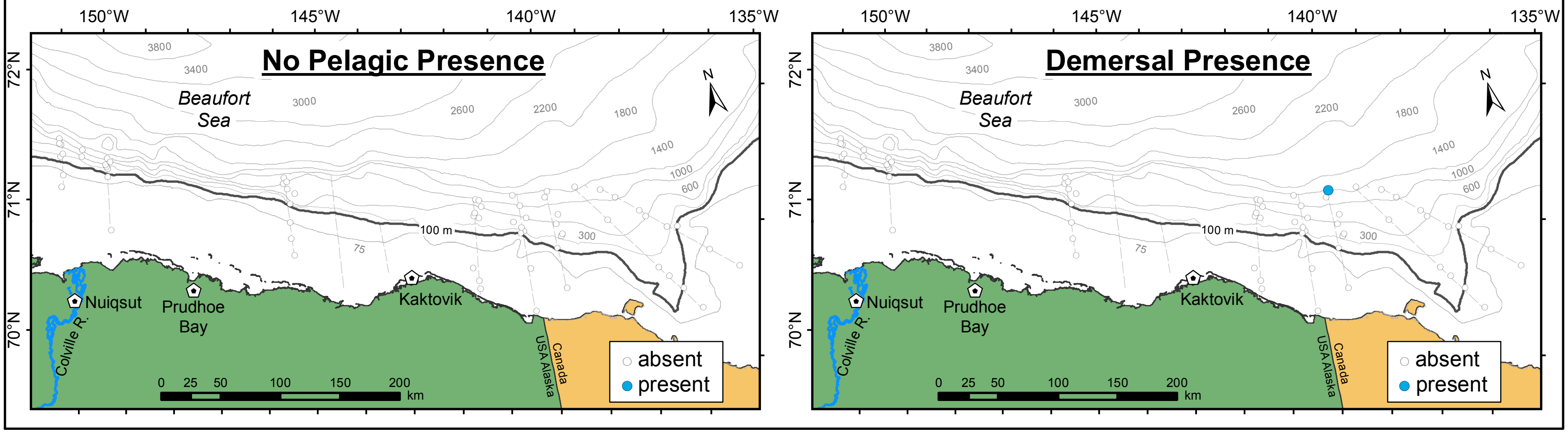
Liparis gibbus **Variegated Snailfish**

Liparis tunicatus **Kelp Snailfish**

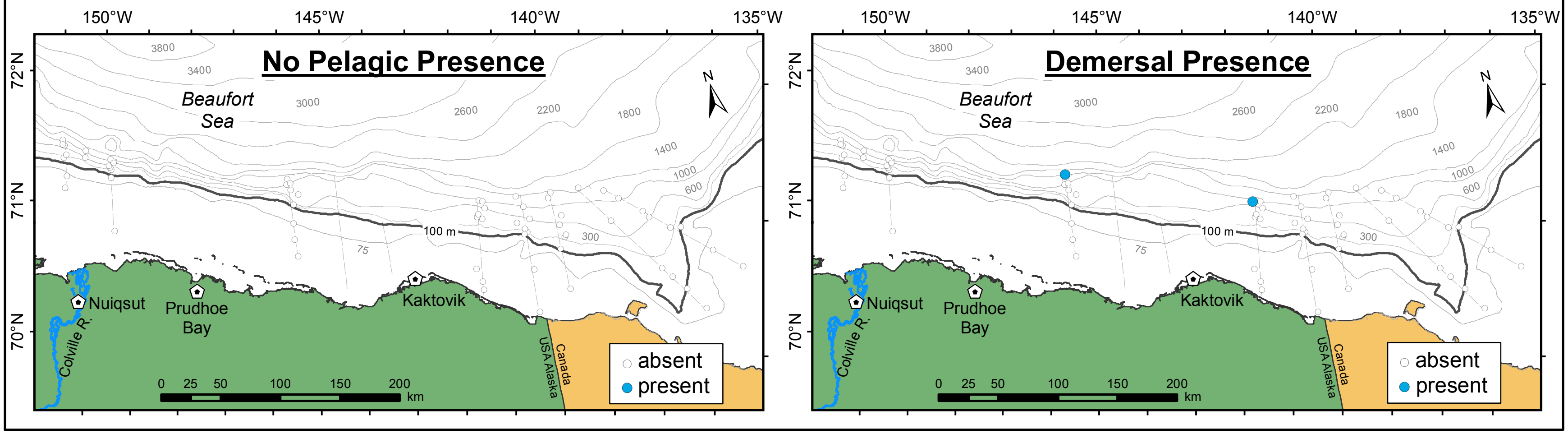
Appendix E2 Figure 15. Presence, Liparidae: *Liparis* spp. <51mm (all, pelagic) and demersal *L. bathyarcticus*, *L. gibbus*, and *L. tunicatus*. Beaufort Sea, 2012–2014.

Liparidae — Snailfishes

Paraliparis spp.



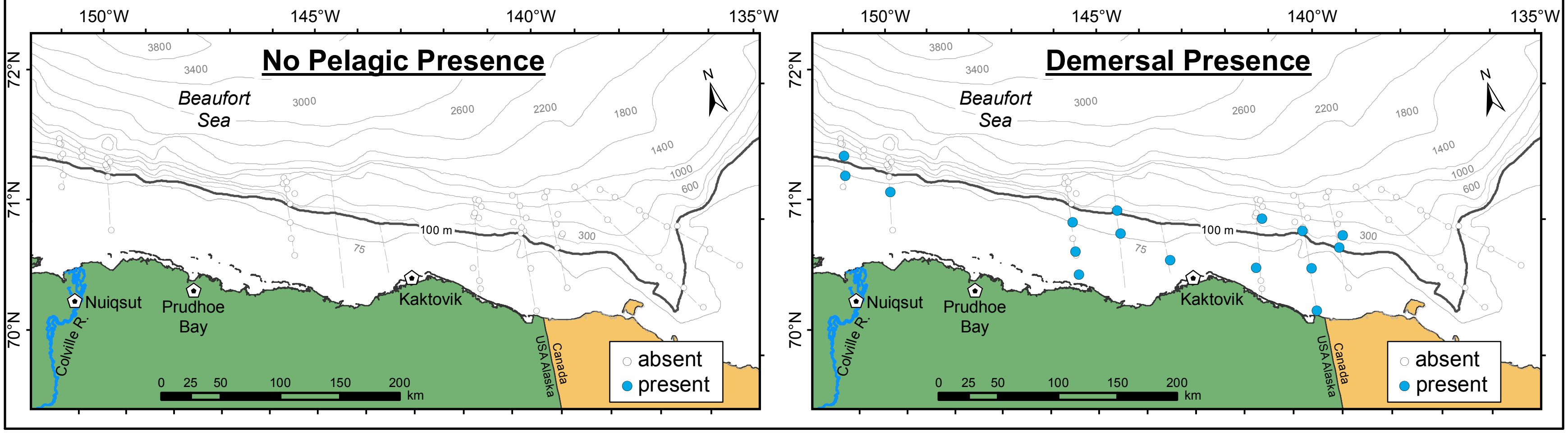
Rhodichthys regina — Threadfin Seasnail



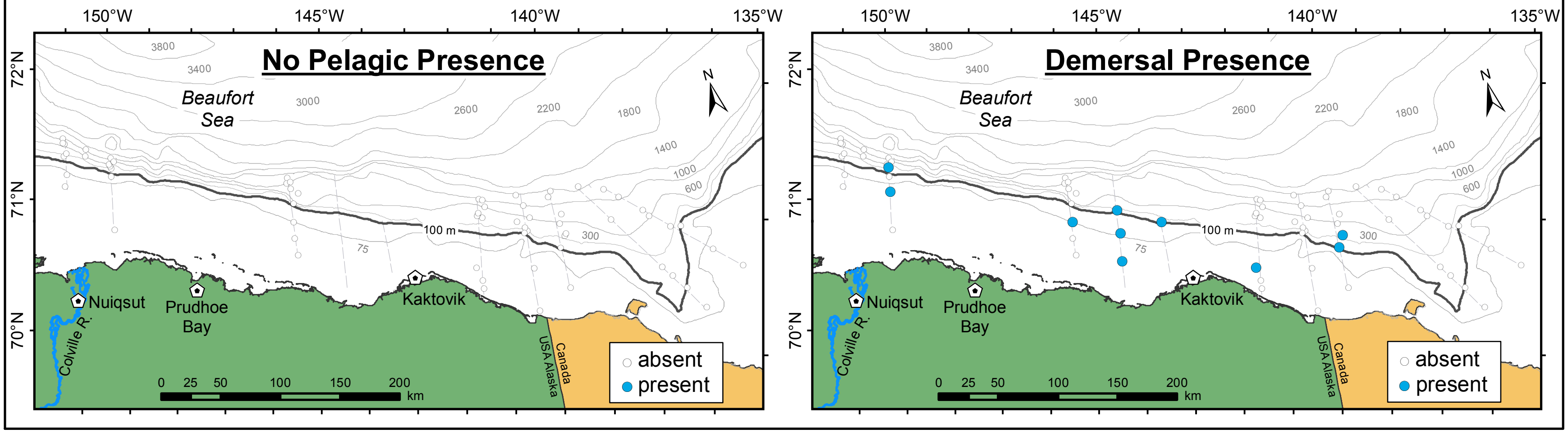
Appendix E2 Figure 16. Presence, Liparidae: *Paraliparis* spp. and *Rhodichthys regina*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae **Eelpouts**

Gymnelus hemifasciatus **Halfbarred Pout**



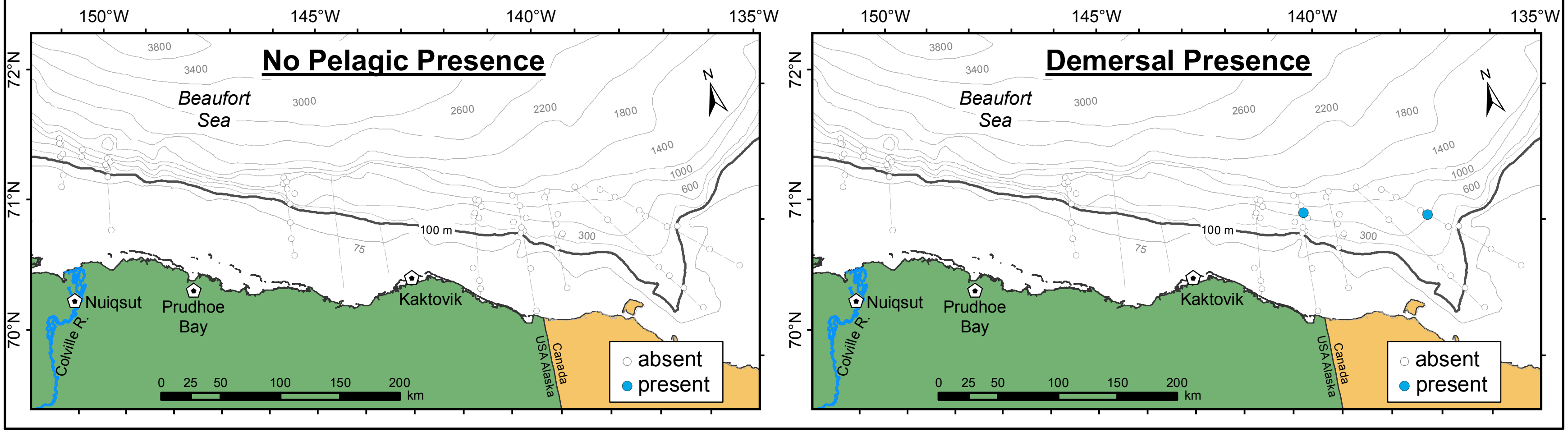
Gymnelus viridis **Fish Doctor**



Appendix E2 Figure 17. Presence, Zoarcidae: *Gymnelus hemifasciatus* and *G. viridis*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae **Eelpouts**

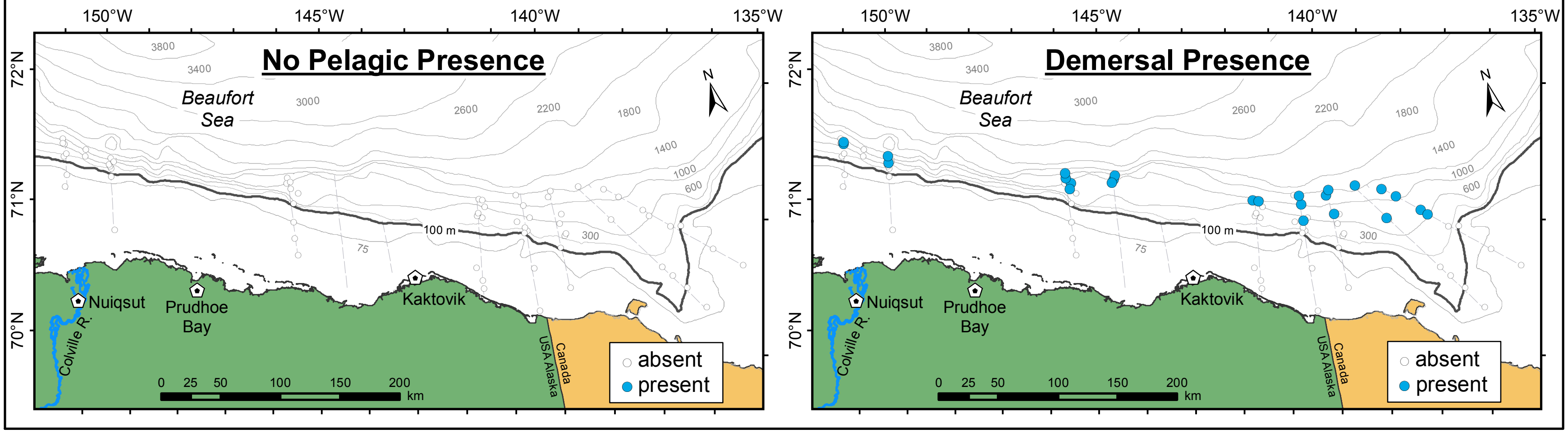
Lycenchelys kolthoffi **Checkered Wolf Eel**



No Pelagic Presence

Demersal Presence

Lycodes adolfi **Adolf's Eelpout**



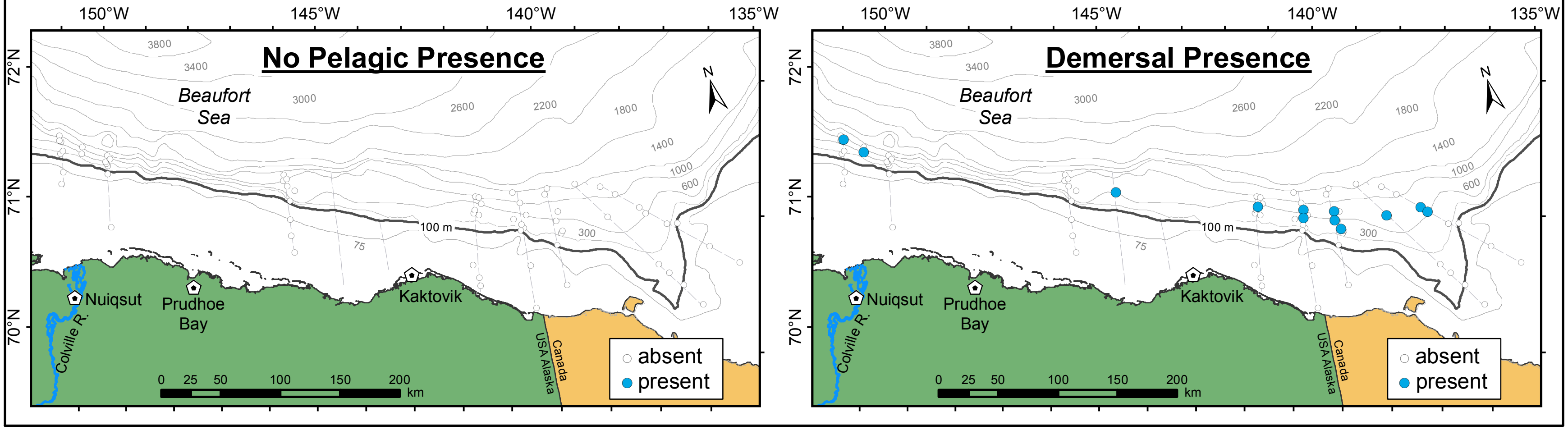
No Pelagic Presence

Demersal Presence

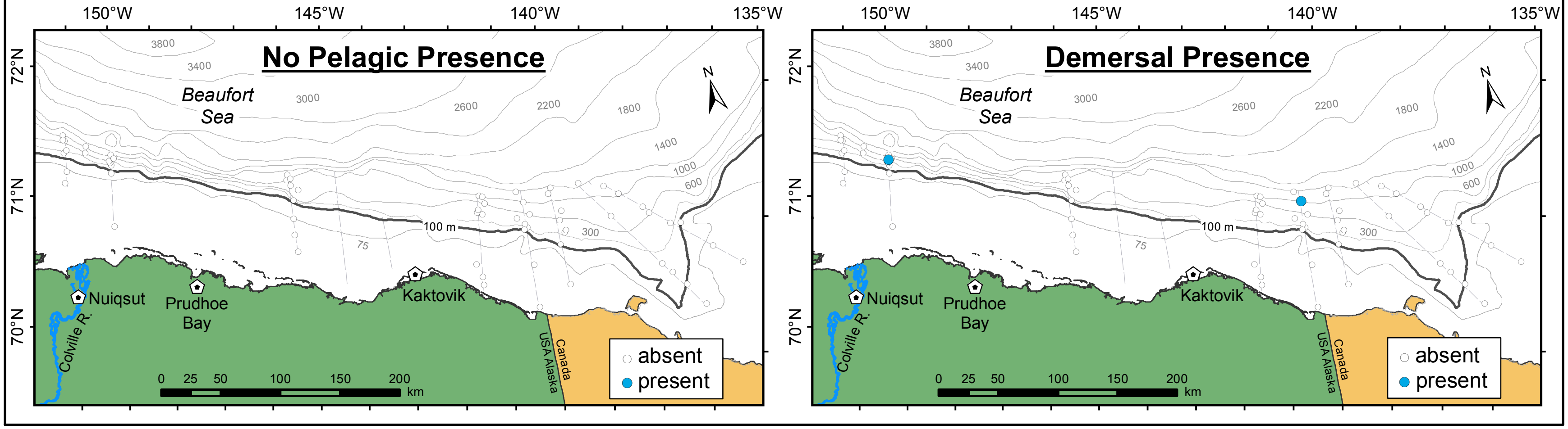
Appendix E2 Figure 18. Presence, Zoarcidae: *Lycenchelys kolthoffi* and *Lycodes adolfi*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae **Eelpouts**

Lycodes eudipleurostictus **Doubleline Eelpout**



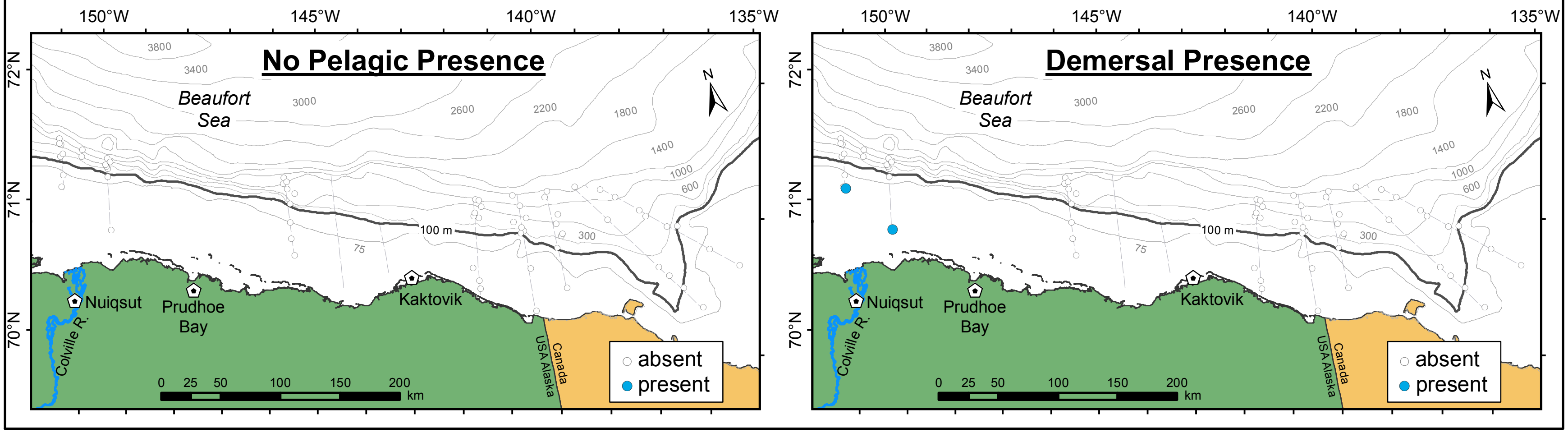
Lycodes frigidus **Glacial Eelpout**



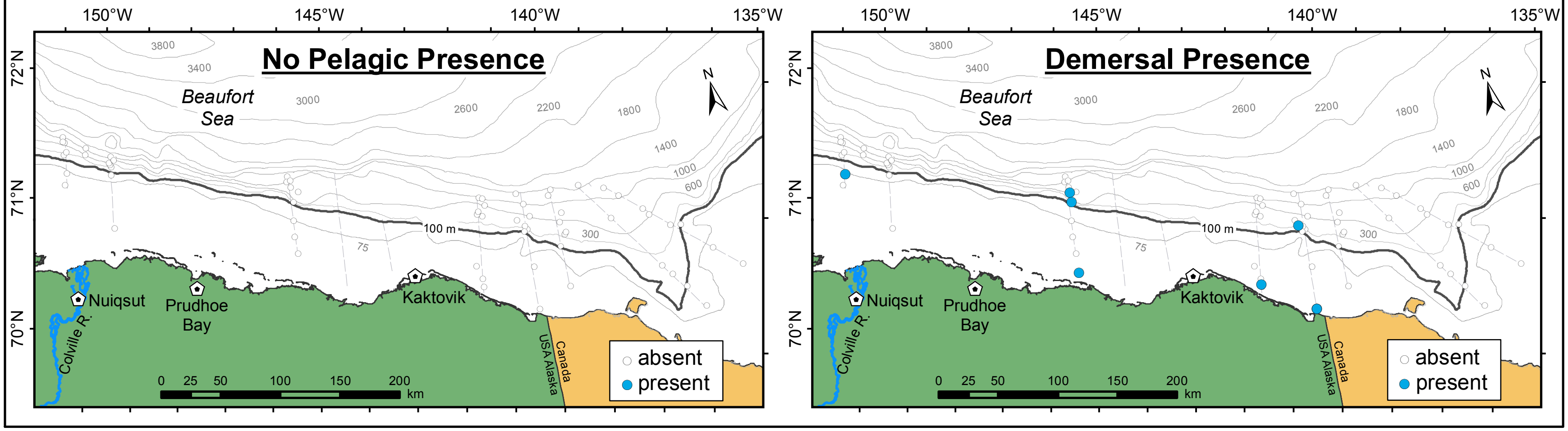
Appendix E2 Figure 19. Presence, Zoarcidae: *Lycodes eudipleurostictus* and *L. frigidus*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae **Eelpouts**

Lycodes jugoricus **Shulupaoluk**



Lycodes mucosus **Saddled Eelpout**



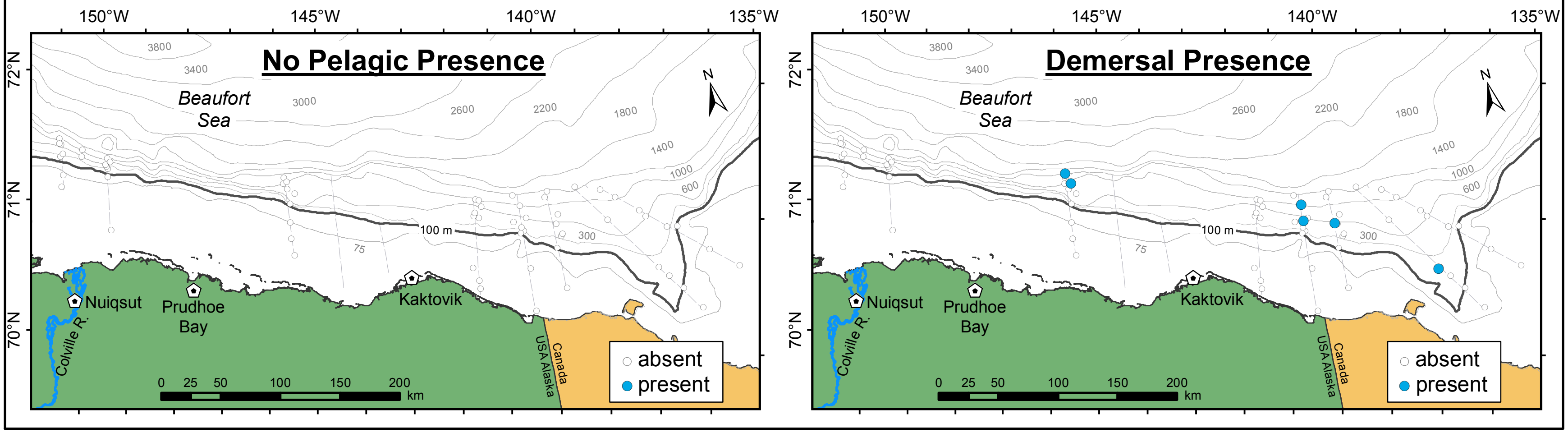
Appendix E2 Figure 20. Presence, Zoarcidae: *Lycodes jugoricus* and *L. mucosus*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae

Eelpouts

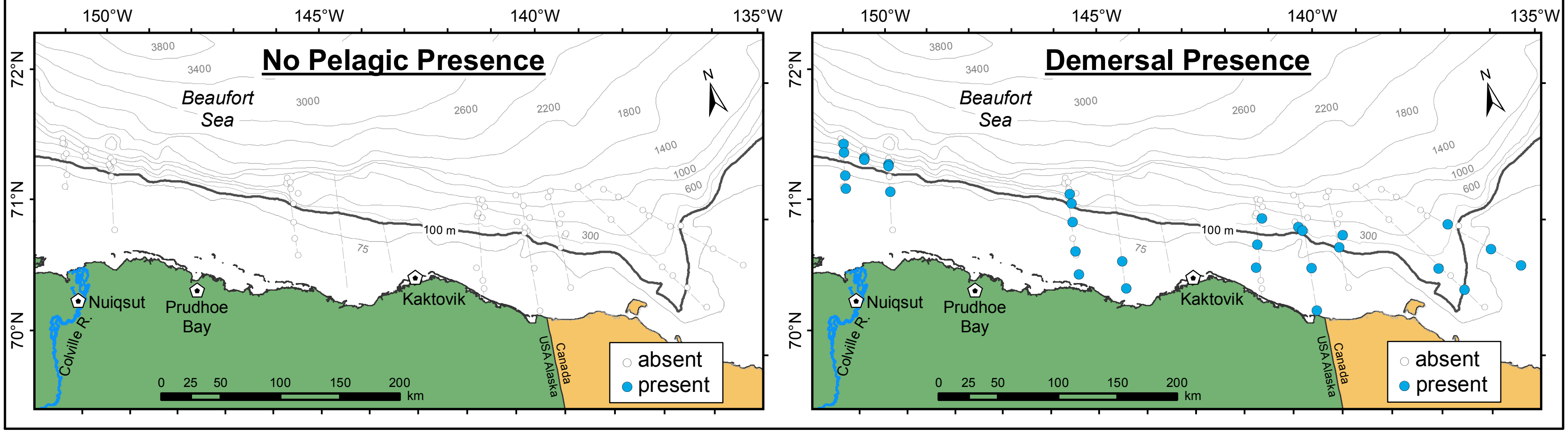
Lycodes pallidus

Pale Eelpout



Lycodes polaris

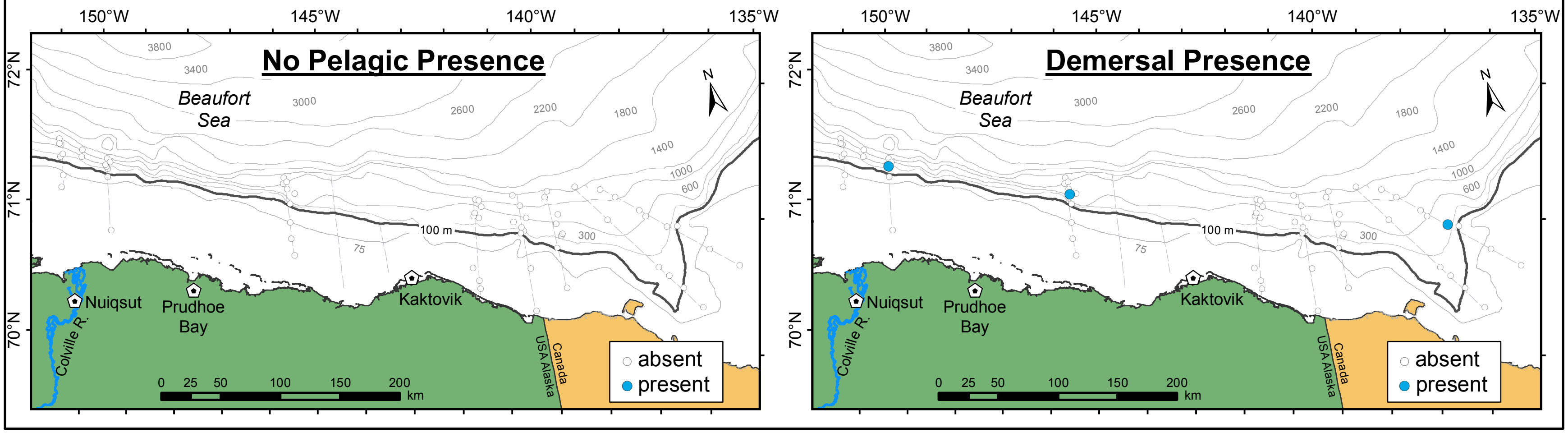
Canadian Eelpout



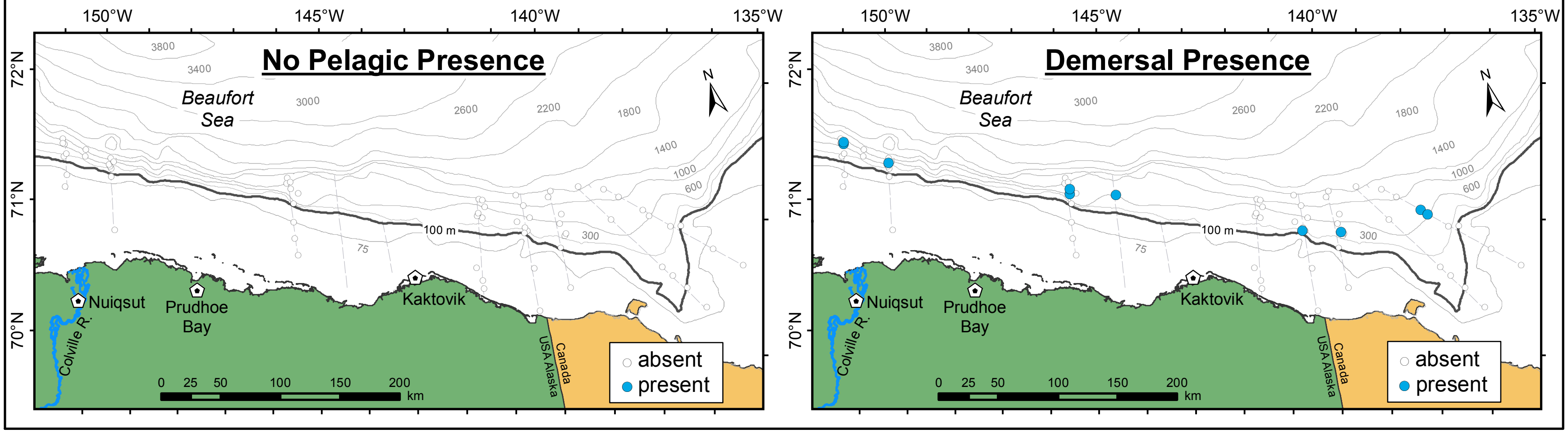
Appendix E2 Figure 21. Presence, Zoarcidae: *Lycodes pallidus* and *L. polaris*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae **Eelpouts**

Lycodes raridens **Marbled Eelpout**



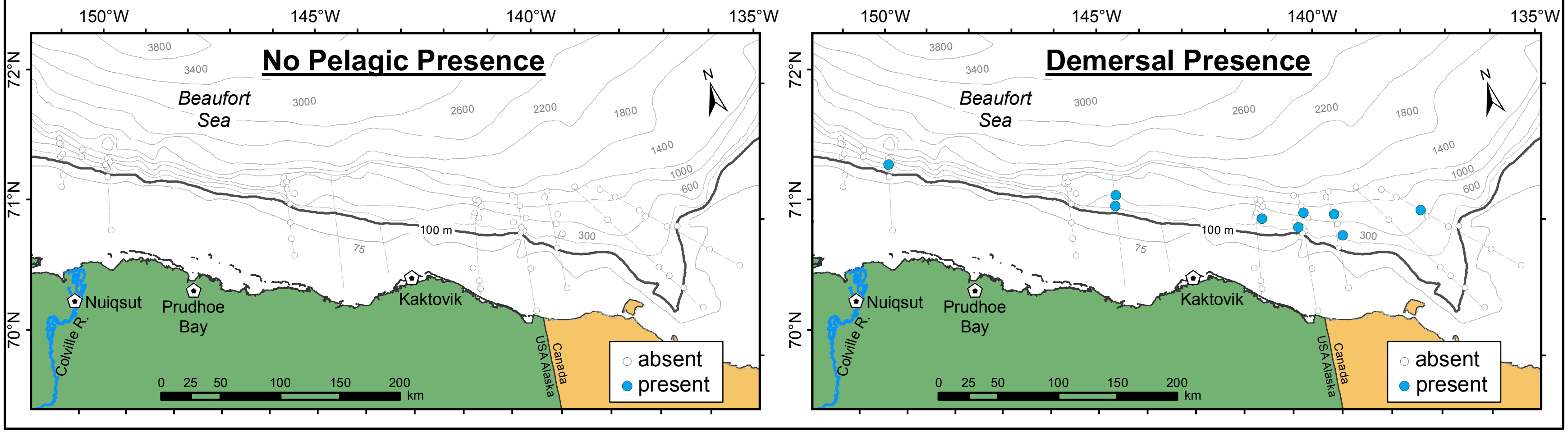
Lycodes reticulatus **Arctic Eelpout**



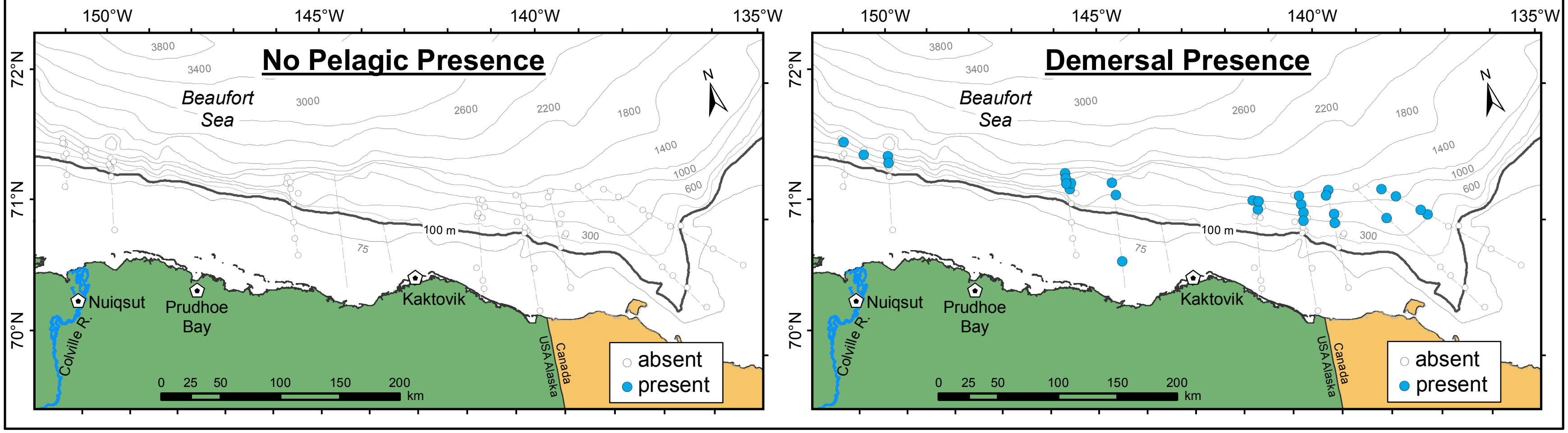
Appendix E2 Figure 22. Presence, Zoarcidae: *Lycodes raridens* and *L. reticulatus*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae Eelpouts

Lycodes rossi **Threespot eelpout**



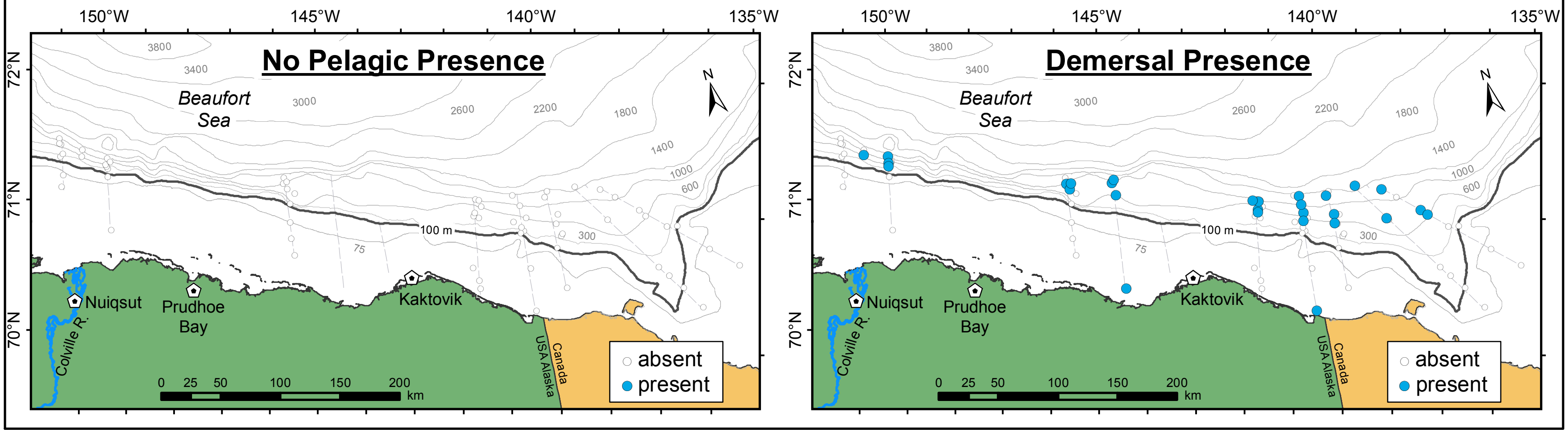
Lycodes sagittarius **Archer Eelpout**



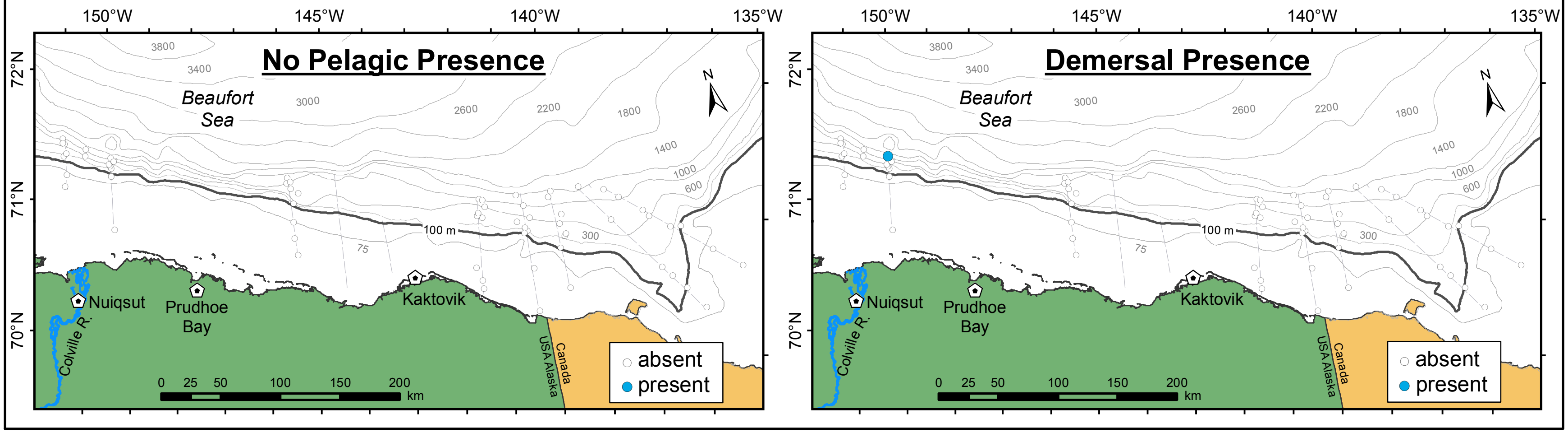
Appendix E2 Figure 23. Presence, Zoarcidae: *Lycodes rossi* and *L. sagittarius*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Zoarcidae Eelpouts

Lycodes seminudus Longear Eelpout

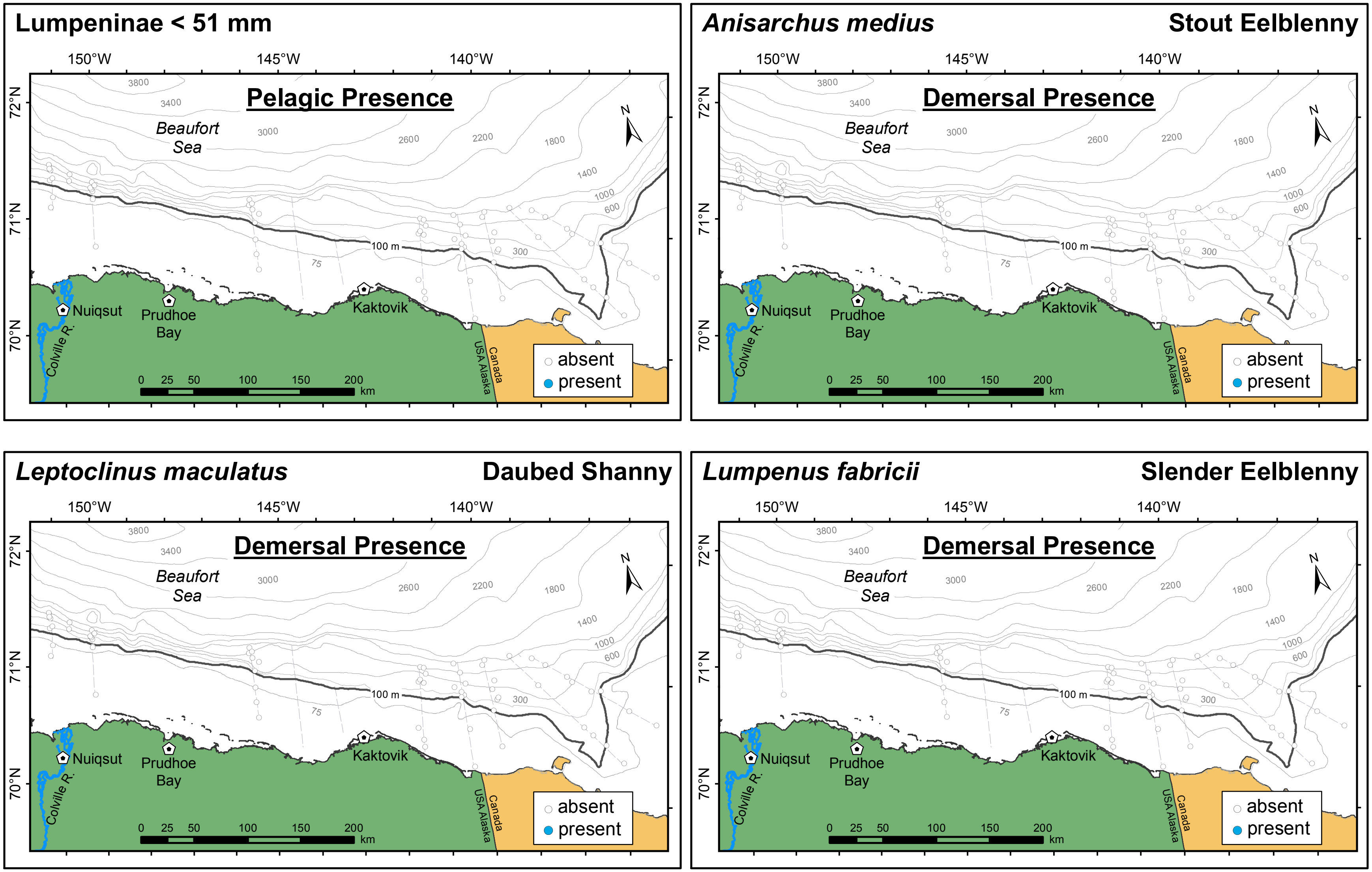


Lycodes squamiventer Scalebelly Eelpout



Appendix E2 Figure 24. Presence, Zoarcidae: *Lycodes seminudus* and *L. squamiventer*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Stichaeidae Pricklebacks


Lumpeninae < 51 mm

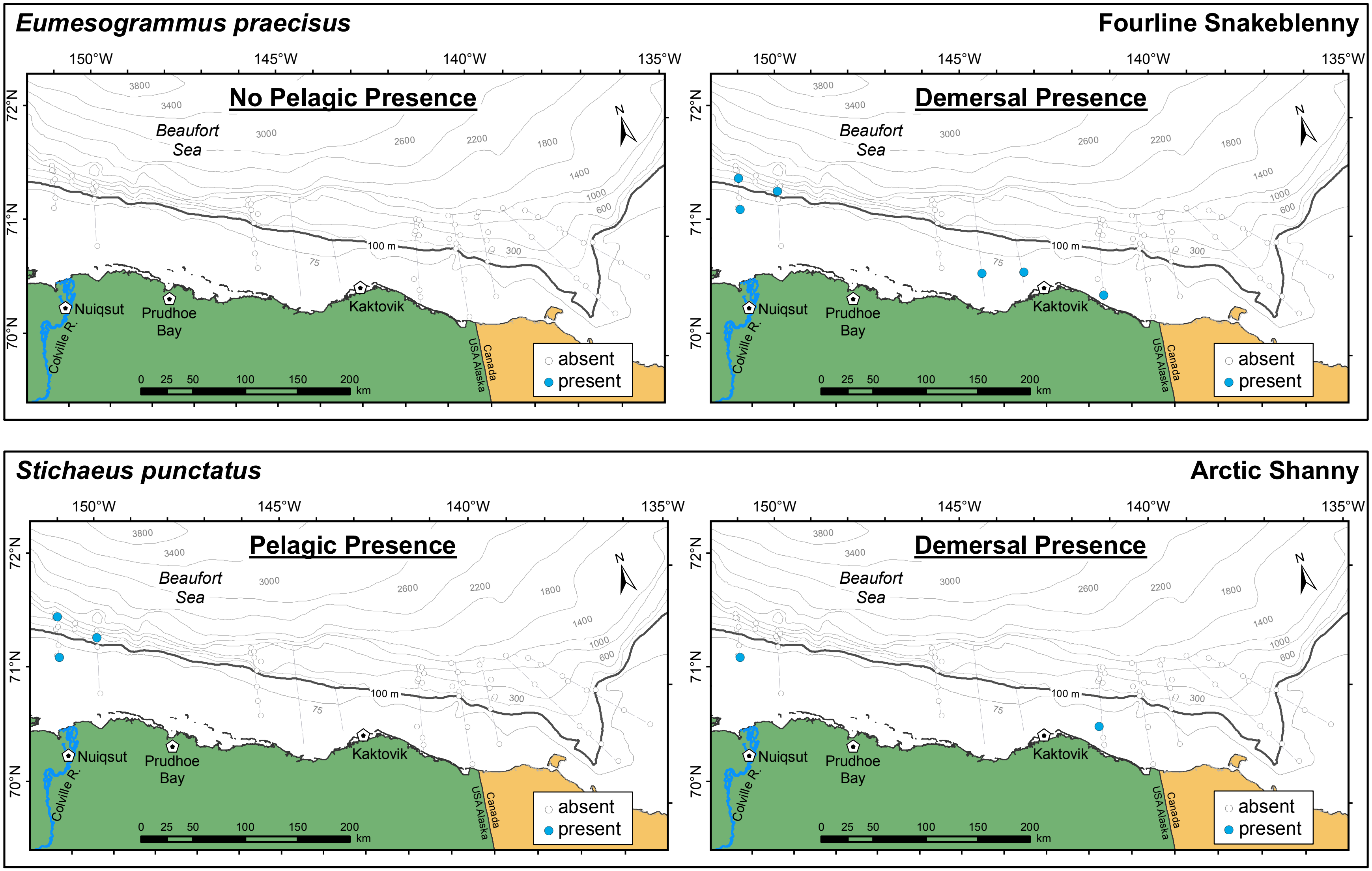
Anisarchus medius **Stout Eelblenny**

Leptoclinus maculatus **Daubed Shanny**

Lumpenus fabricii **Slender Eelblenny**

Appendix E2 Figure 25. Presence, Stichaeidae subfamily Lumpeninae: <51 mm (all, pelagic) and demersal *Anisarchus medius*, *Leptoclinus maculatus* and *Lumpenus fabricii*. Beaufort Sea, 2012–2014.

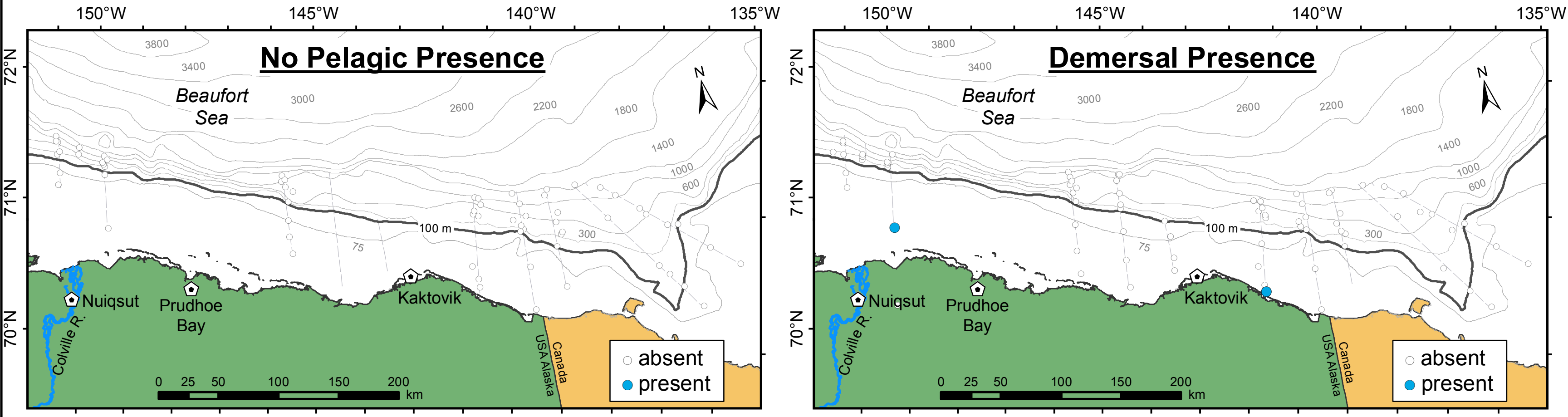
Stichaeidae **Pricklebacks**



Appendix E2 Figure 26. Presence, Stichaeidae: *Eumesogrammus praecisus* and *Stichaeus punctatus*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Ammodytidae **Sand lances**

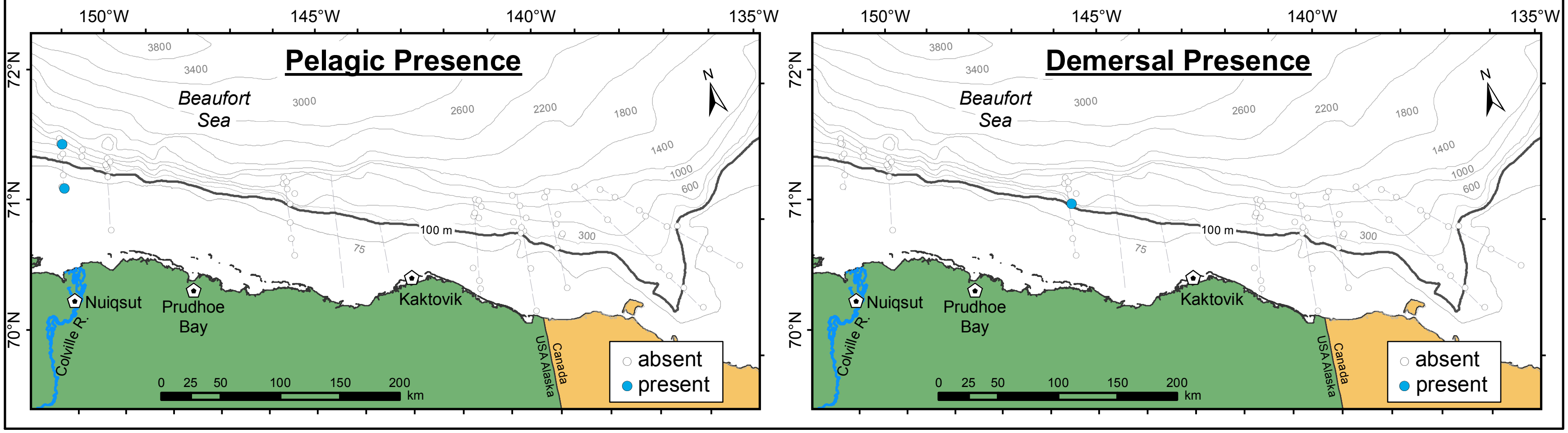
Ammodytes hexapterus **Arctic Sand Lance**



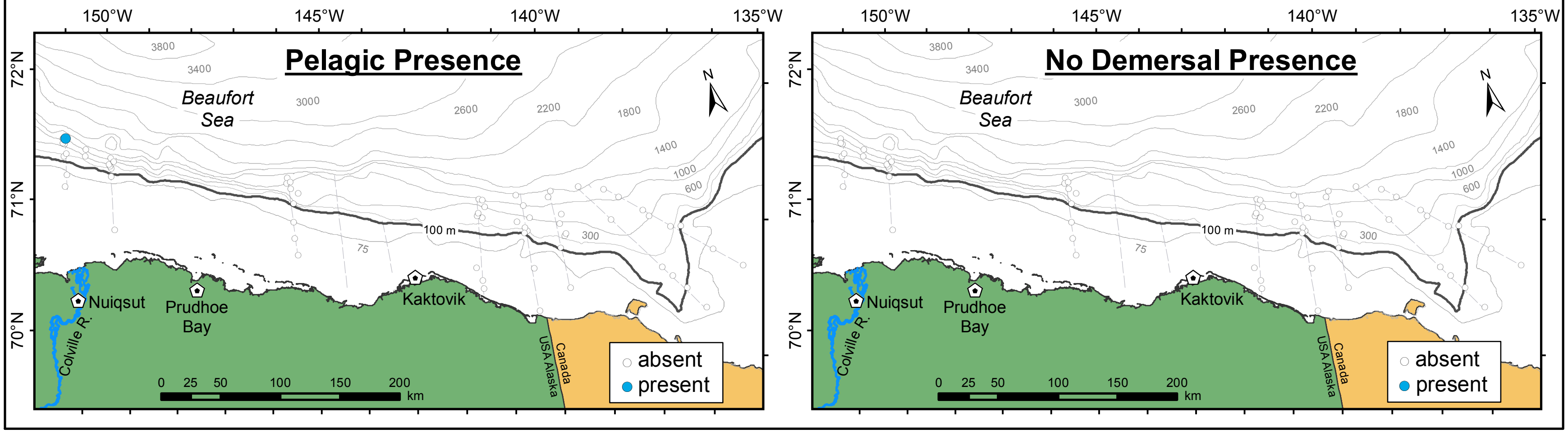
Appendix E2 Figure 27. Presence, Ammodytidae: *Ammodytes hexapterus*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Pleuronectidae **Righteye flounders**

Pleuronectidae larvae



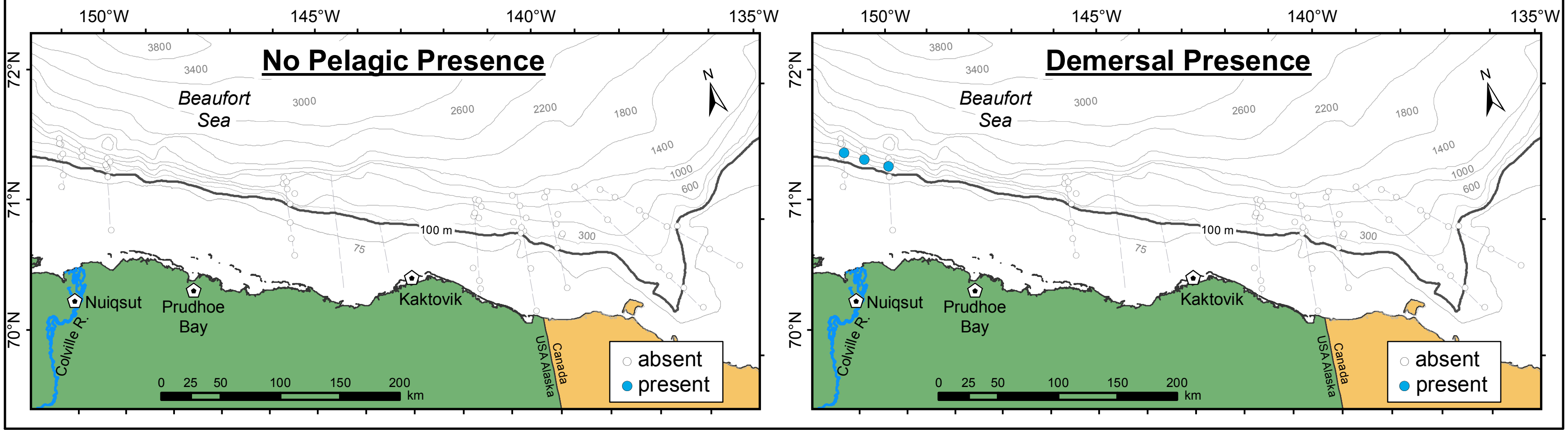
Limanda proboscidea Longhead Dab



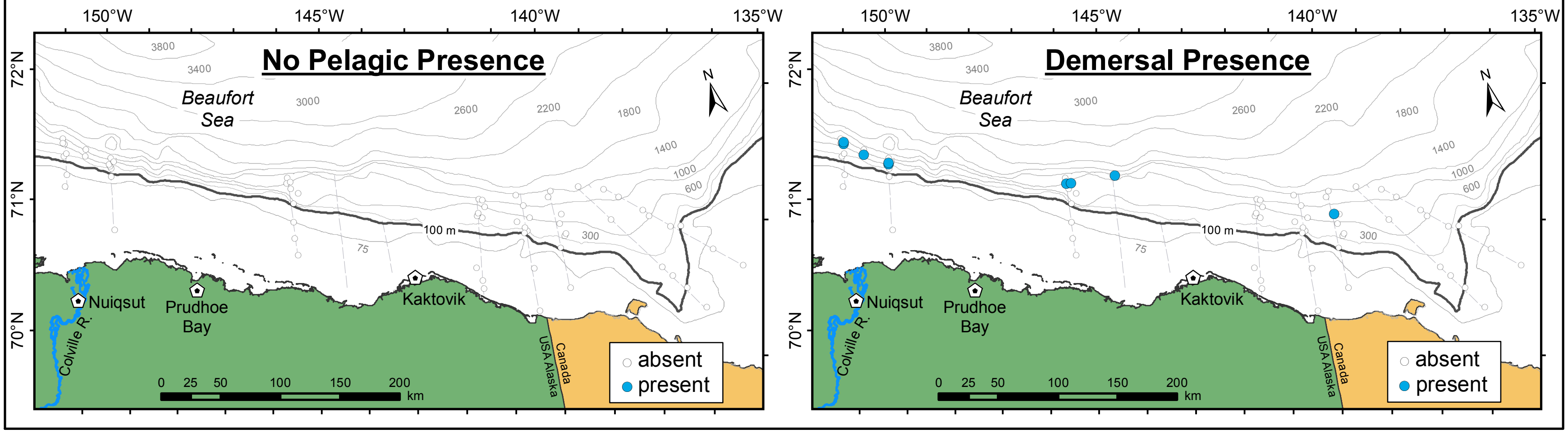
Appendix E2 Figure 28. Presence, Pleuronectidae: Pleuronectid larvae and *Limanda proboscidea*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

Pleuronectidae **Righteye flounders**

Hippoglossoides robustus **Bering Flounder**



Reinhardtius hippoglossoides **Greenland Halibut**



Appendix E2 Figure 29. Presence, Pleuronectidae: *Hippoglossoides robustus* and *Reinhardtius hippoglossoides*. Pelagic and demersal fish presence in the Beaufort Sea, 2012–2014.

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix E3

Maps of Pelagic and Demersal Fish Abundance and Biomass

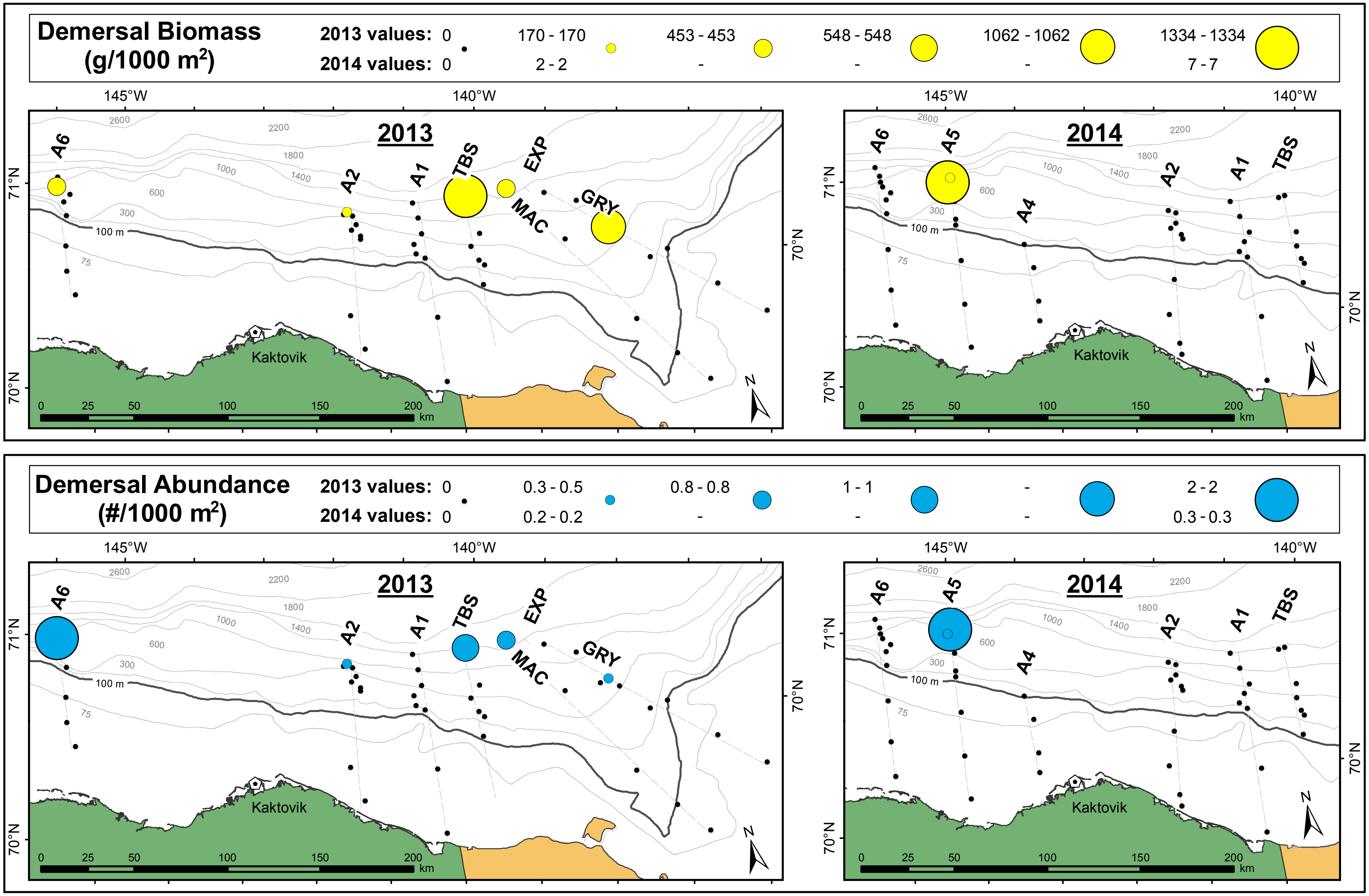
Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

LIST OF FIGURES

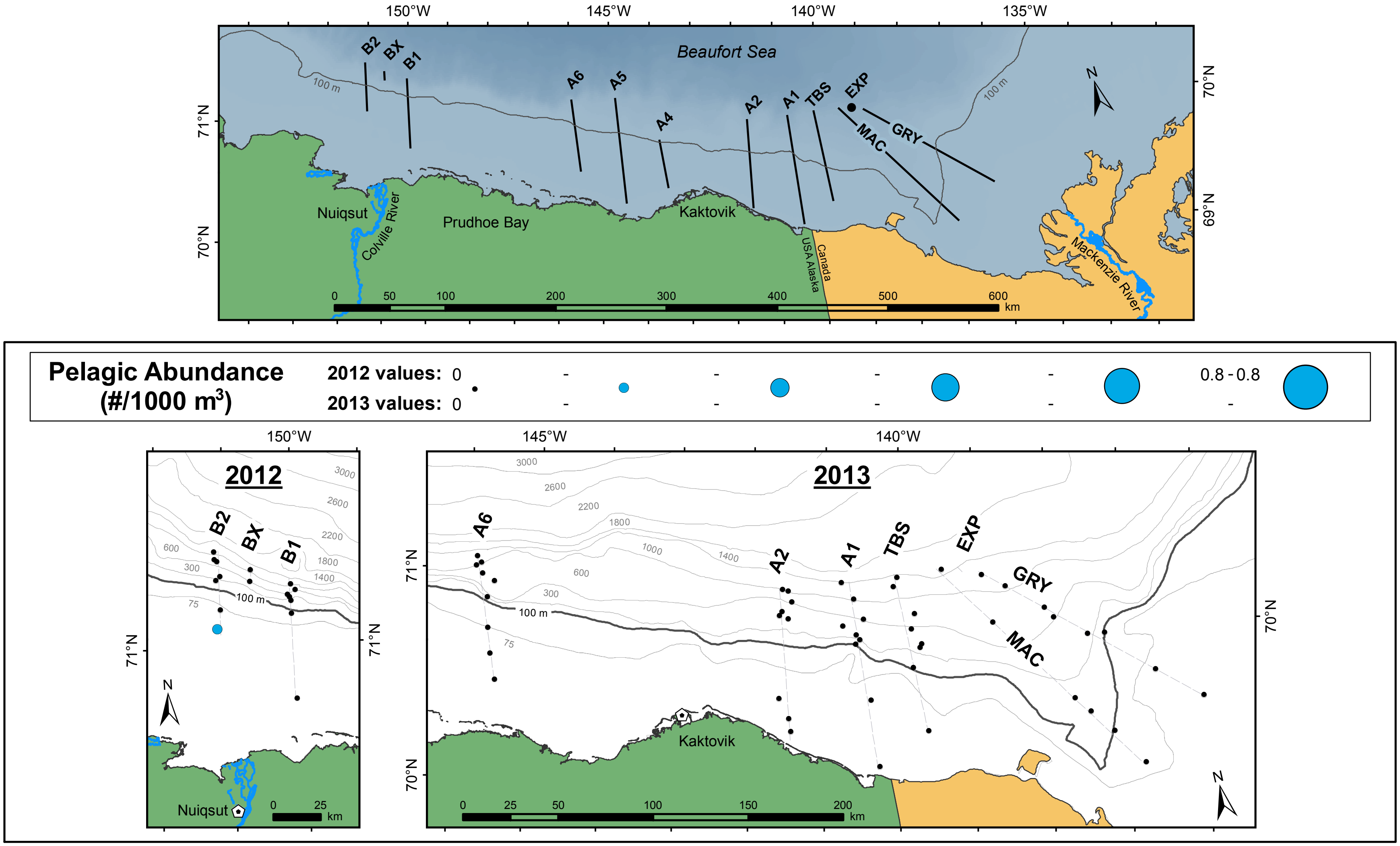
LIST OF TABLES

Rajidae - Skates Rajidae Skates

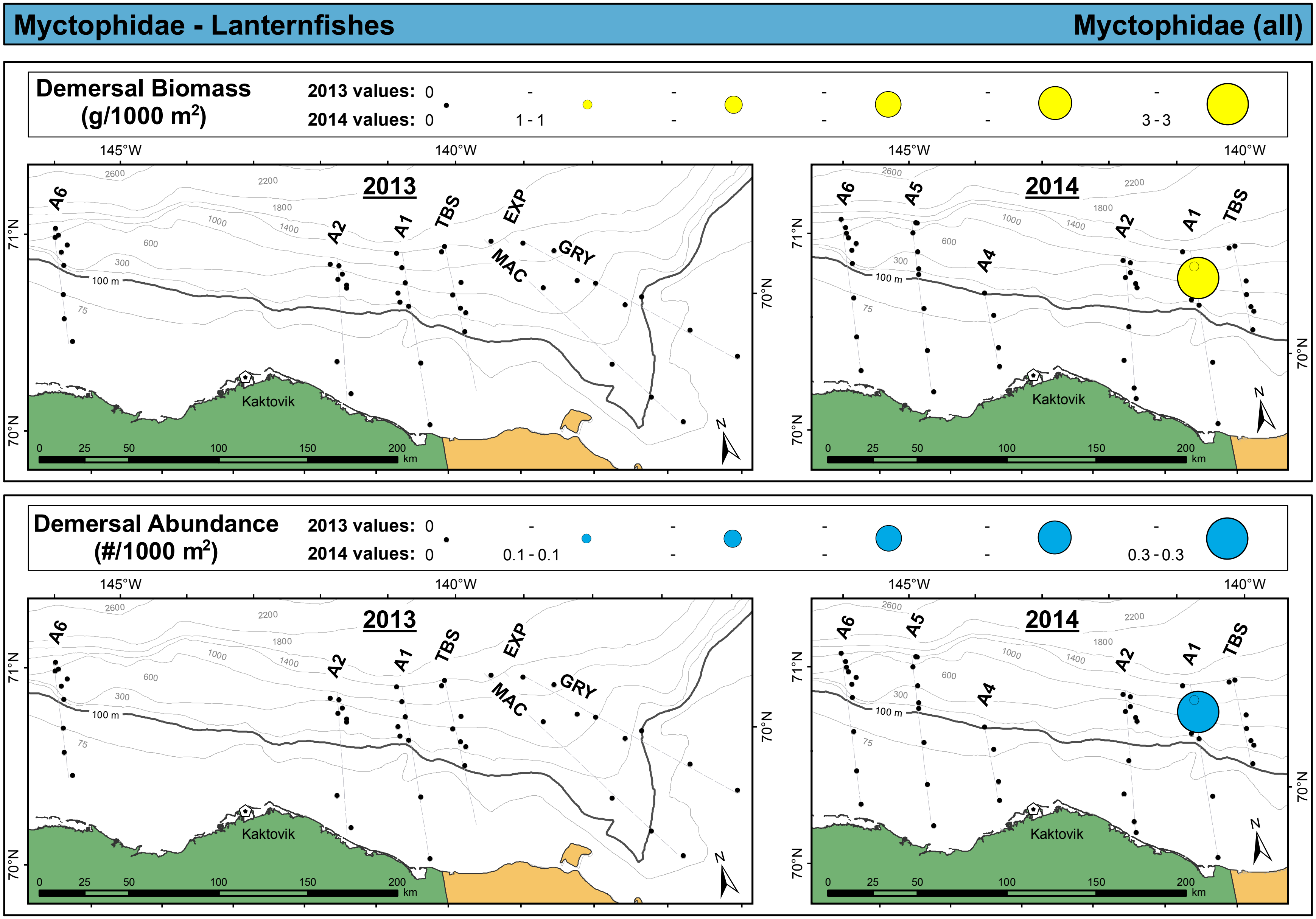


Appendix E3 Figure 1. Maps of demersal abundance, Rajidae. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Osmeridae - Smelts ***Mallotus catervarius*** **Pacific Capelin**

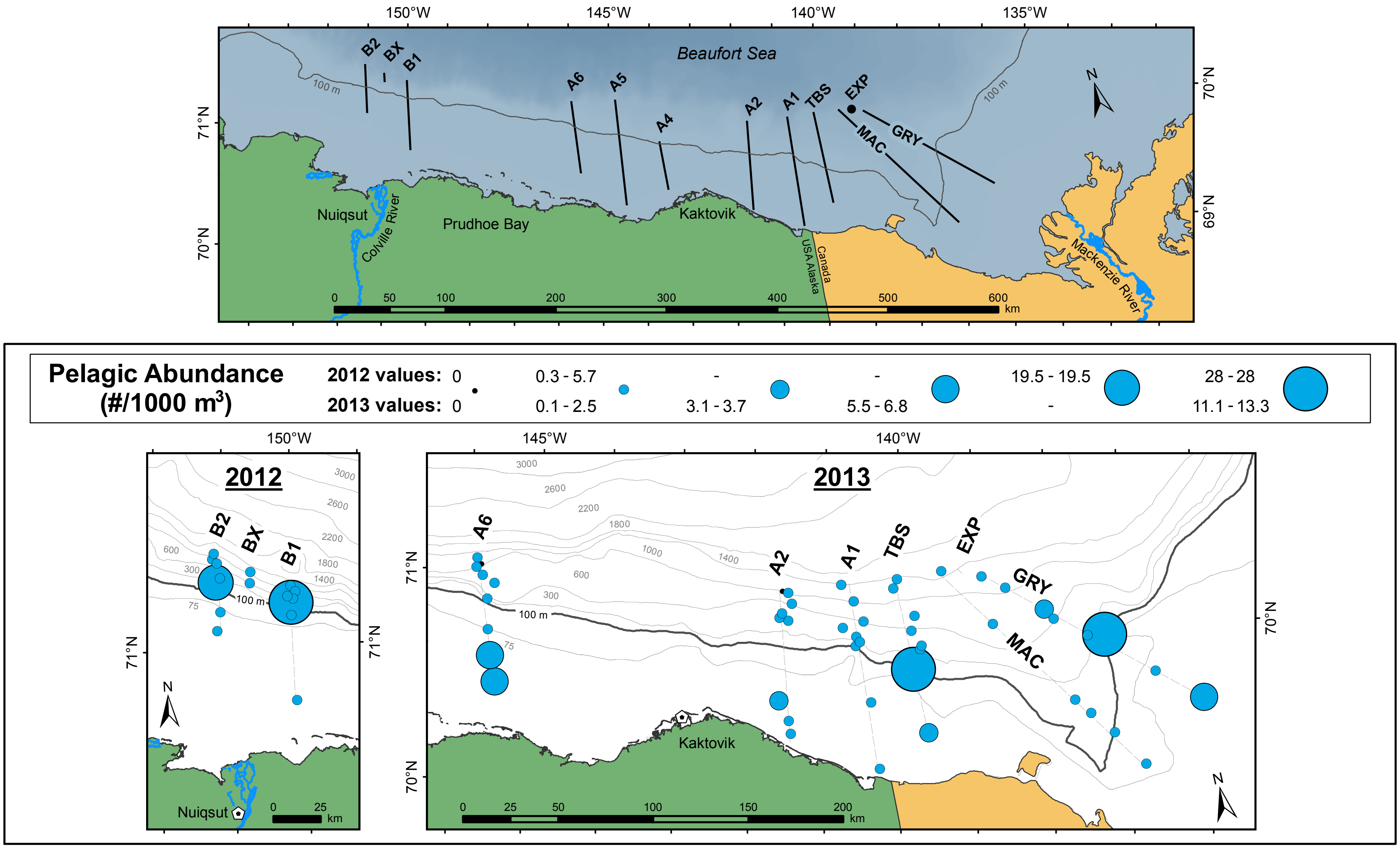


Appendix E3 Figure 2. Maps of pelagic abundance, Osmeridae: *Mallotus catervarius*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in demersal habitat.



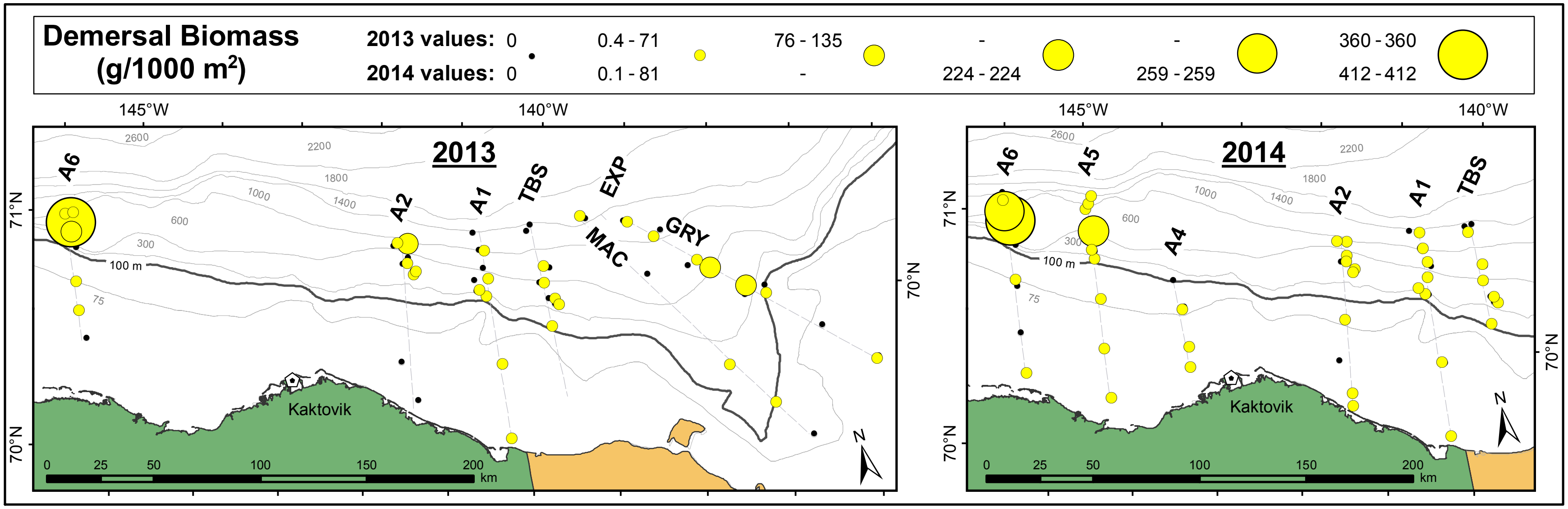
Appendix E3 Figure 3. Maps of demersal abundance, Myctophidae. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

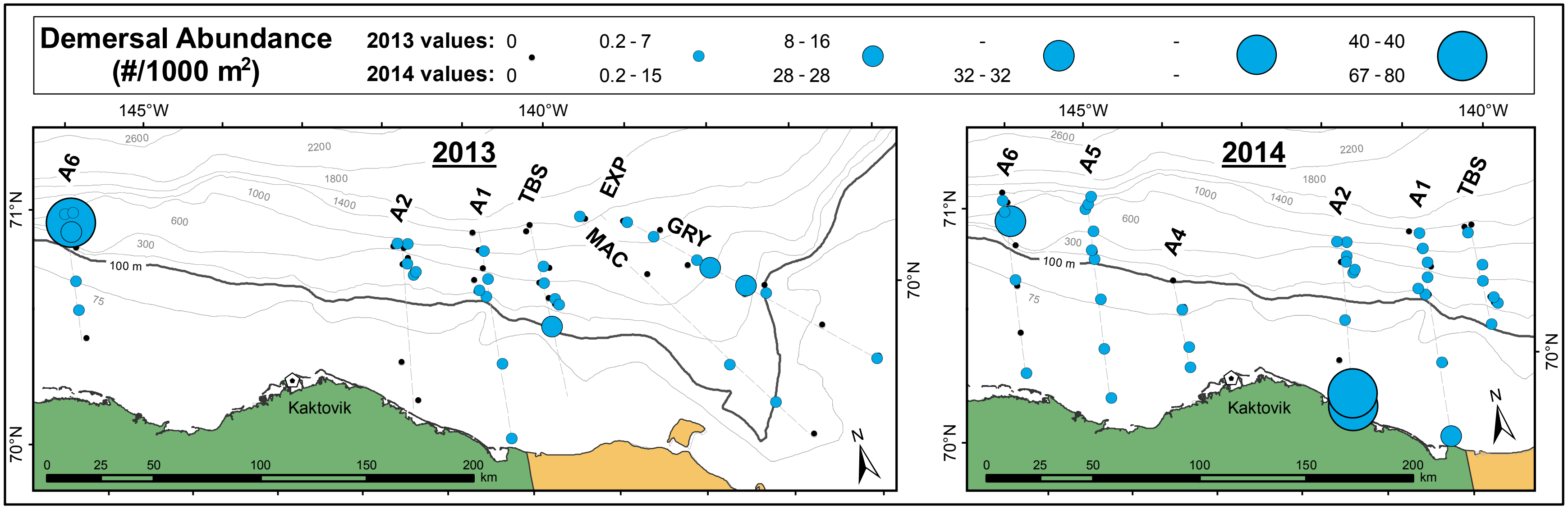
Gadidae - Cods ***Boreogadus saida*** **Arctic Cod**



Appendix E3 Figure 4. Maps of pelagic abundance, Gadidae: *Boreogadus saida*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

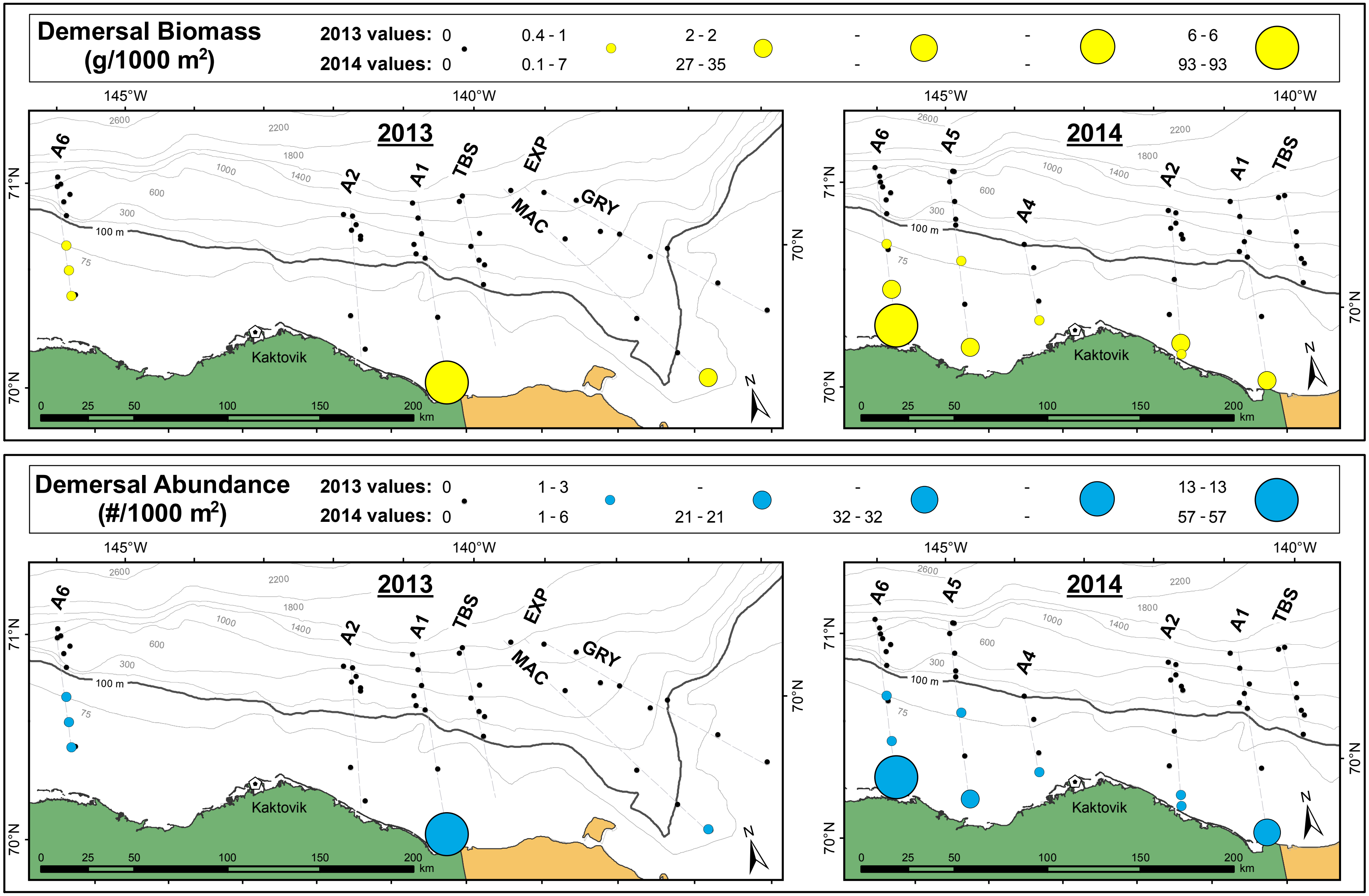
Gadidae - Cods ***Boreogadus saida*** **Arctic Cod**





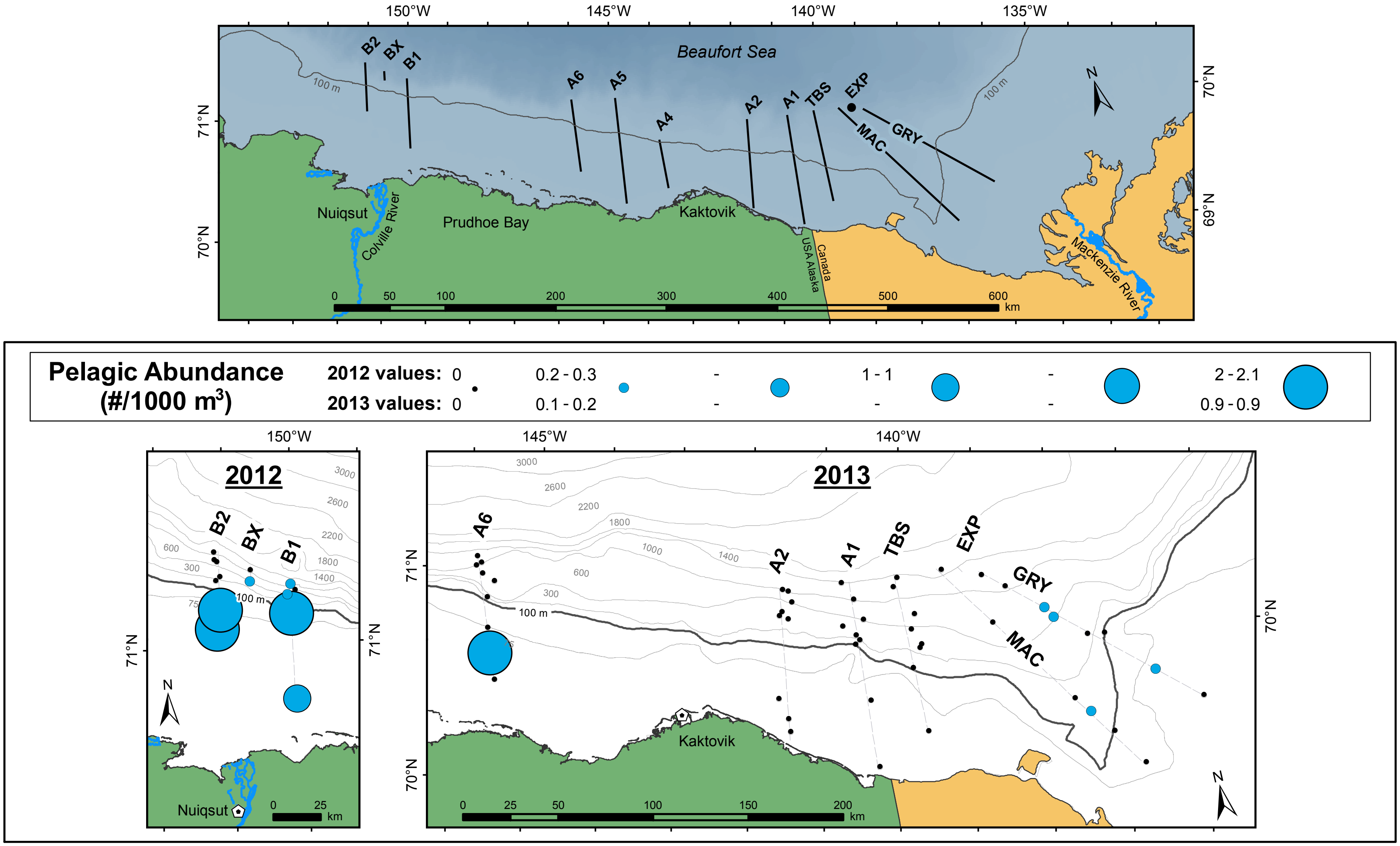
Appendix E3 Figure 5. Maps of demersal abundance, Gadidae: *Boreogadus saida*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins *Artediellus scaber* Hamecon



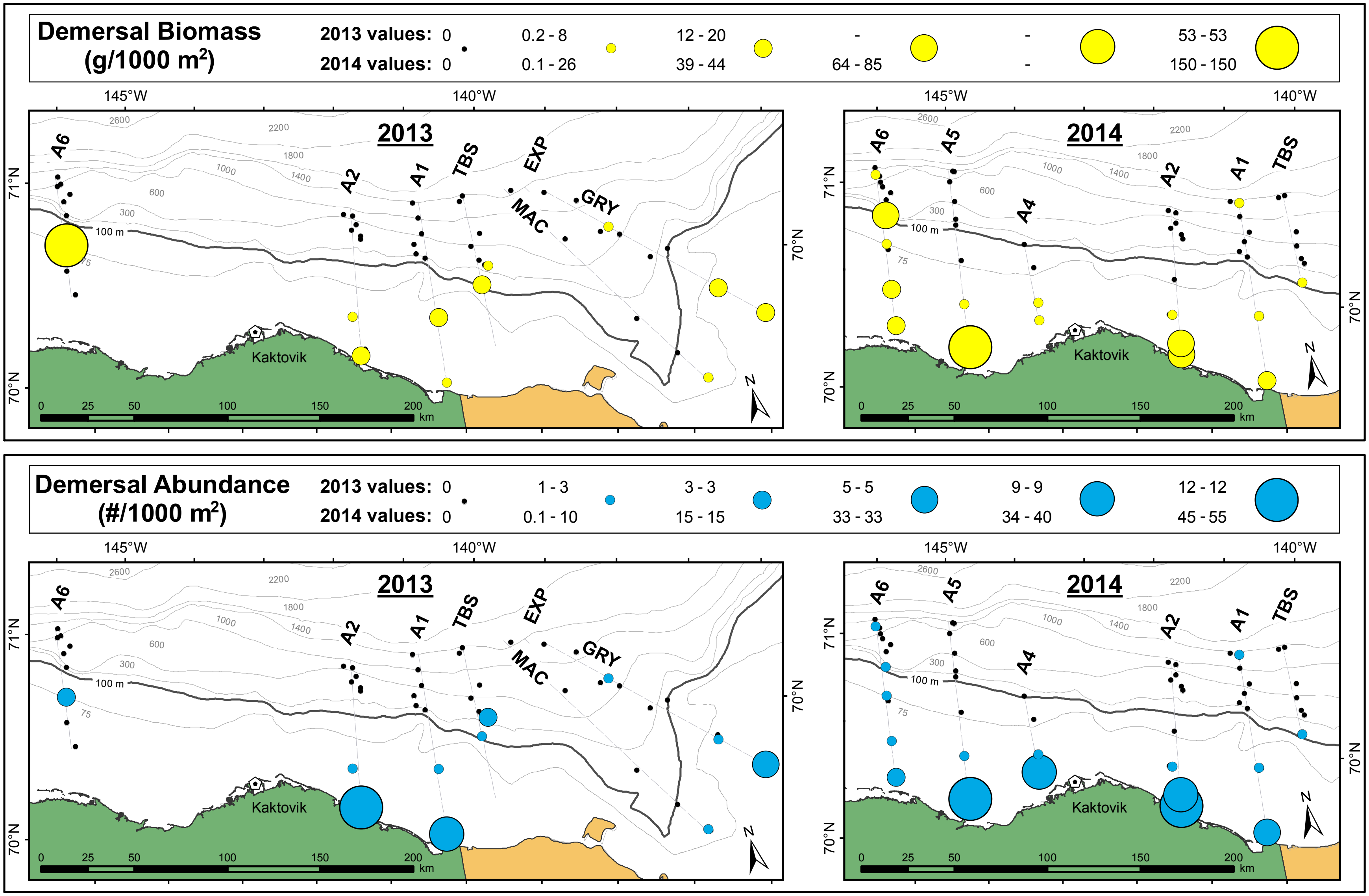
Appendix E3 Figure 6. Maps of demersal abundance, Cottidae: *Artediellus scaber*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Cottidae - Sculpins ***Gymnocanthus tricuspis*** **Arctic Staghorn Sculpin**



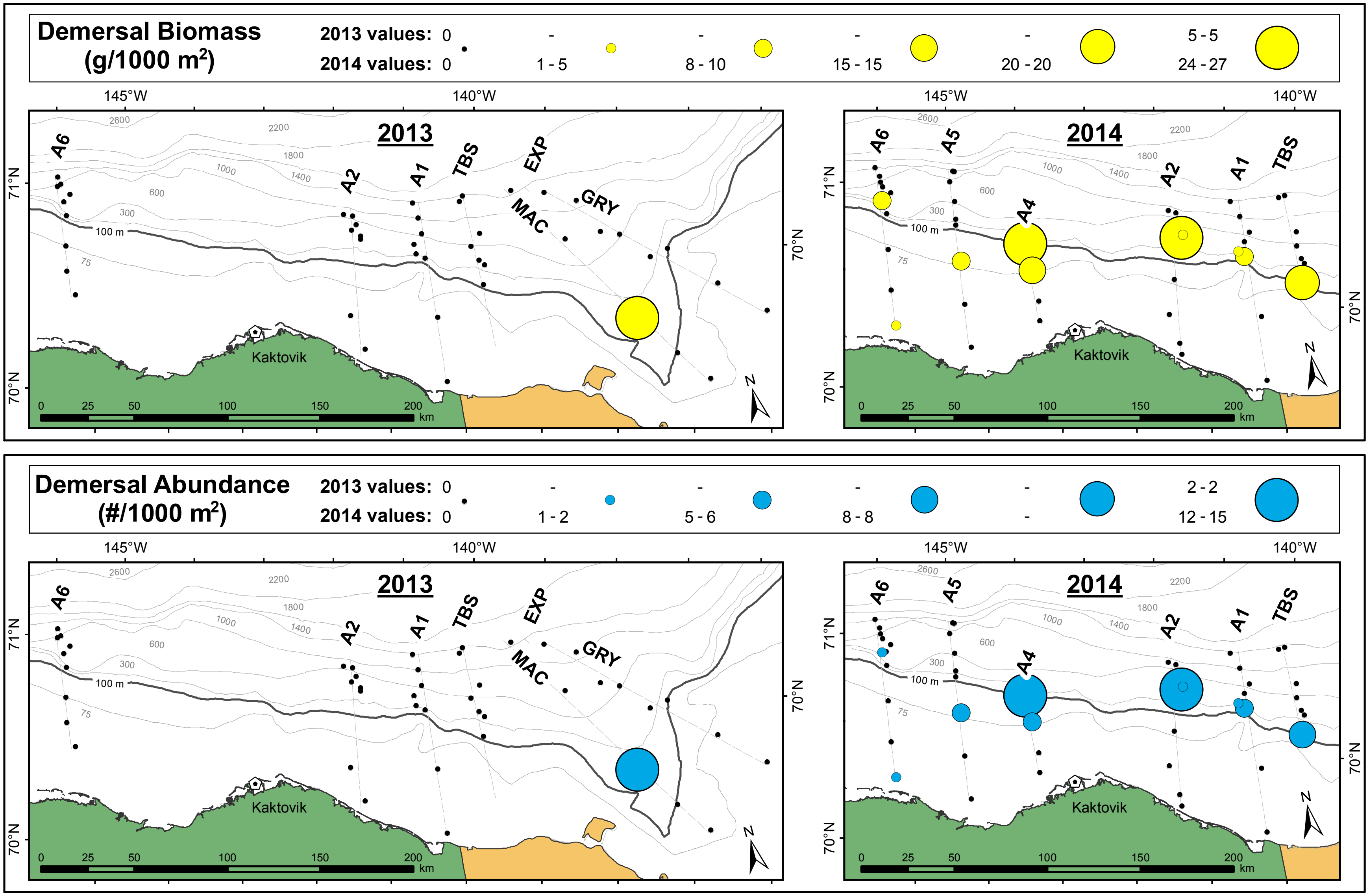
Appendix E3 Figure 7. Maps of pelagic abundance, Cottidae: *Gymnocanthus tricuspis*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins ***Gymnocanthus tricuspis*** **Arctic Staghorn Sculpin**



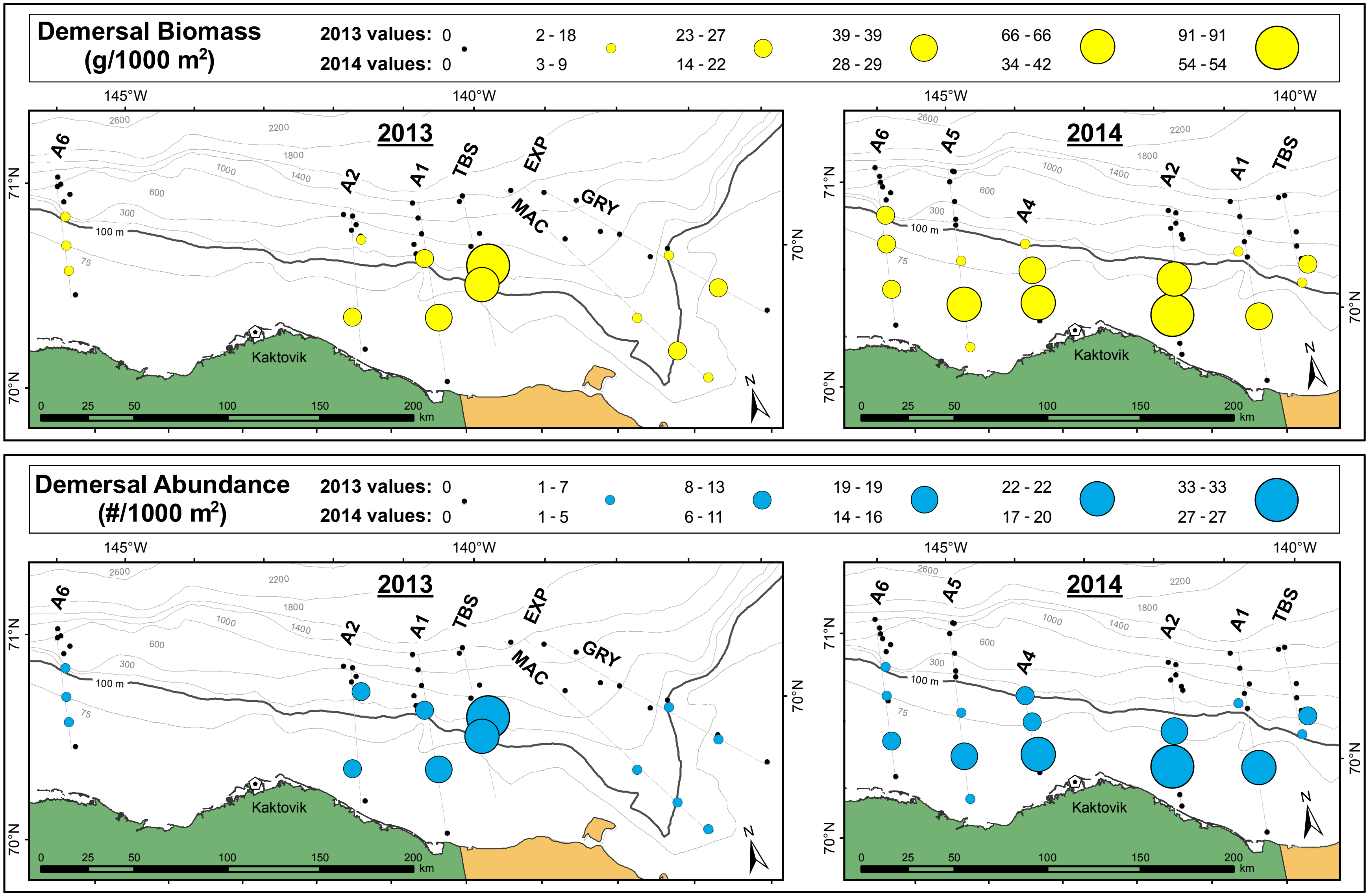
Appendix E3 Figure 8. Maps of demersal abundance, Cottidae: *Gymnocanthus tricuspis*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins *Icelus bicornis* **Twohorn Sculpin**



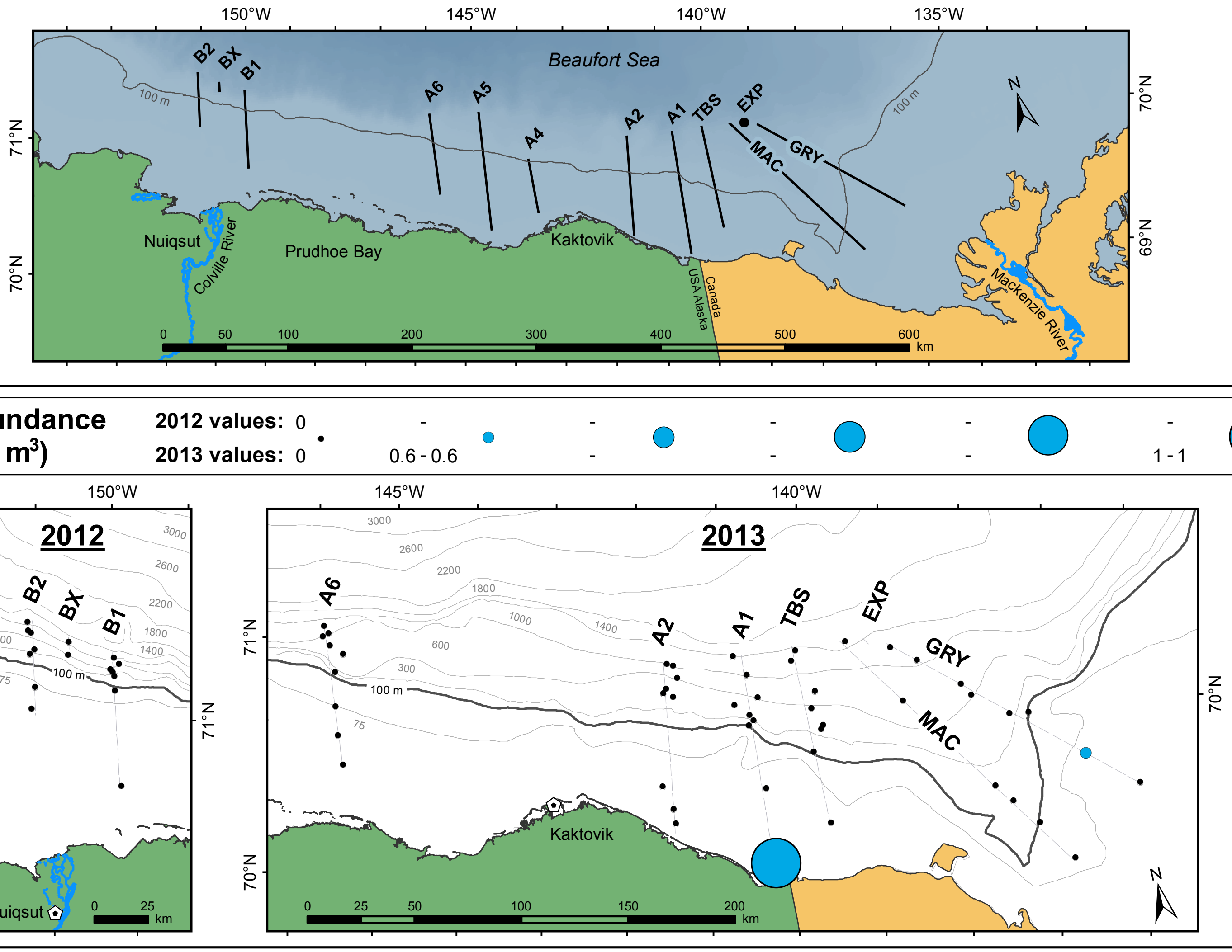
Appendix E3 Figure 9. Maps of demersal abundance, Cottidae: *Icelus bicornis*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. Species abundance not reported from pelagic habitat.

Cottidae - Sculpins *Icelus spatula* Spatulate Sculpin



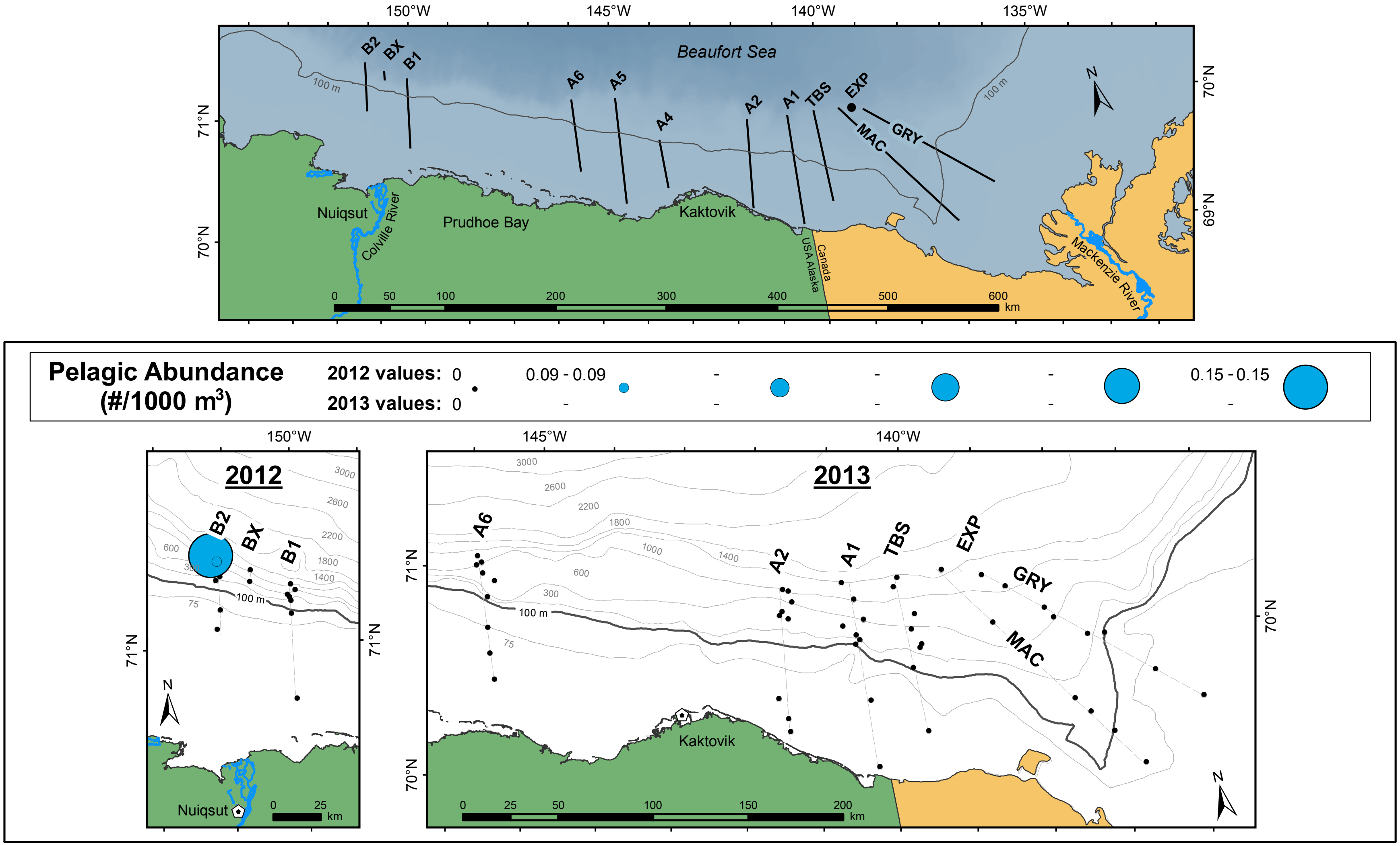
Appendix E3 Figure 10. Maps of demersal abundance, Cottidae: *Icelus spatula*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. Species abundance not reported from pelagic habitat.

Cottidae - Sculpins *Icelus* spp. Twohorn or Spatulate sculpins



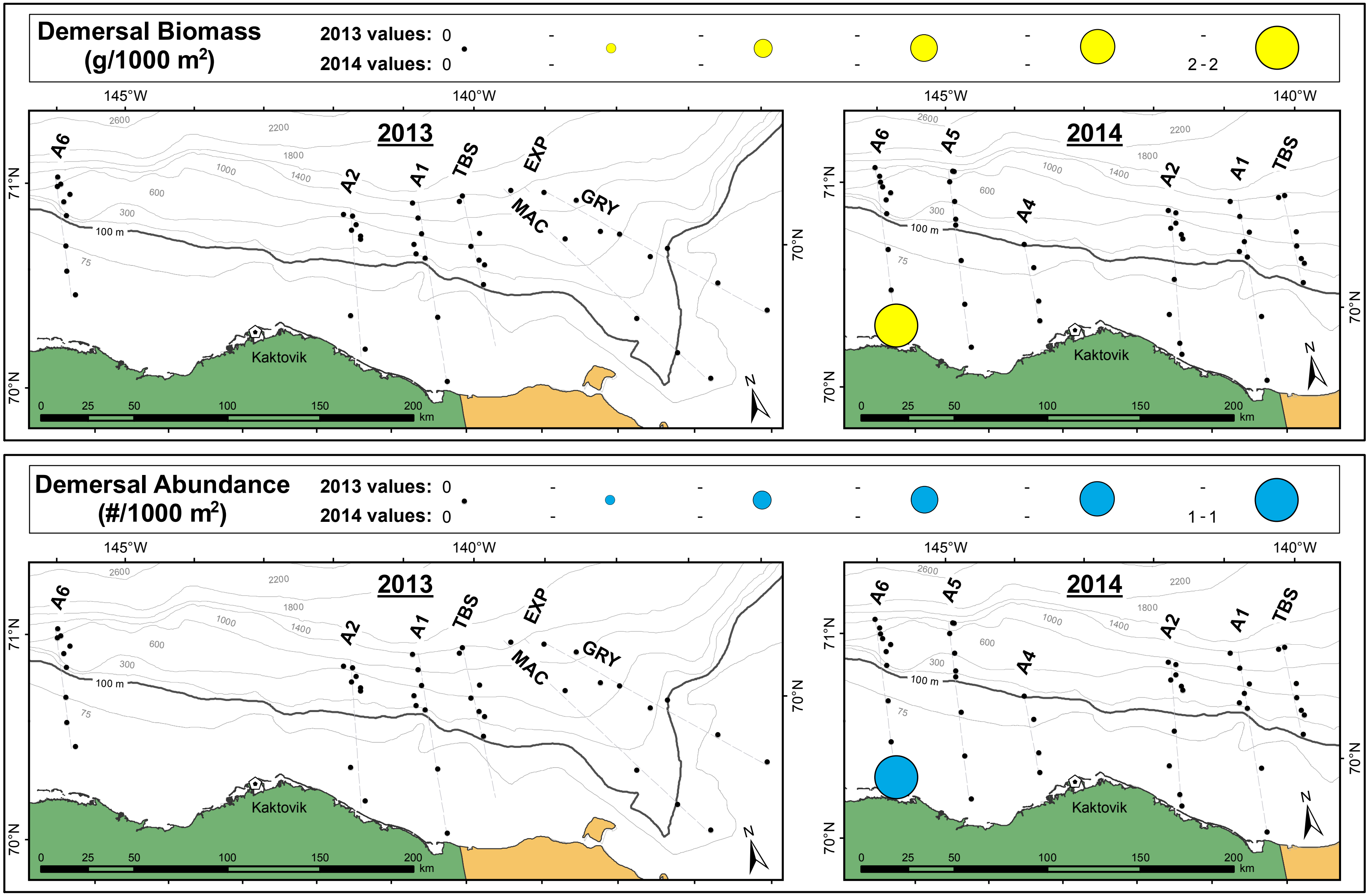
Appendix E3 Figure 11. Maps of pelagic abundance, Cottidae: *Icelus* spp. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins *Myoxocephalus scorpius* Shorthorn Sculpin



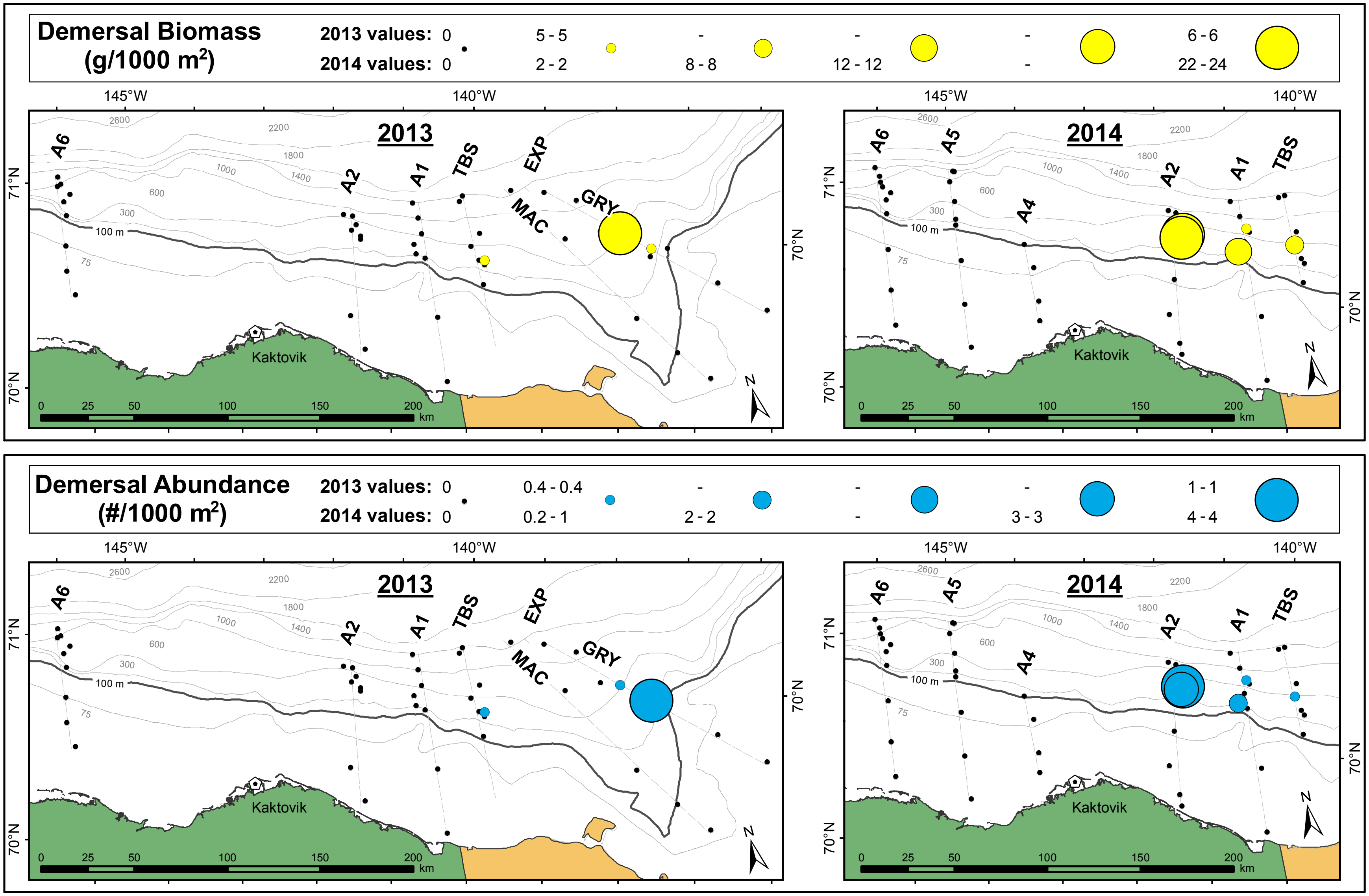
Appendix E3 Figure 12. Maps of pelagic abundance, Cottidae: *Myoxocephalus scorpius*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins *Myoxocephalus scorpius* **Shorthorn Sculpin**



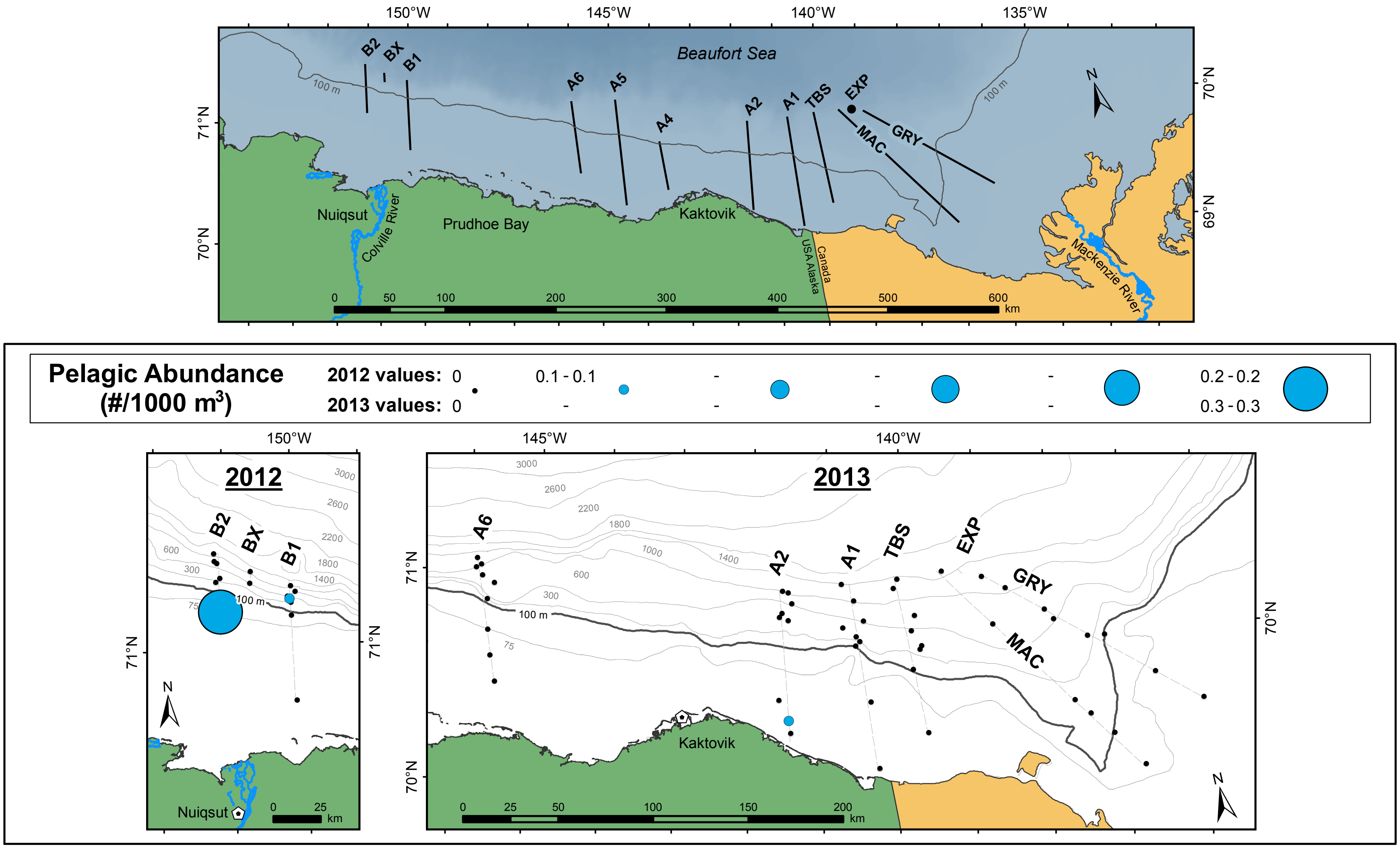
Appendix E3 Figure 13. Maps of demersal abundance, Cottidae: *Myoxocephalus scorpius*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins ***Triglops nybelini*** **Bigeye Sculpin**

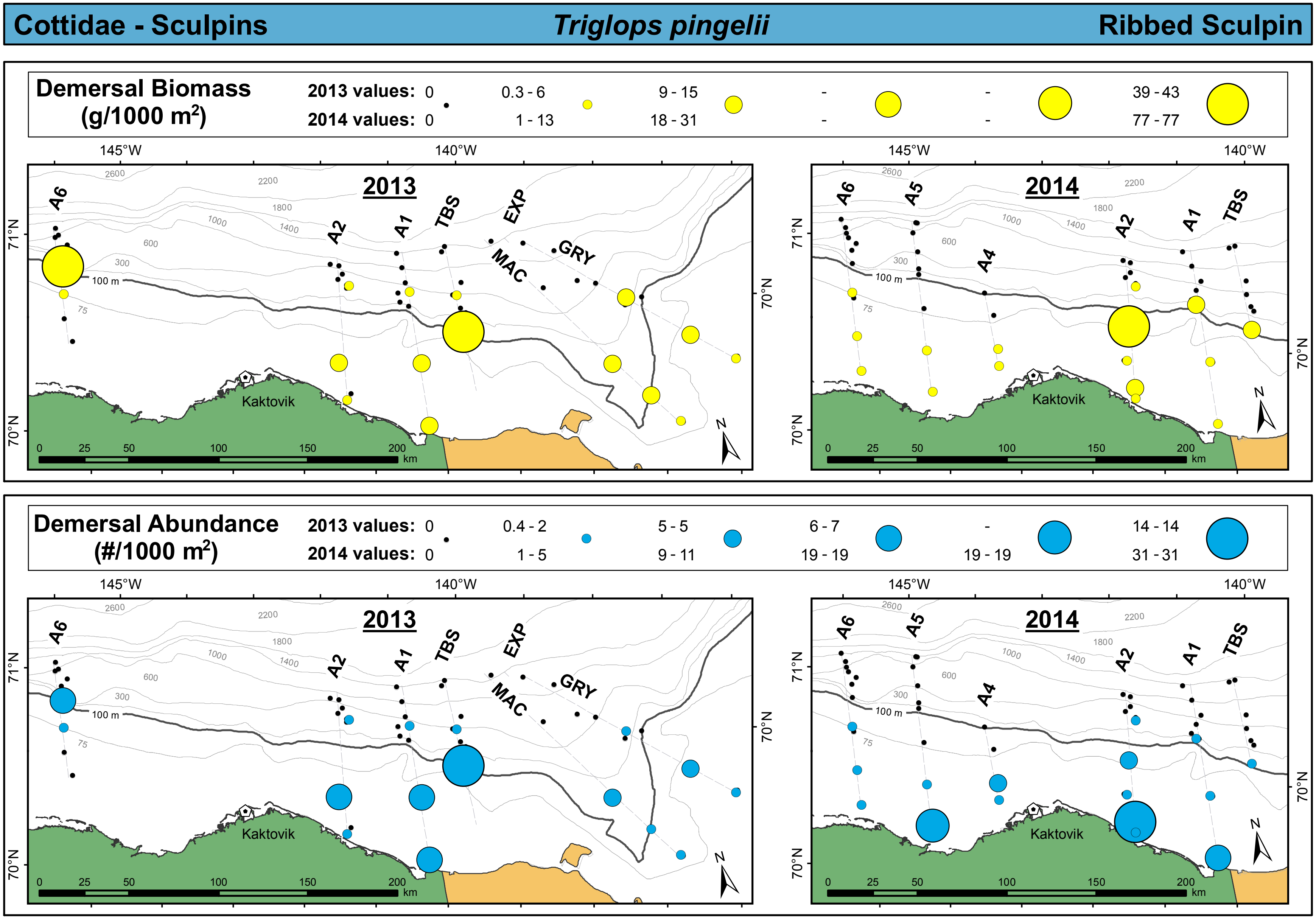


Appendix E3 Figure 14. Maps of demersal abundance, Cottidae: *Triglops nybelini*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Cottidae - Sculpins *Triglops pingelii* **Ribbed Sculpin**

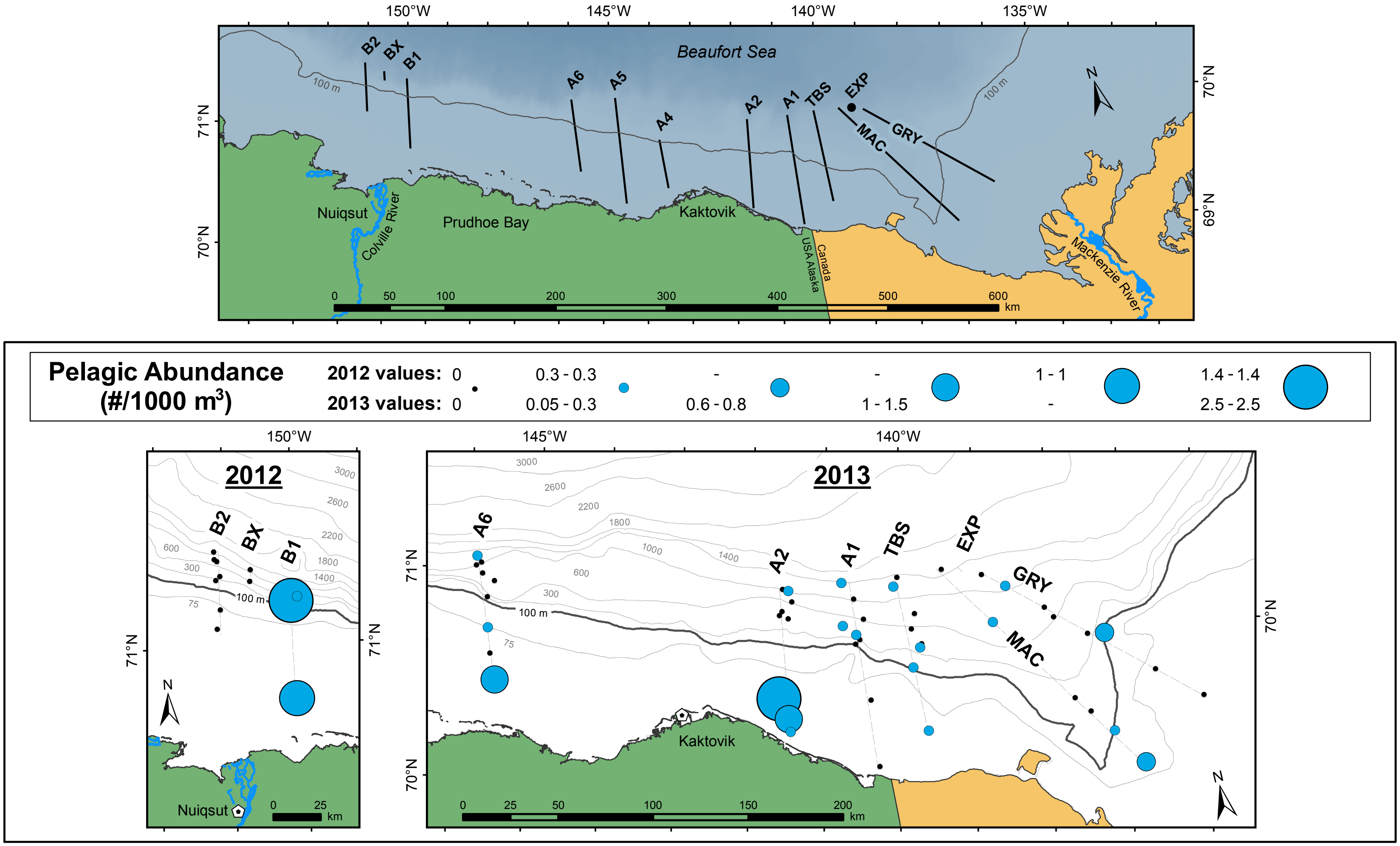


Appendix E3 Figure 15. Maps of pelagic abundance, Cottidae: *Triglops pingelii*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.



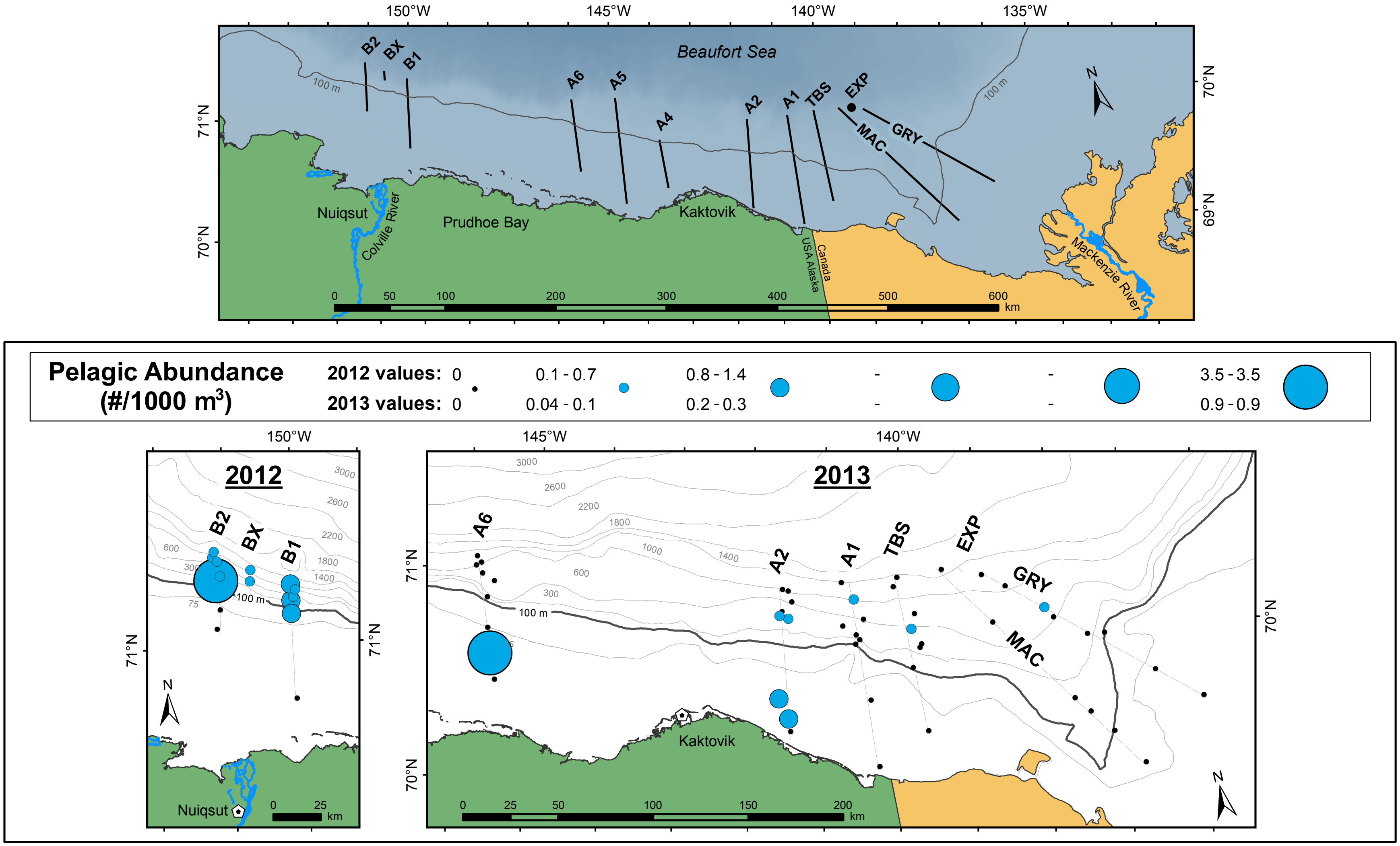
Appendix E3 Figure 16. Maps of demersal abundance, Cottidae: *Triglops pingelii*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Cottidae - Sculpins **Cottidae <50 mm** **Sculpins**



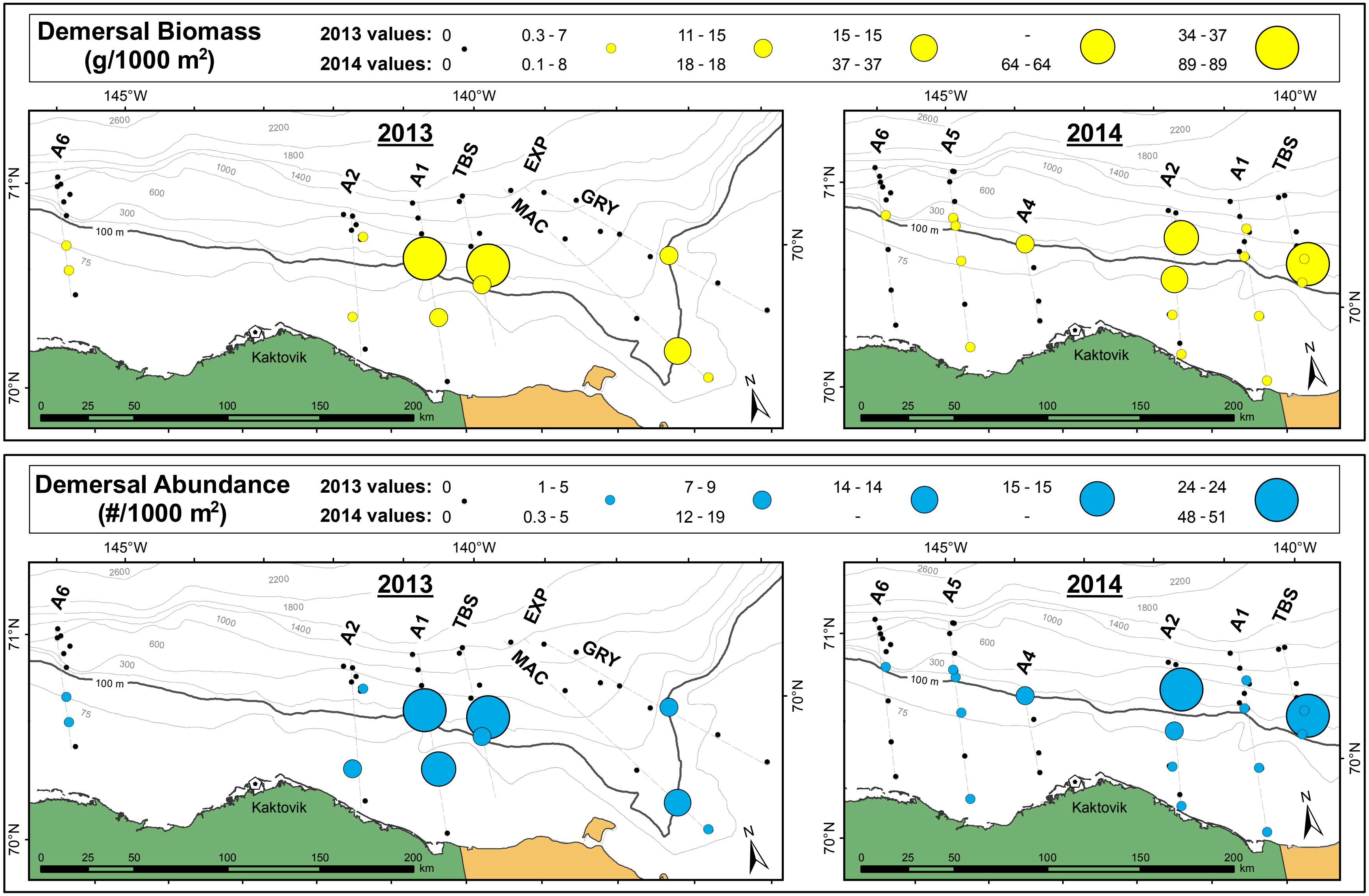
Appendix E3 Figure 17. Maps of pelagic abundance, Cottidae: Cottidae unidentified <50 mm. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Agonidae - Poachers *Aspidophoroides olrikii* Arctic Alligatorfish



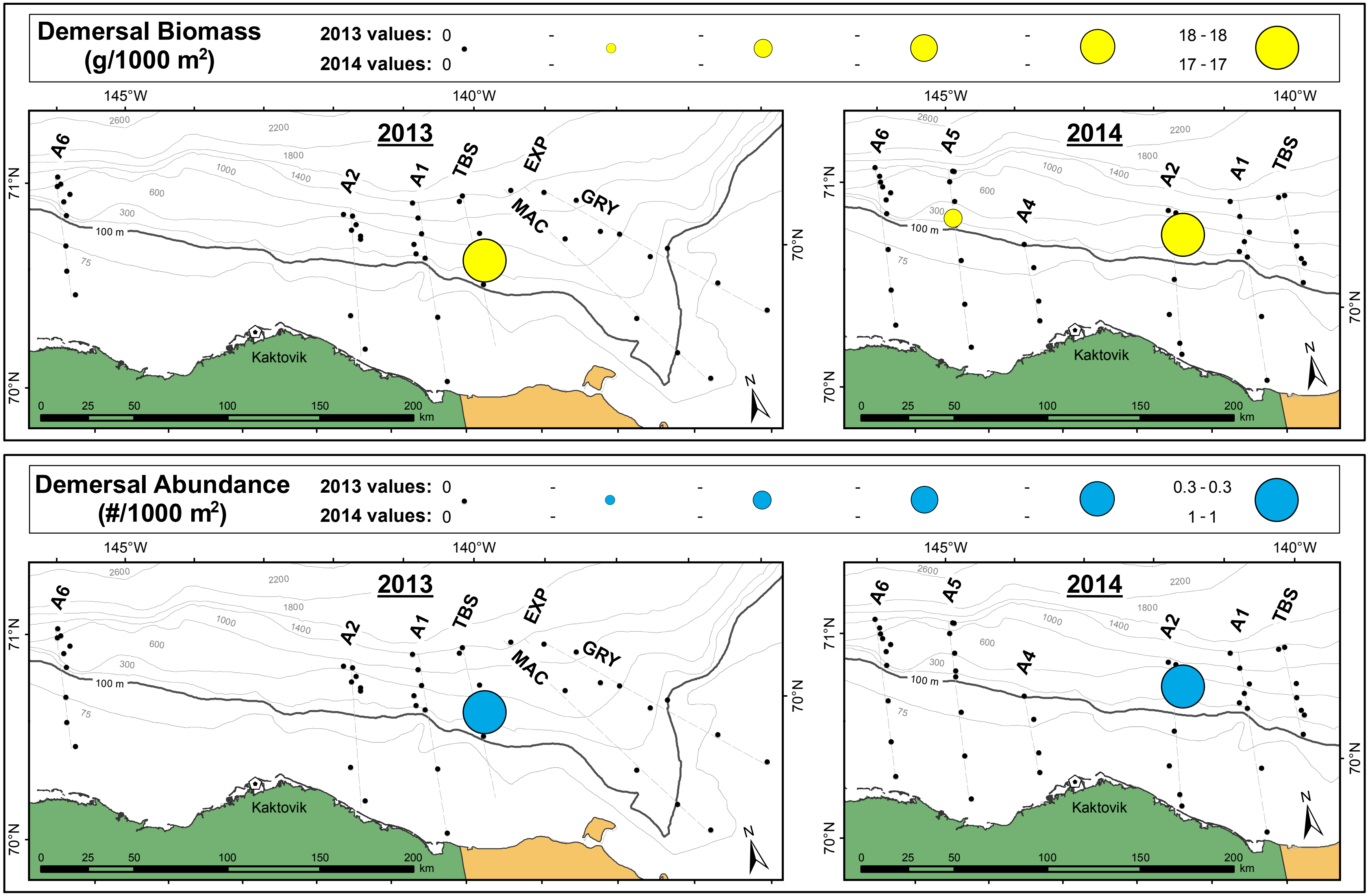
Appendix E3 Figure 18. Maps of pelagic abundance, Agonidae: *Aspidophoroides olrikii*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Agonidae - Poachers ***Aspidophoroides olrikii*** **Arctic Alligatorfish**



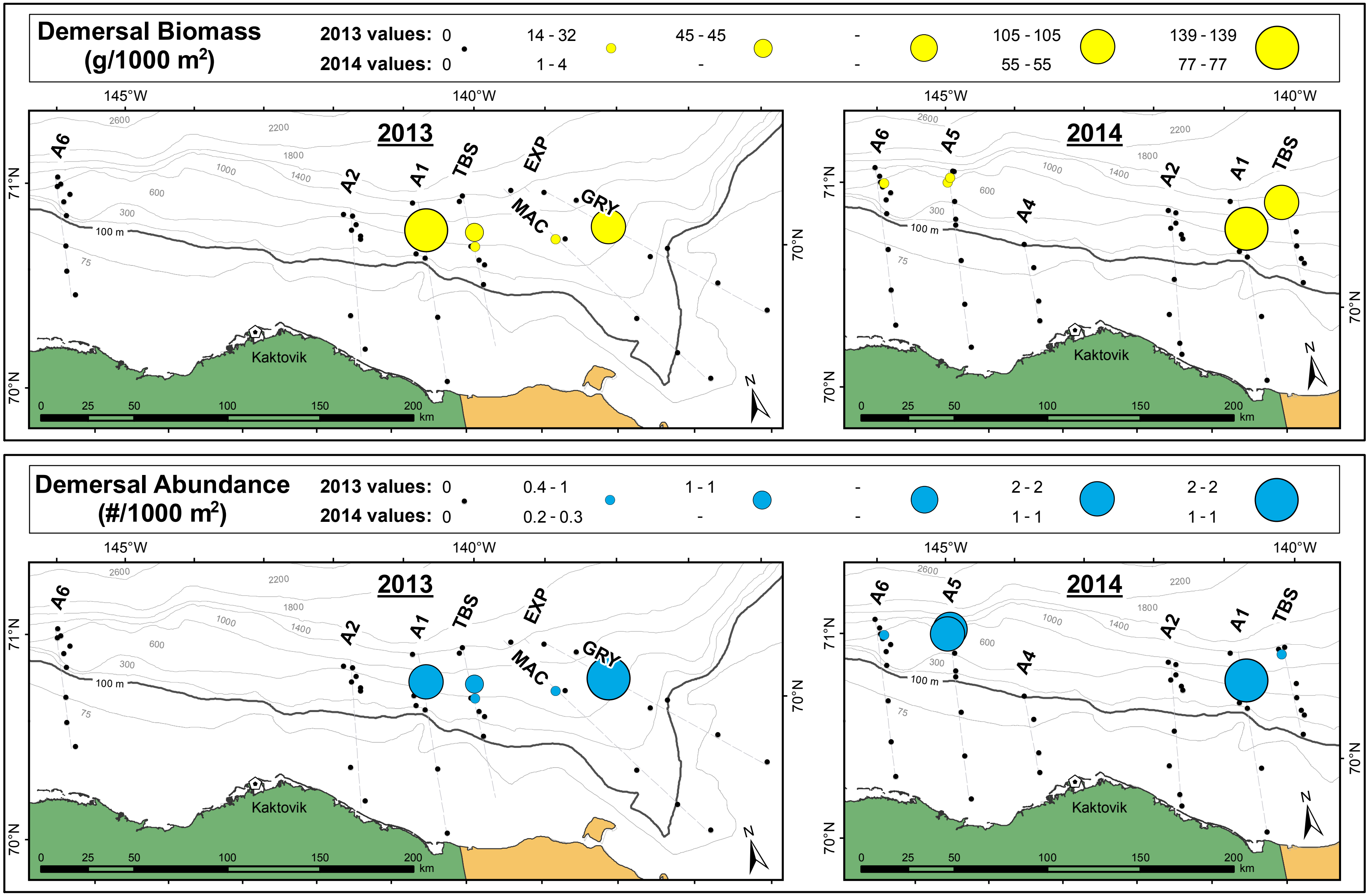
Appendix E3 Figure 19. Maps of demersal abundance, Agonidae: *Aspidophoroides olrikii*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Agonidae - Poachers ***Leptagonus decagonus*** **Atlantic Poacher**



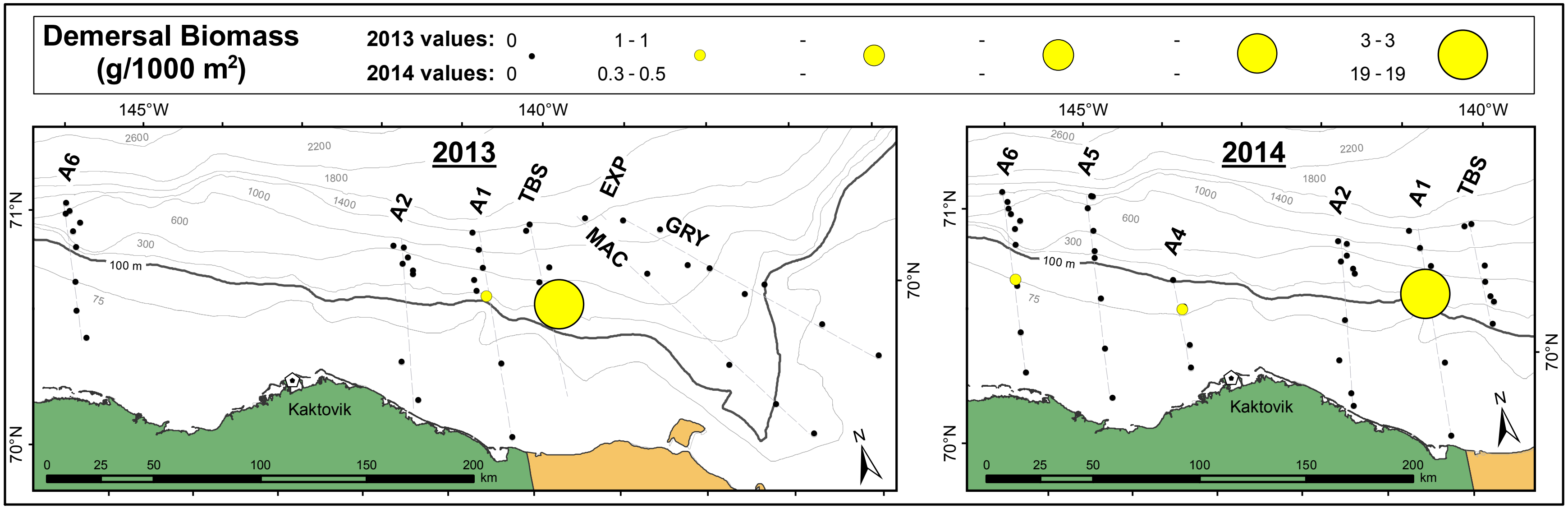
Appendix E3 Figure 20. Maps of demersal abundance, Agonidae: *Leptagonus decagonus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

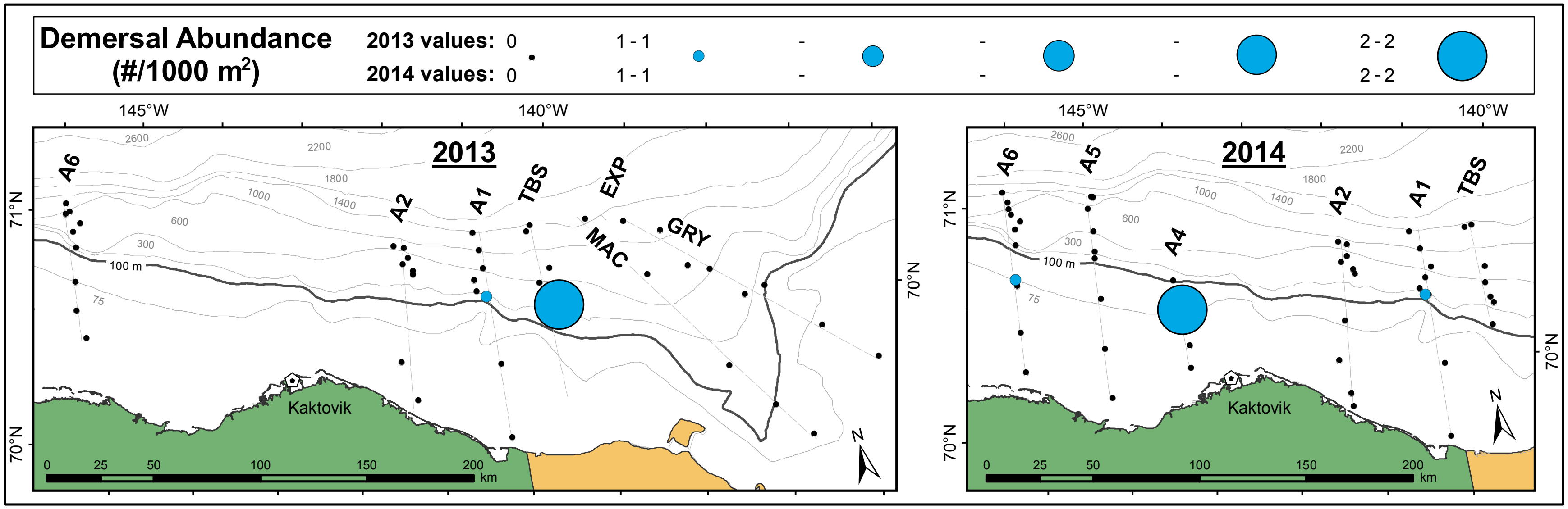
Psychrolutidae - Fathead sculpins ***Cottunculus microps*** **Polar Sculpin**



Appendix E3 Figure 21. Maps of demersal abundance, Psychrolutidae: *Cottunculus microps*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

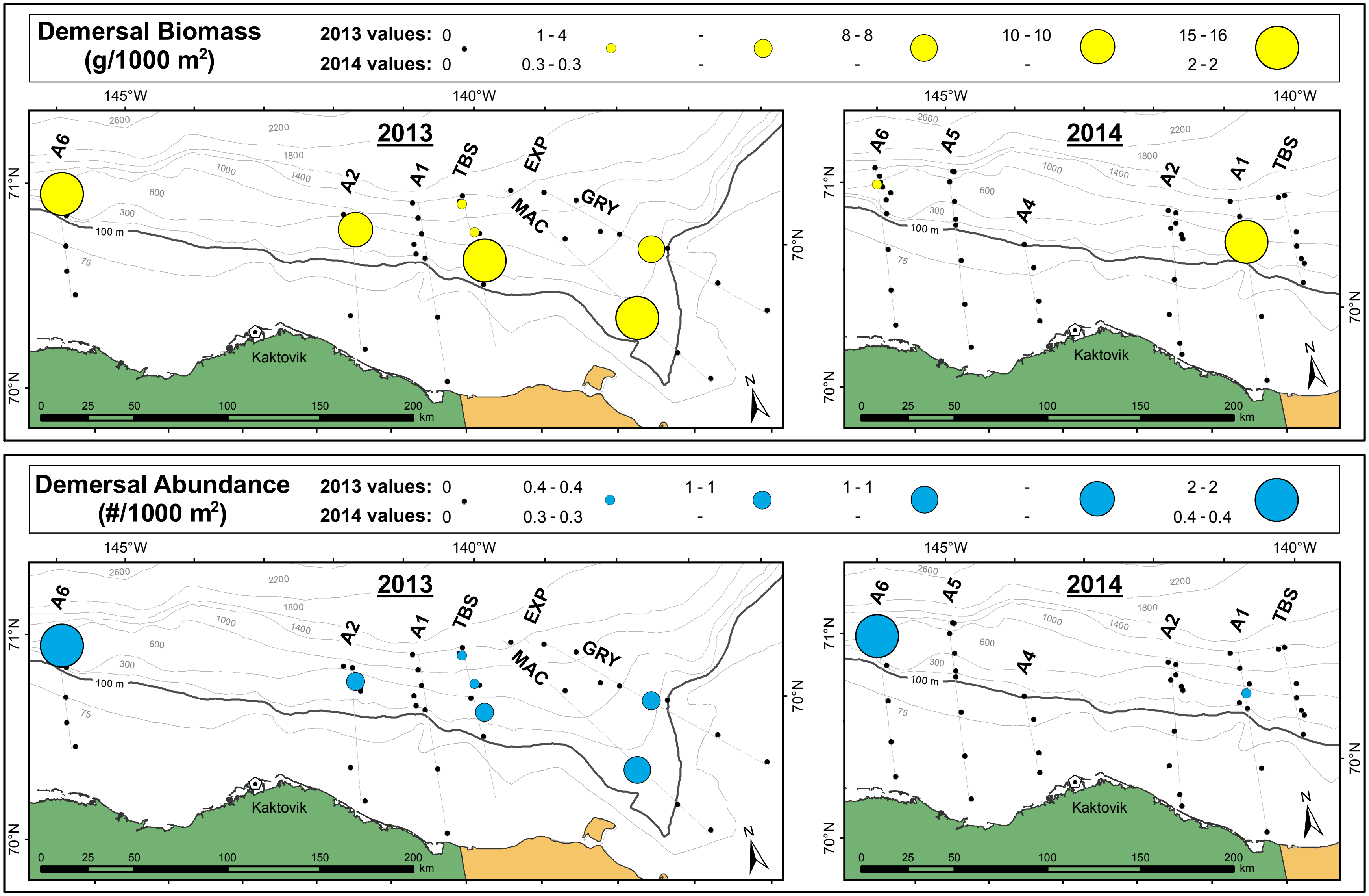
Cyclopteridae - Lumpfishes ***Eumicrotremus derjugini*** **Leatherfin Lumpsucker**





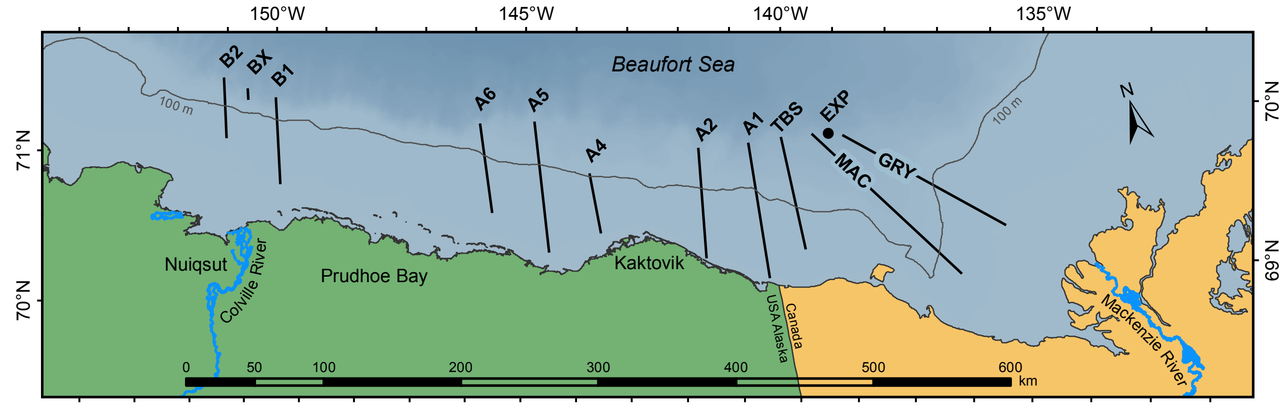
Appendix E3 Figure 22. Maps of demersal abundance, Cyclopteridae: *Eumicrotremus derjugini*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

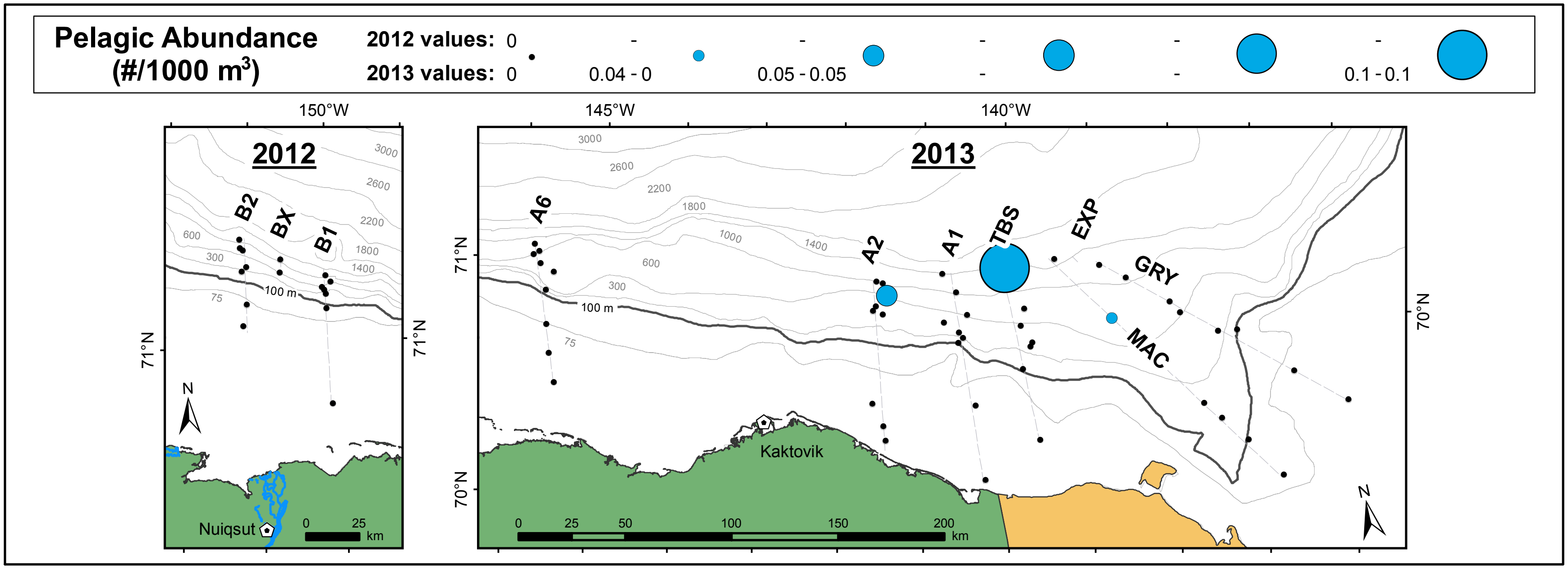
Liparidae - Snailfishes ***Careproctus lerikimae*** **Dusty Snailfish**



Appendix E3 Figure 23. Maps of demersal abundance, Liparidae: *Careproctus lerikimae*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

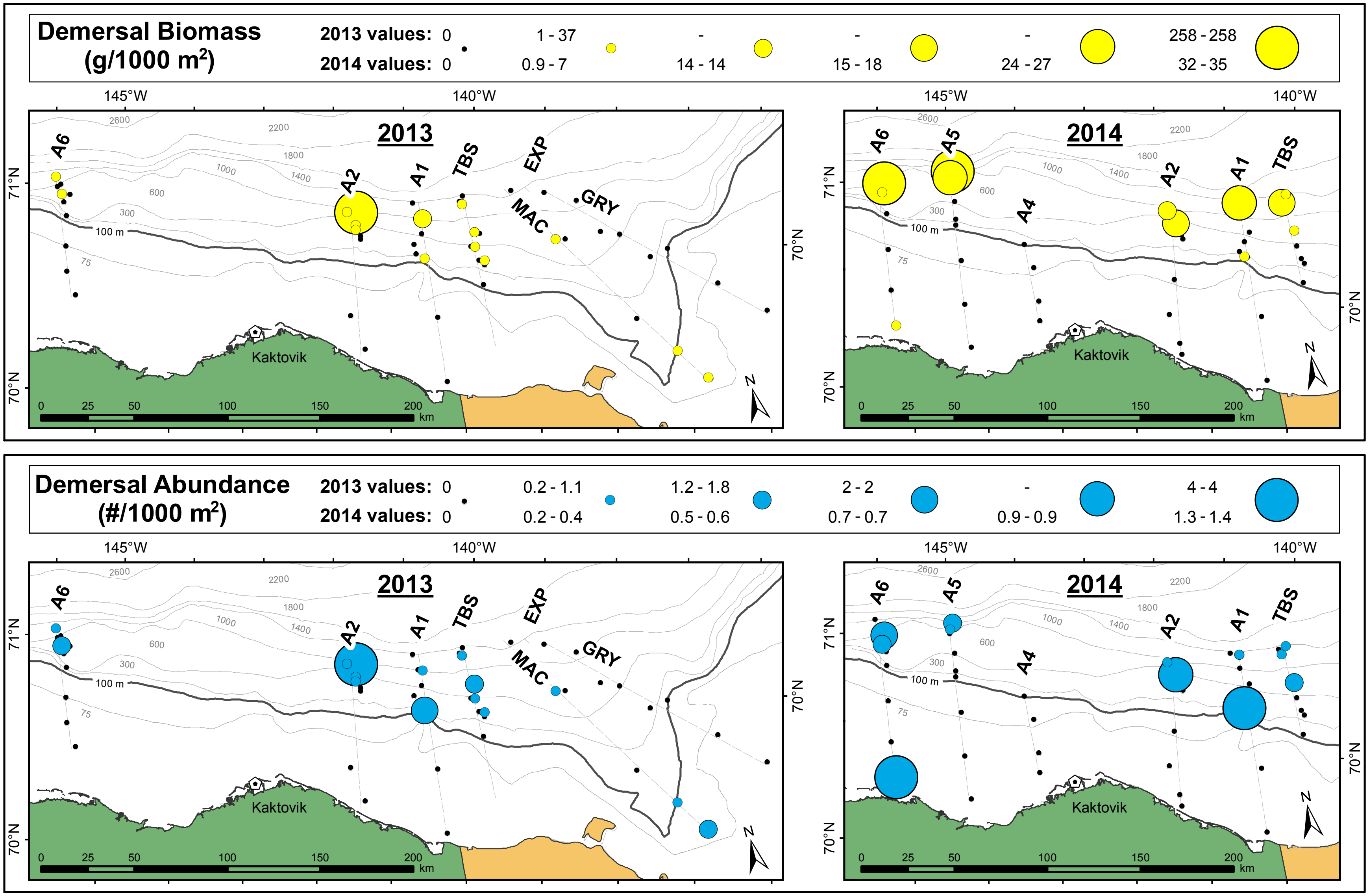
Liparidae - Snailfishes ***Liparis fabricii*** **Gelatinous Seasnail**





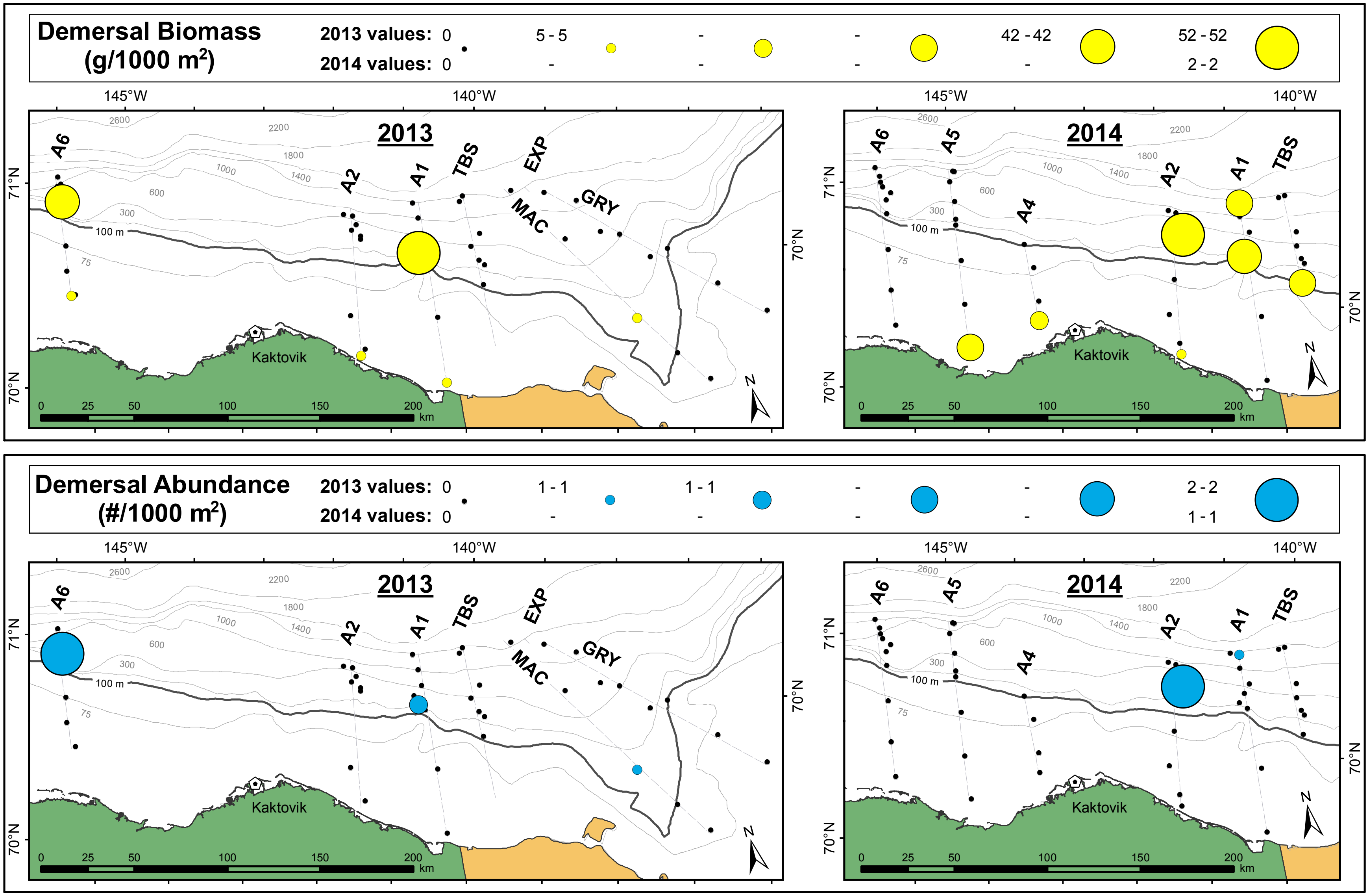
Appendix E3 Figure 24. Maps of pelagic abundance, Liparidae: *Liparis fabricii*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Liparidae - Snailfishes *Liparis fabricii* Gelatinous Seasnail



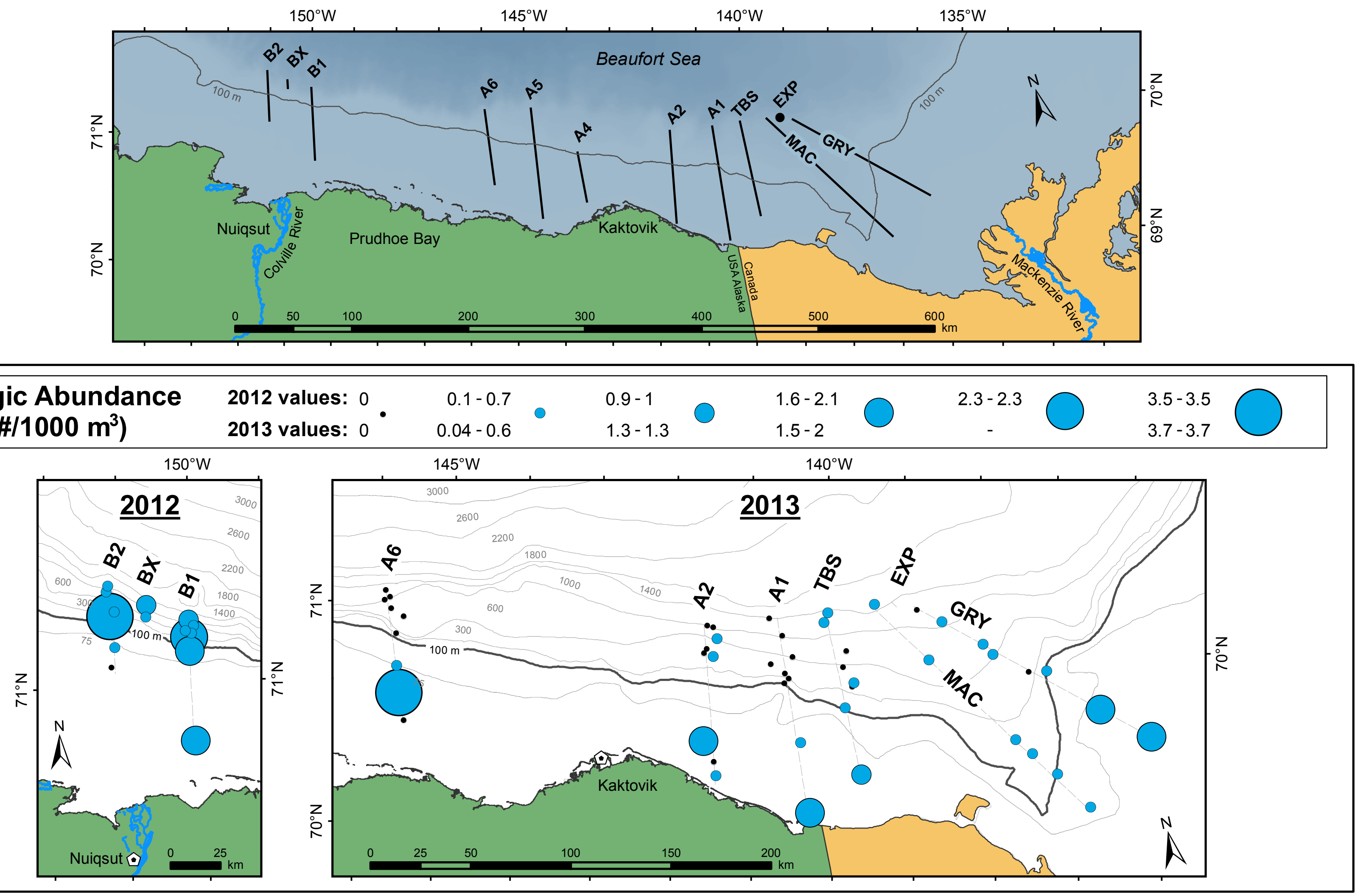
Appendix E3 Figure 25. Maps of demersal abundance, Liparidae: *Liparis fabricii*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Liparidae - Snailfishes *Liparis gibbus* Variegated Snailfish



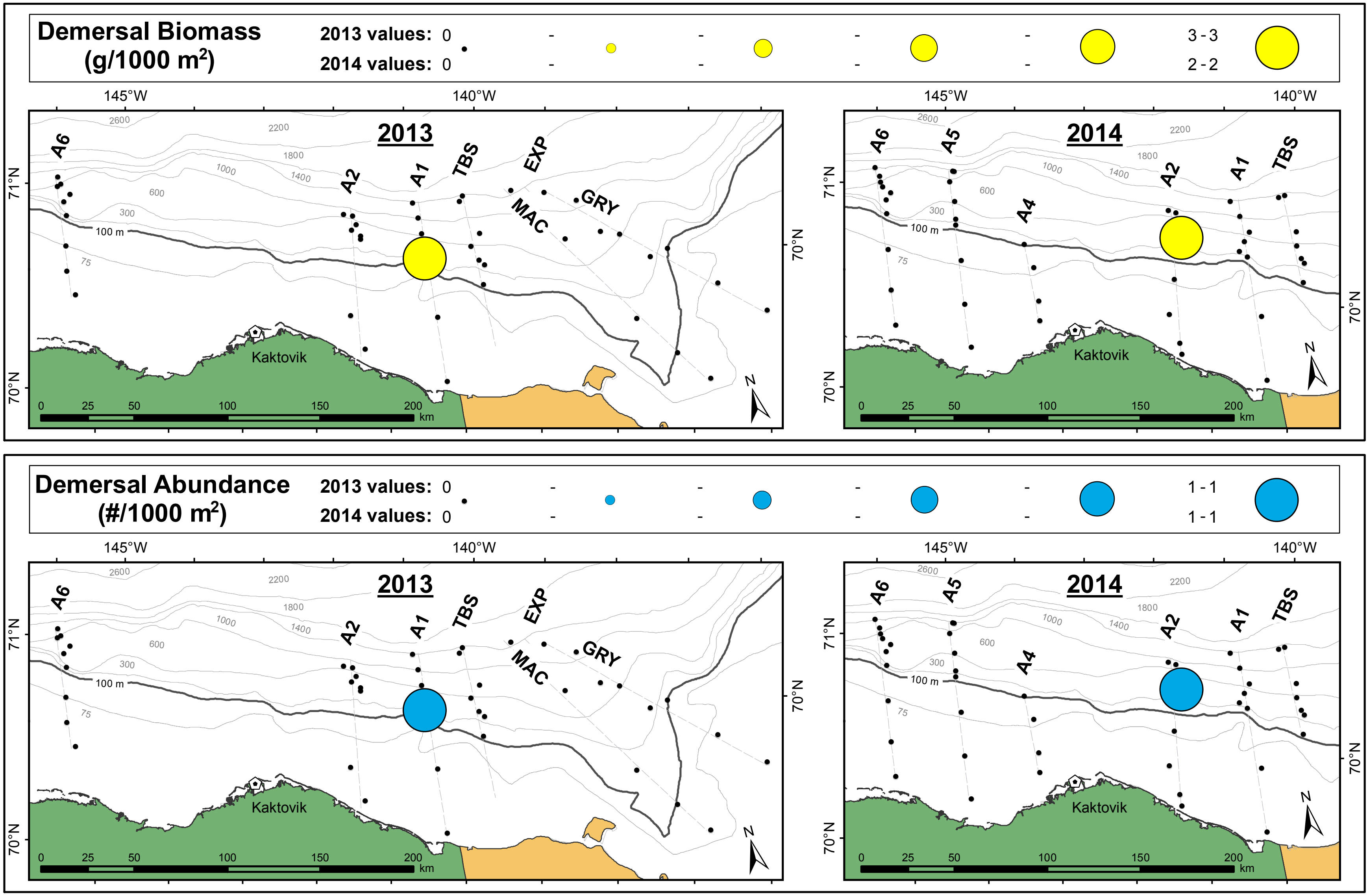
Appendix E3 Figure 26. Maps of demersal abundance, Liparidae: *Liparis gibbus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. Species abundance not reported from pelagic habitat.

Liparidae - Snailfishes ***Liparis*** **spp. <50 mm** **Snailfishes**



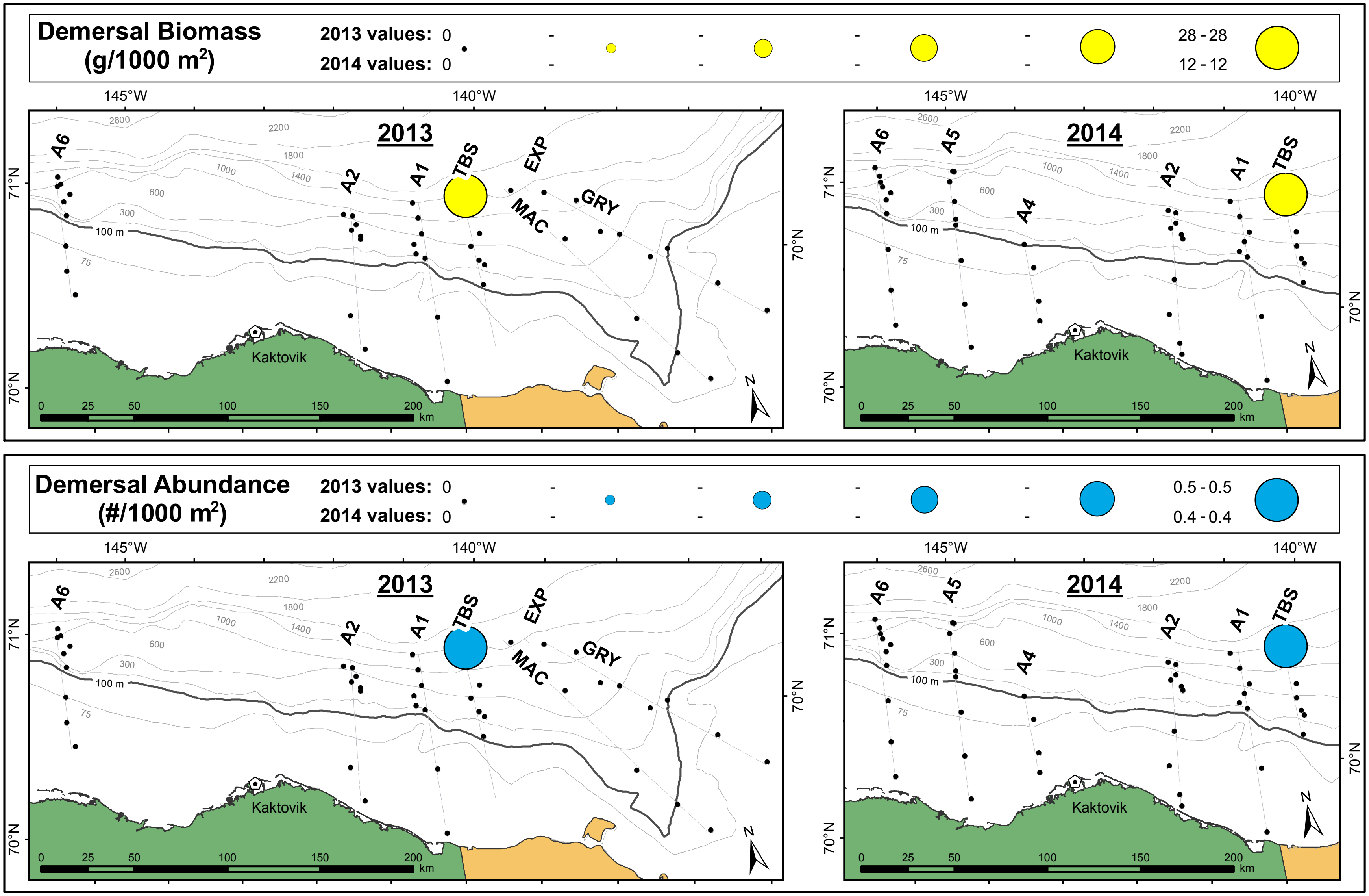
Appendix E3 Figure 27. Maps of pelagic abundance, Liparidae: *Liparis* spp. <50 mm total length. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Liparidae - Snailfishes *Liparis tunicatus* **Kelp Snailfish**



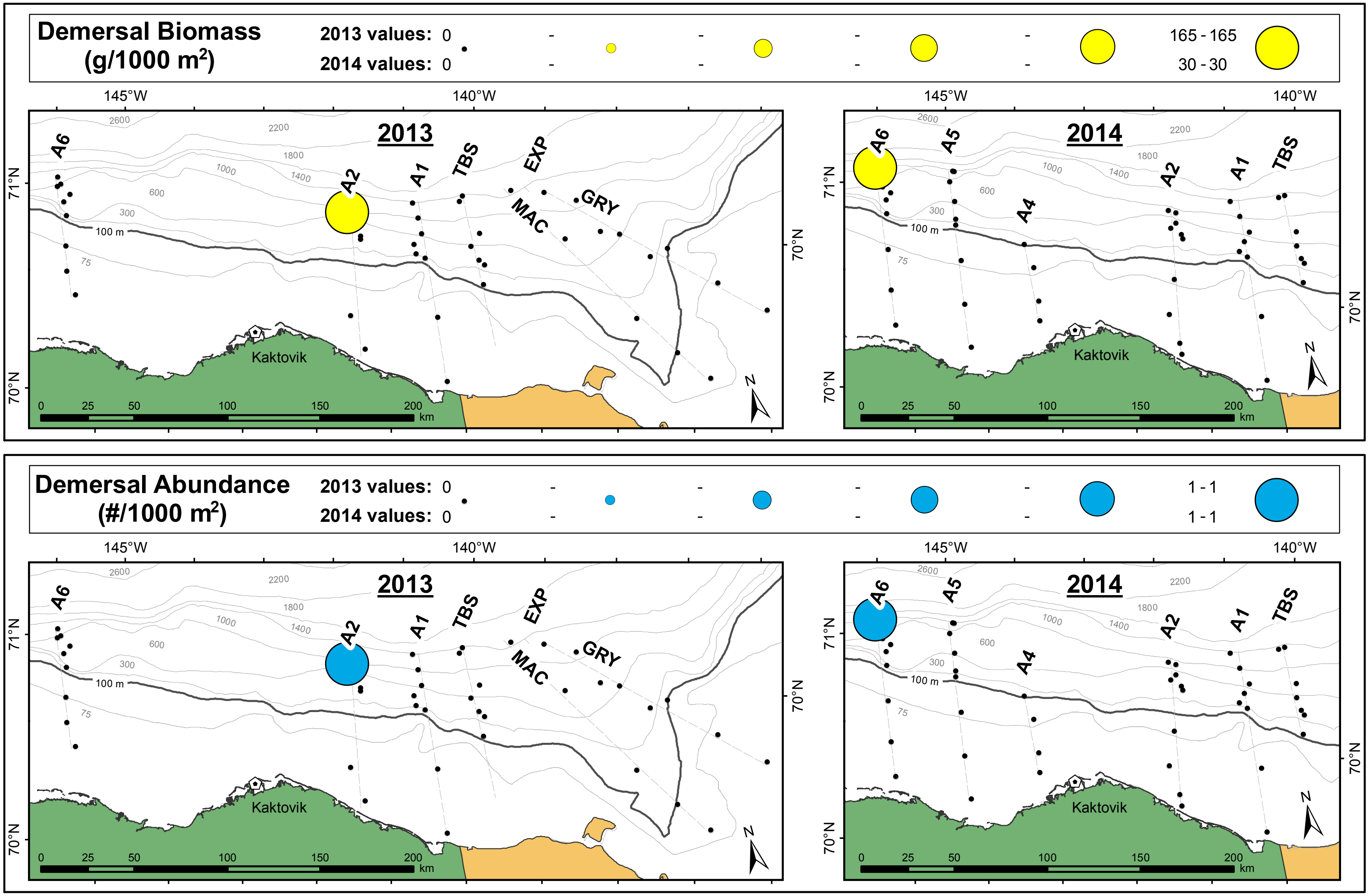
Appendix E3 Figure 28. Maps of demersal abundance, Liparidae: *Liparis tunicatus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. Species abundance not reported from pelagic habitat.

Liparidae - Snailfishes *Paraliparis* spp.



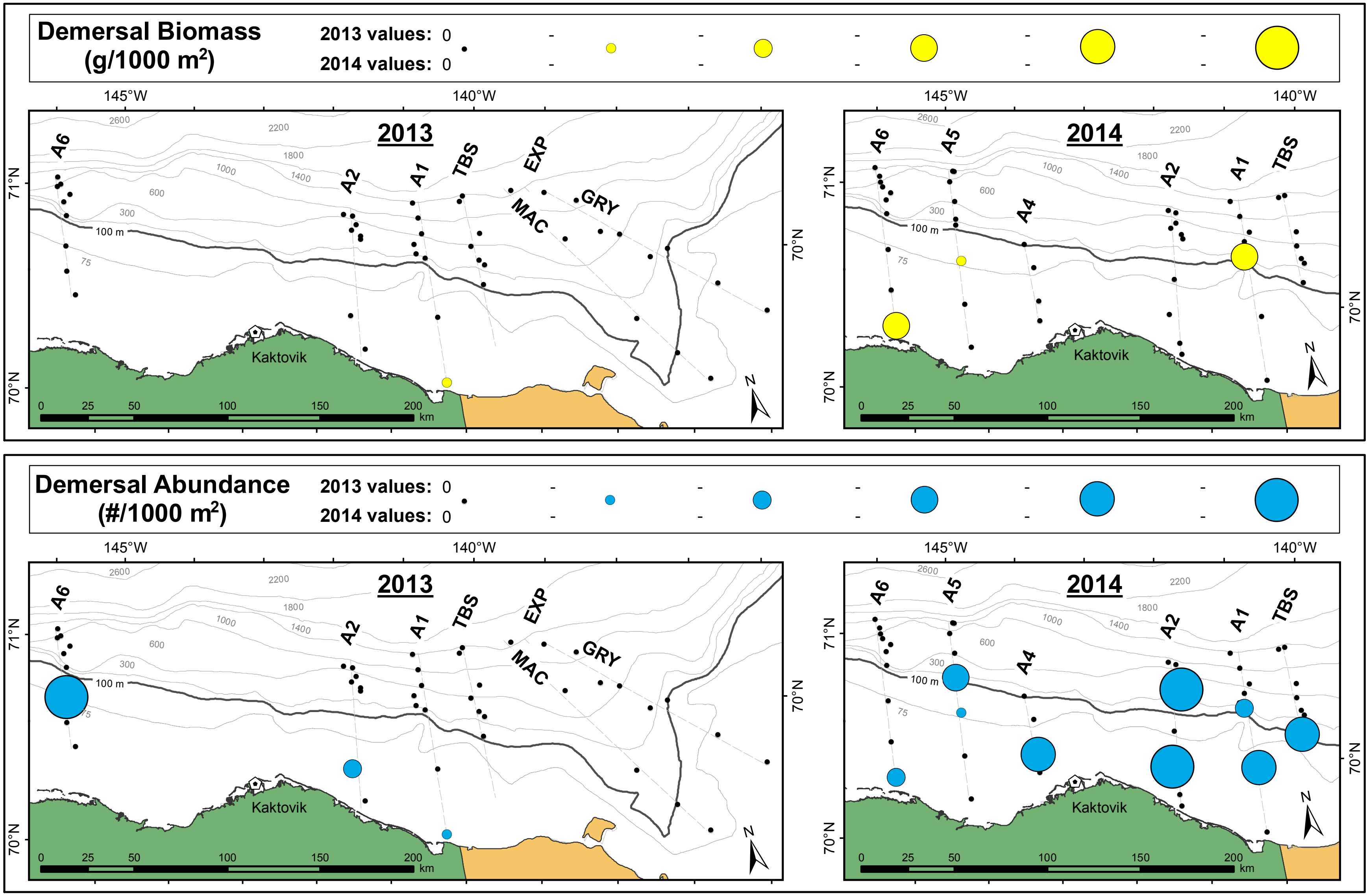
Appendix E3 Figure 29. Maps of demersal abundance, Liparidae: *Paraliparis* spp. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Liparidae - Snailfishes ***Rhodichthys regina*** **Threadfin Seasnail**



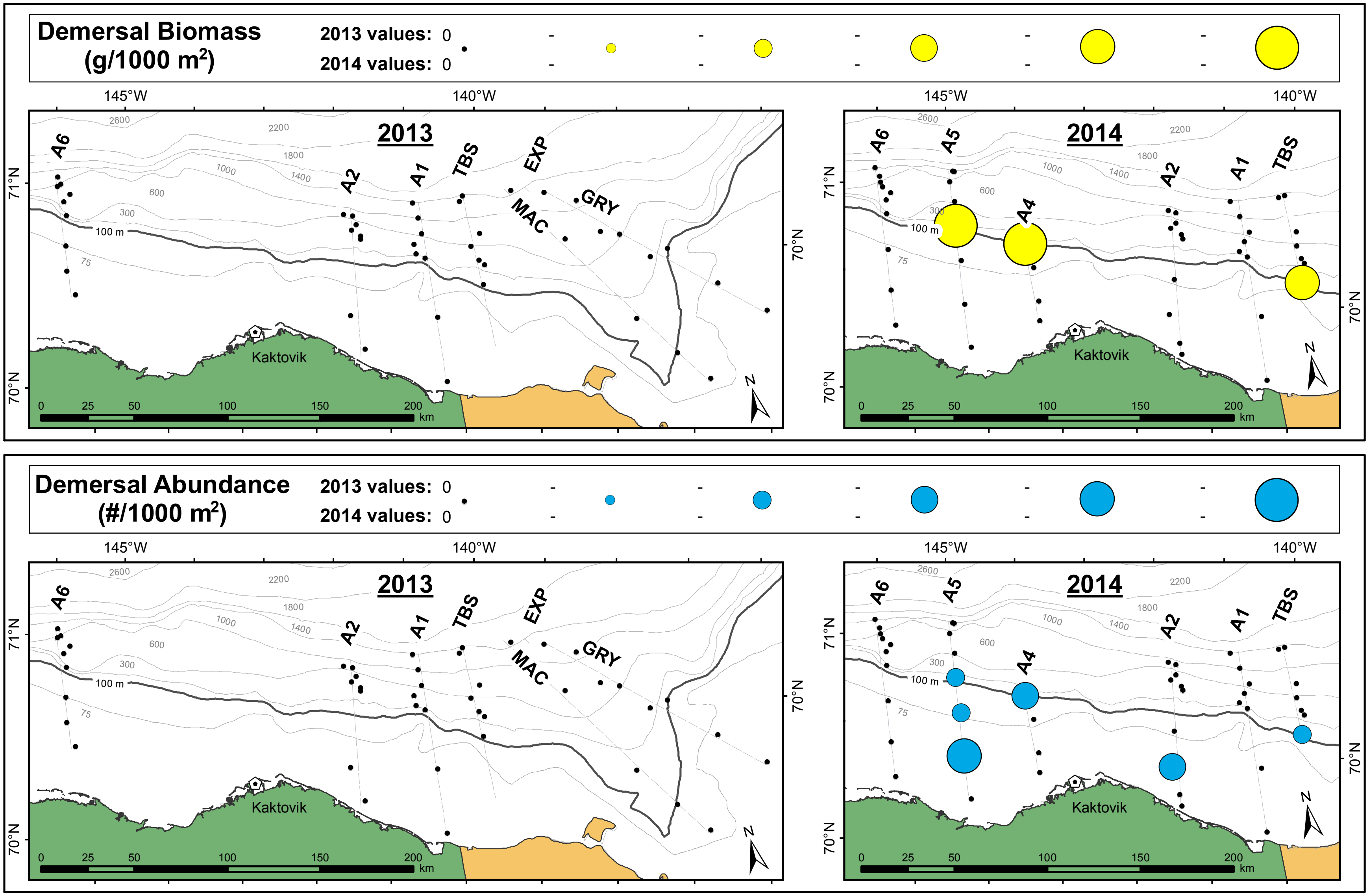
Appendix E3 Figure 30. Maps of demersal abundance, Liparidae: *Rhodichthys regina*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Gymnelus hemifasciatus*** **Halfbarred Pout**



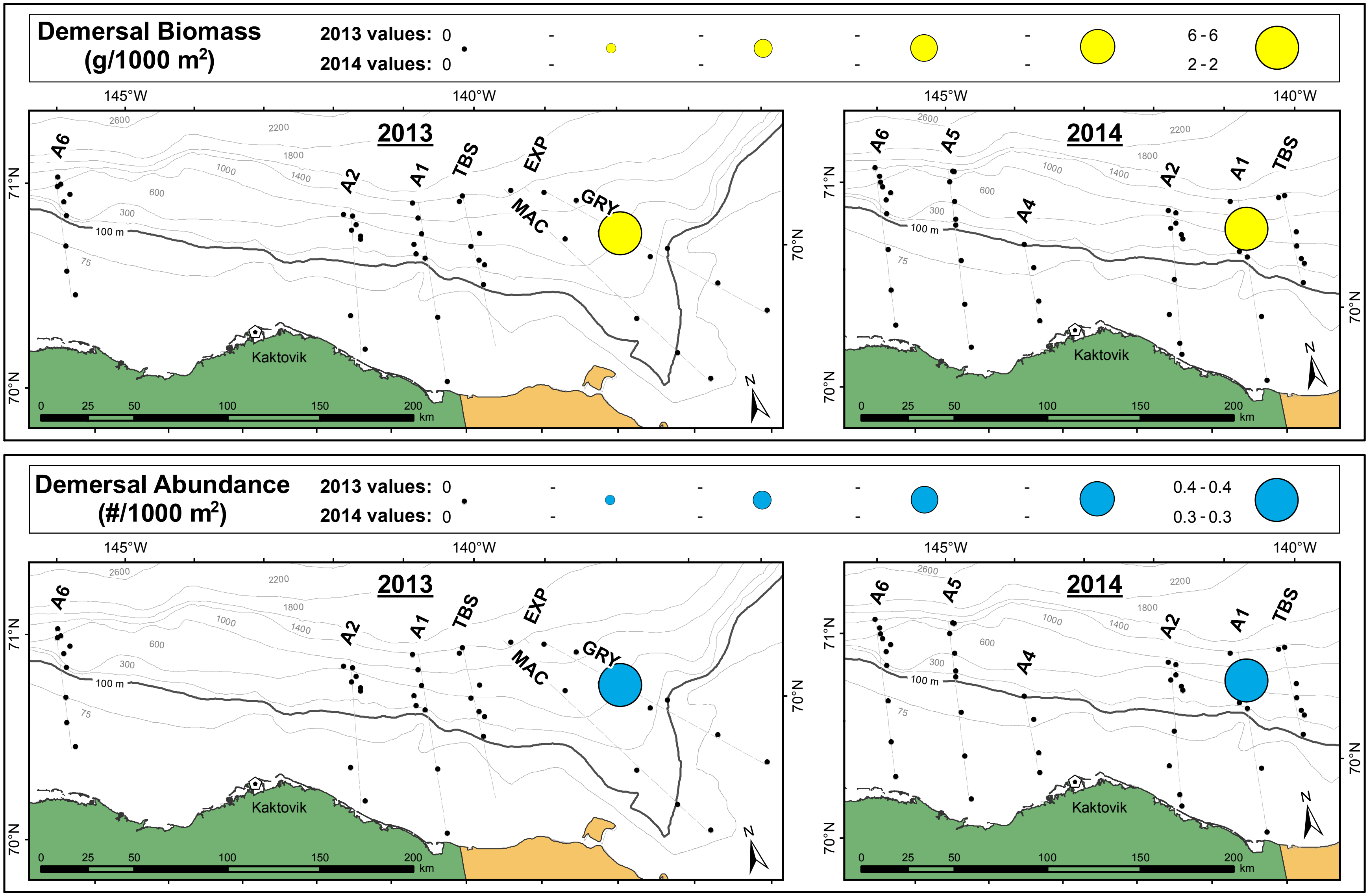
Appendix E3 Figure 31. Maps of demersal abundance, Zoarcidae: *Gymnelus hemifasciatus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts *Gymnelus viridis* **Fish Doctor**



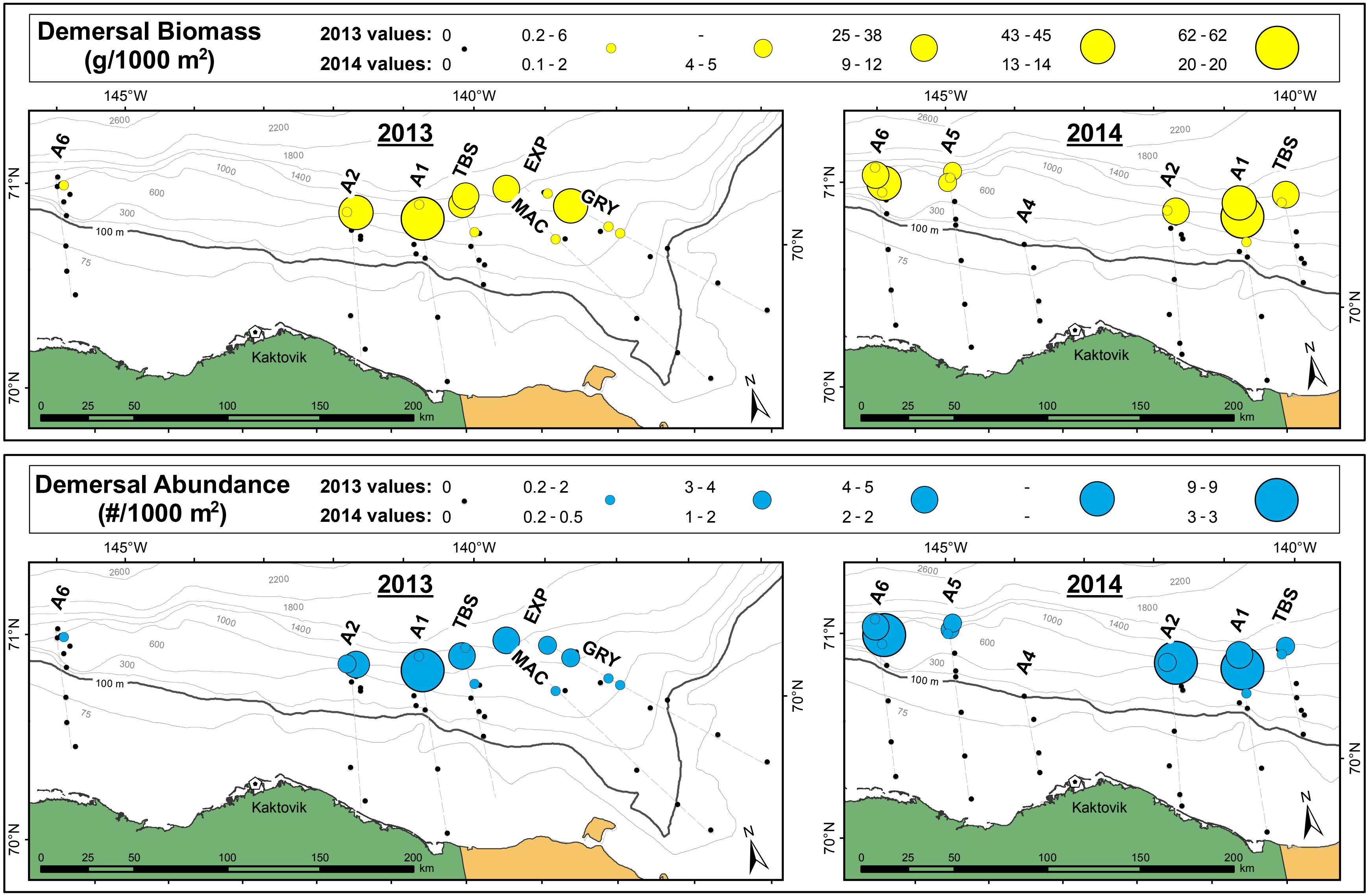
Appendix E3 Figure 32. Maps of demersal abundance, Zoarcidae: *Gymnelus viridis*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycenchelys kolthoffi*** **Checkered Wolf Eel**



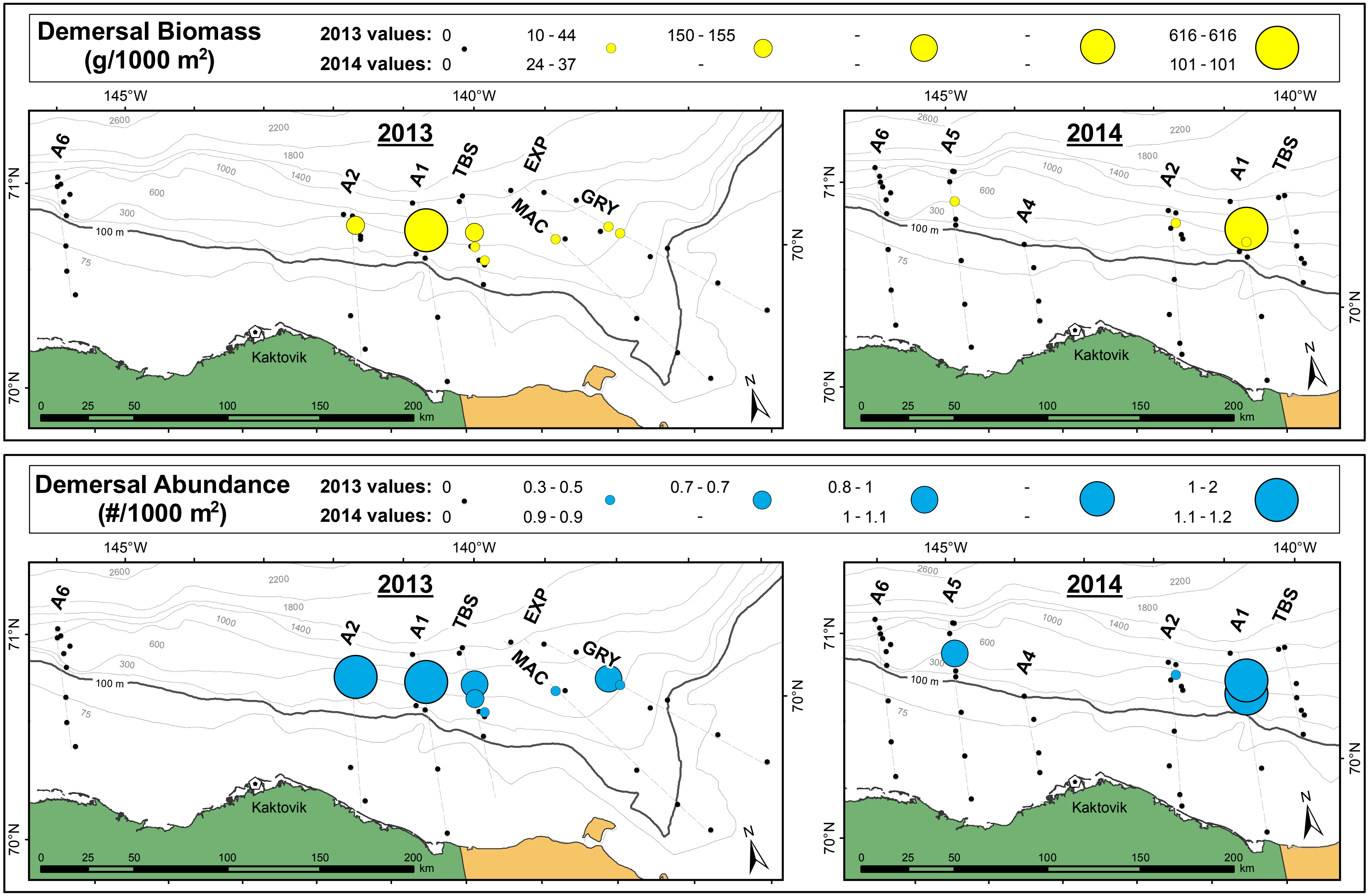
Appendix E3 Figure 33. Maps of demersal abundance, Zoarcidae: *Lycenchelys kolthoffi*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes adolfi*** **Adolf's Eelpout**



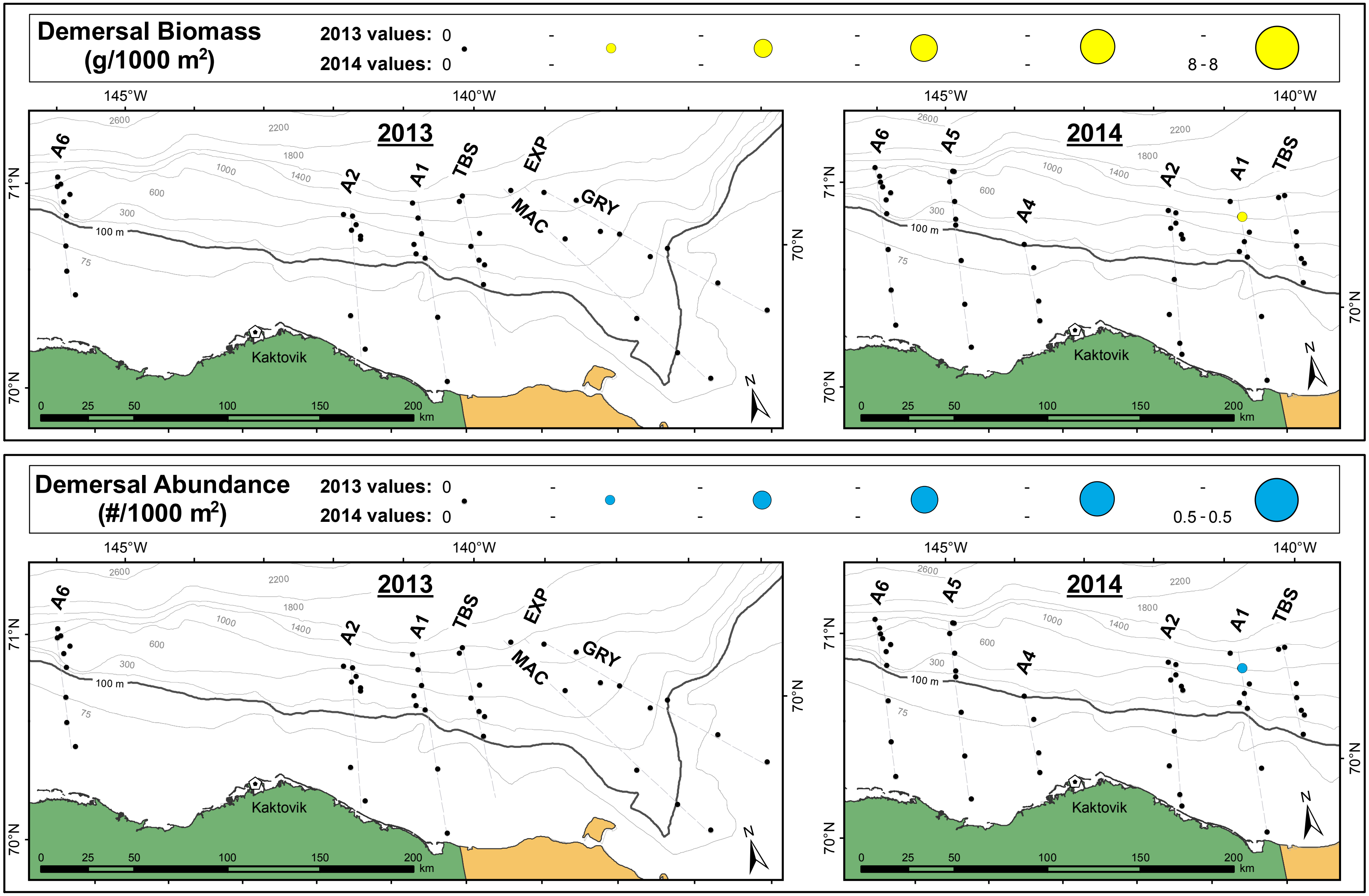
Appendix E3 Figure 34. Maps of demersal abundance, Zoarcidae: *Lycodes adolfi*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes eudipleurostictus*** **Doubleline Eelpout**



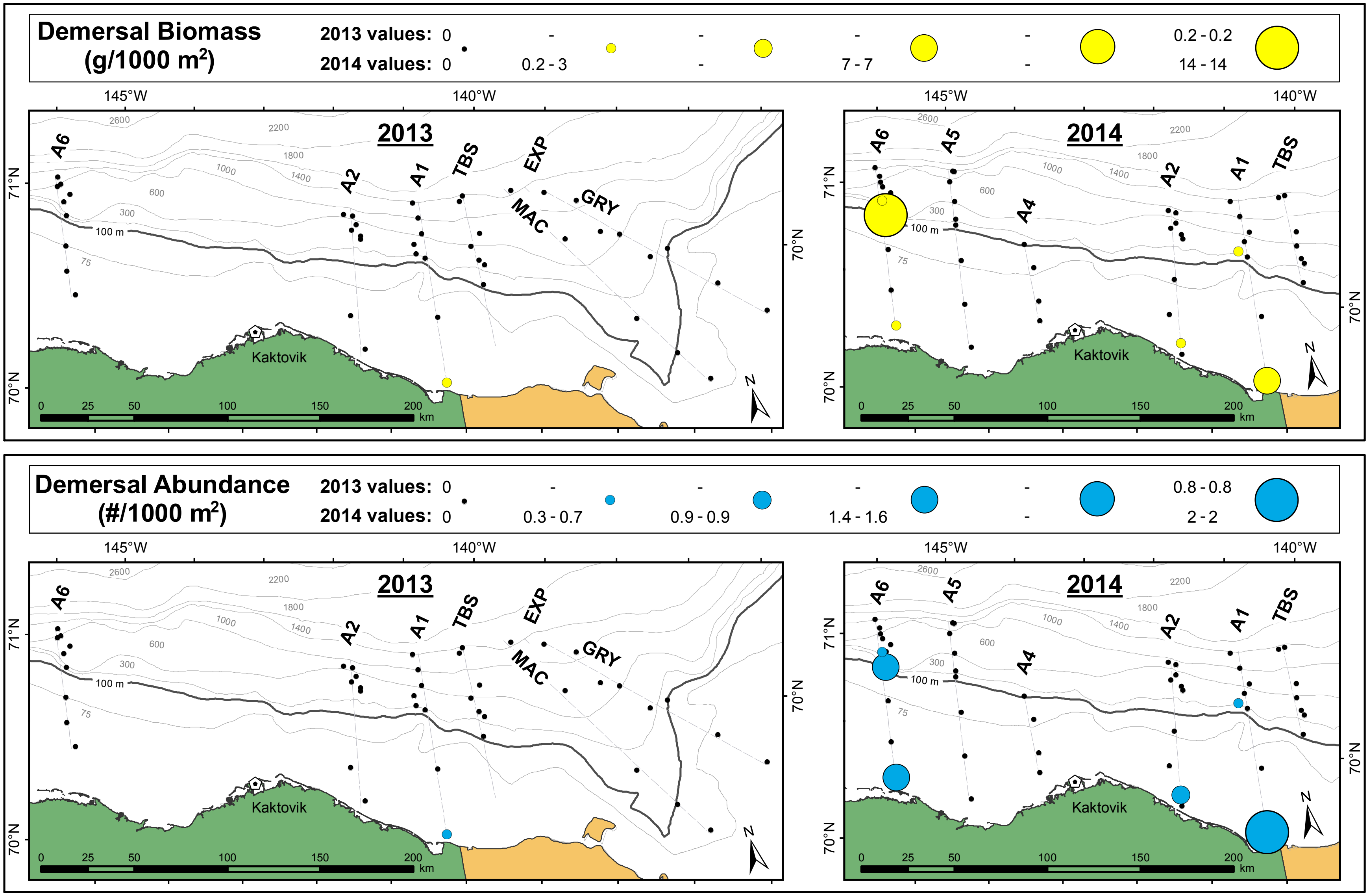
Appendix E3 Figure 35. Maps of demersal abundance, Zoarcidae: *Lycodes eudipleurostictus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts *Lycodes frigidus* Glacial Eelpout



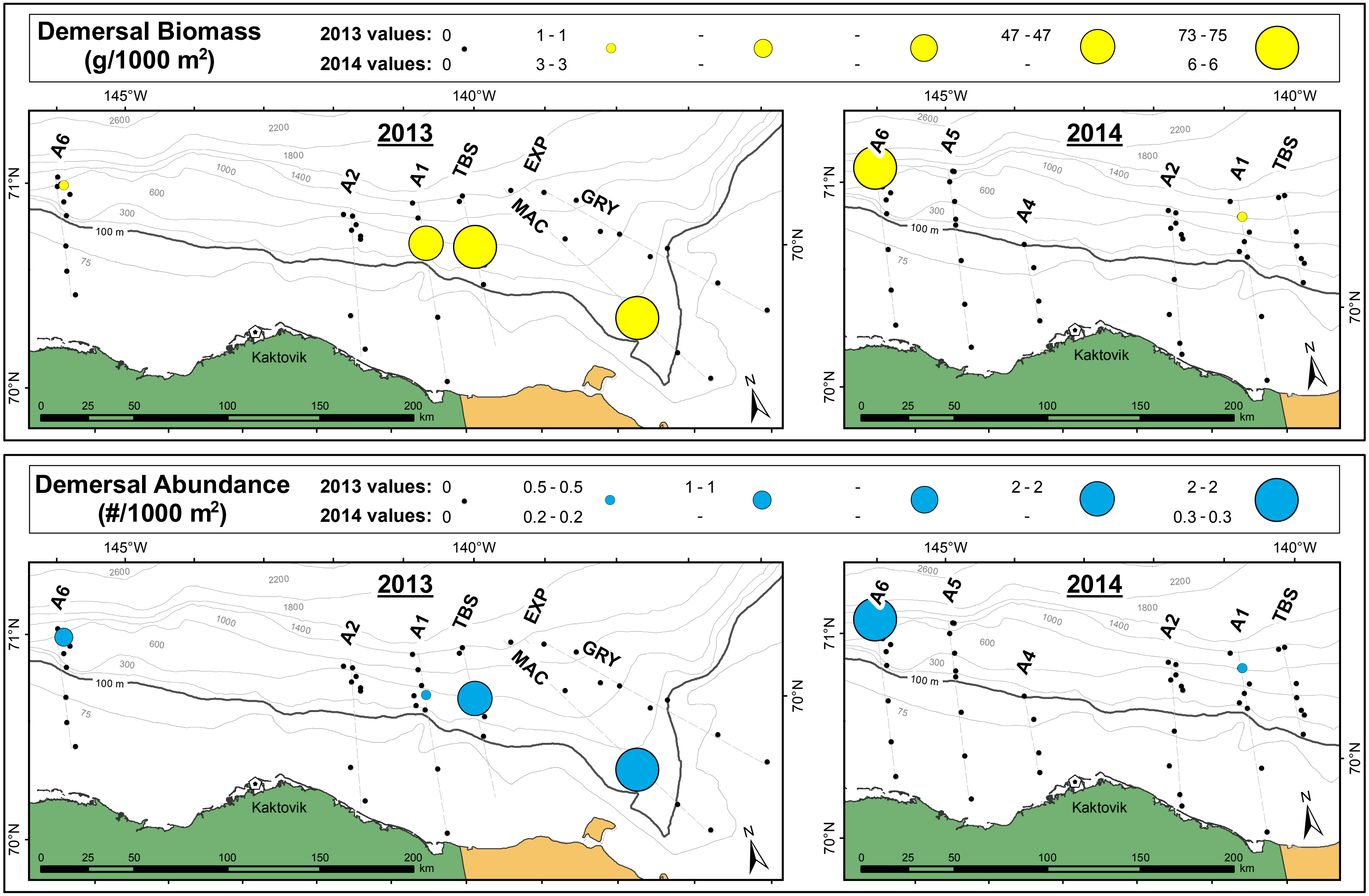
Appendix E3 Figure 36. Maps of demersal abundance, Zoarcidae: *Lycodes frigidus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes mucosus*** **Saddled Eelpout**



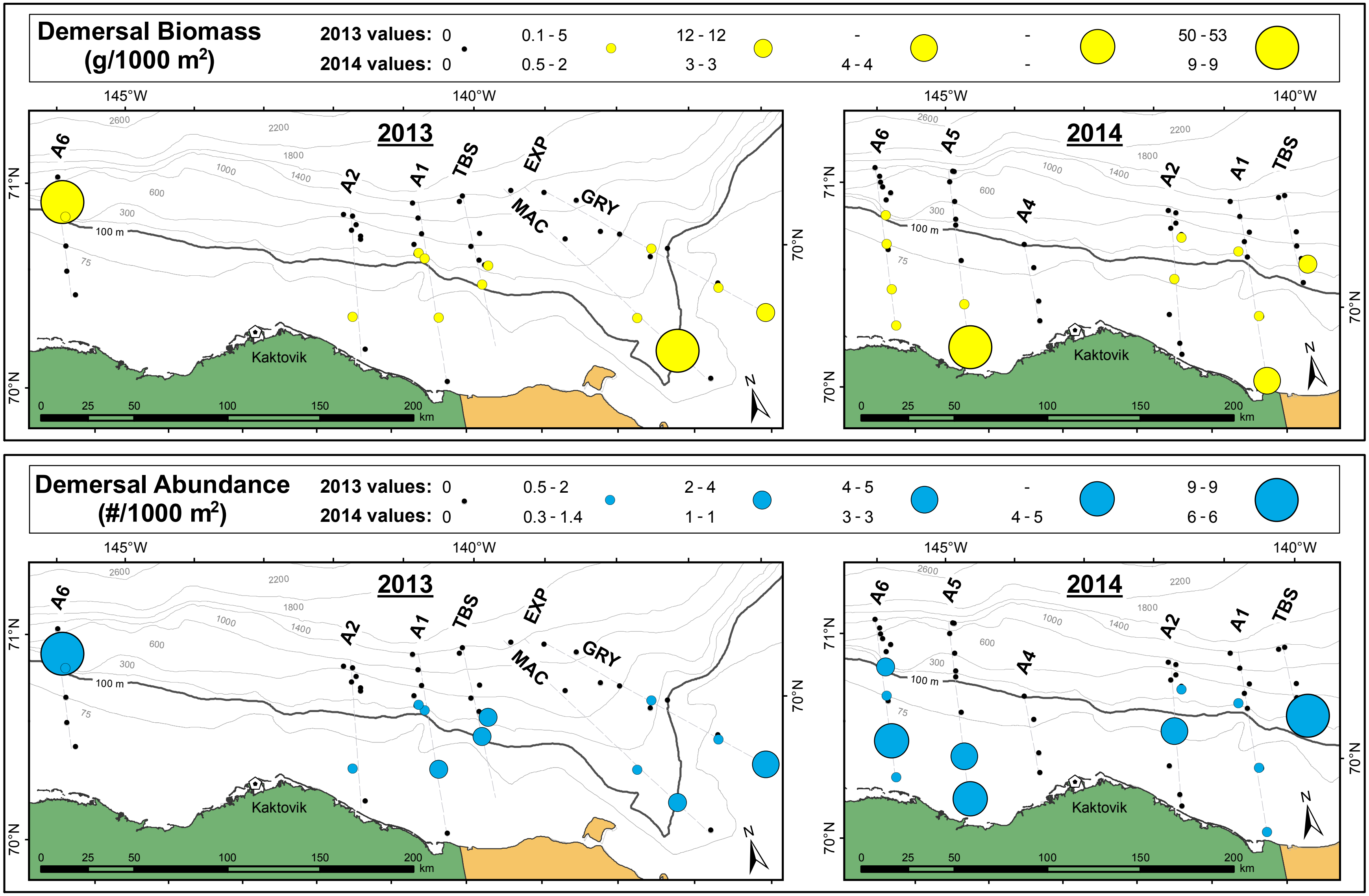
Appendix E3 Figure 37. Maps of demersal abundance, Zoarcidae: *Lycodes mucosus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes pallidus*** **Pale Eelpout**



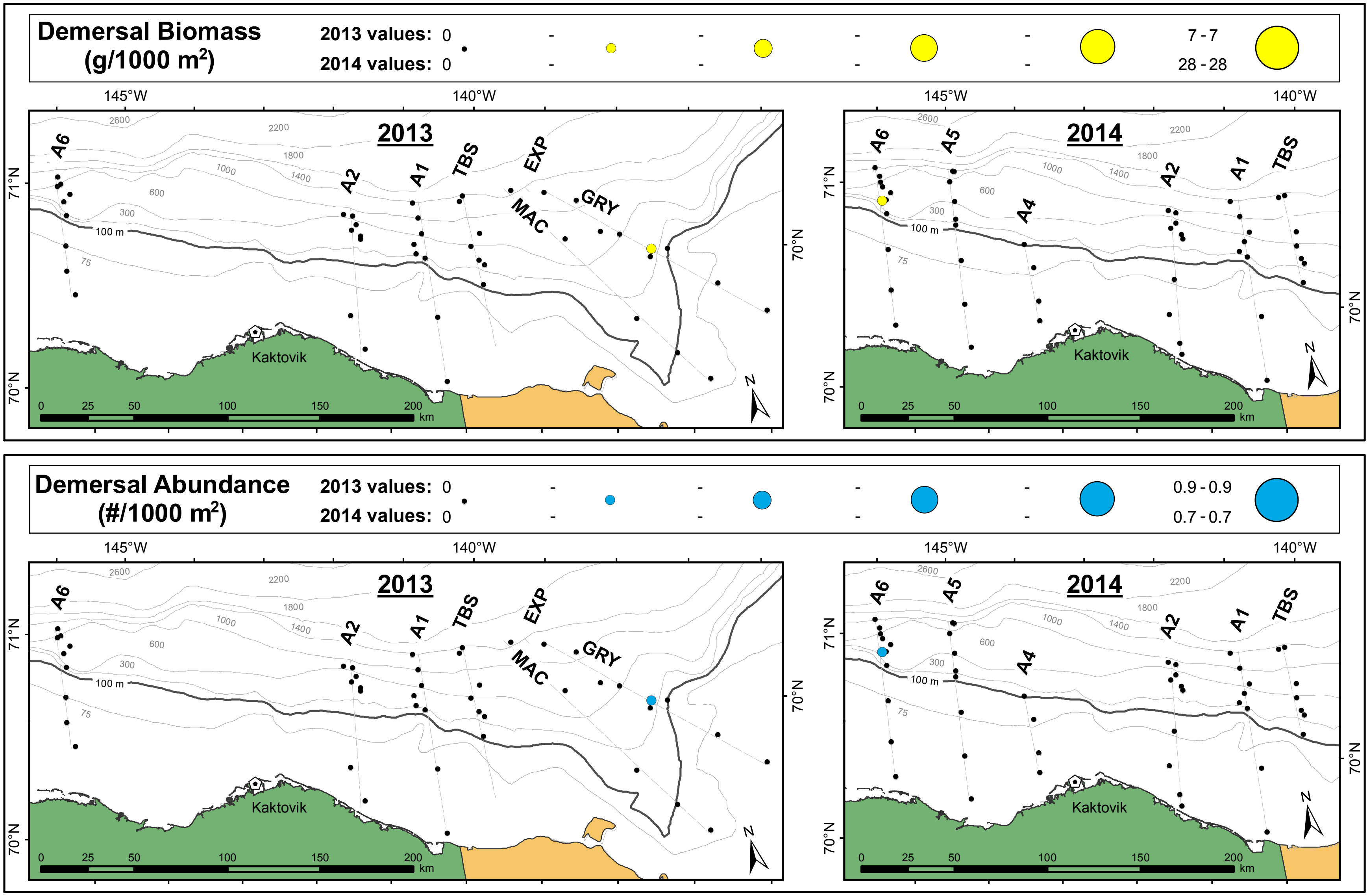
Appendix E3 Figure 38. Maps of demersal abundance, Zoarcidae: *Lycodes pallidus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes polaris*** **Canadian Eelpout**



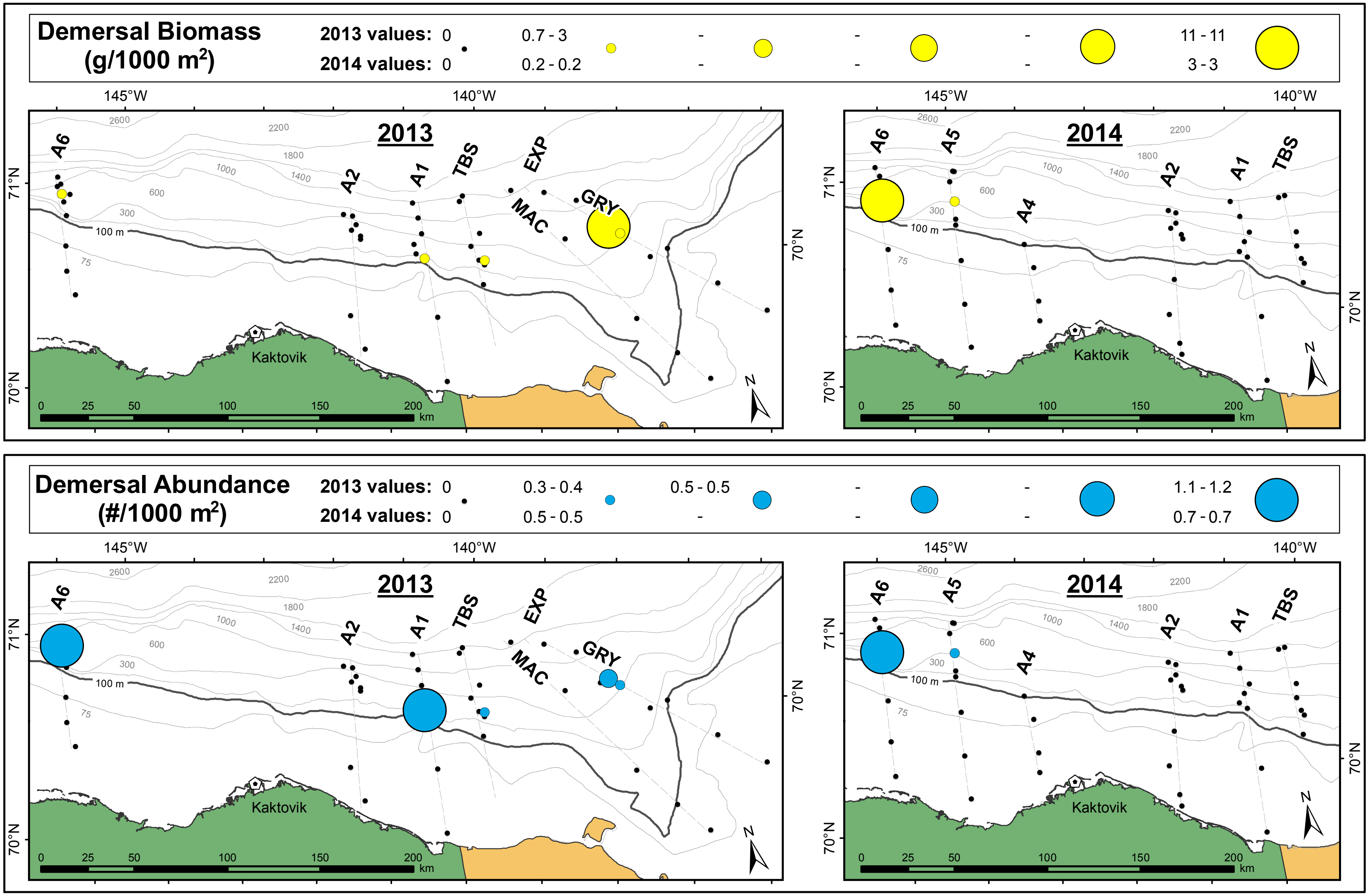
Appendix E3 Figure 39. Maps of demersal abundance, Zoarcidae: *Lycodes polaris*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts *Lycodes raridens* Marbled Eelpout



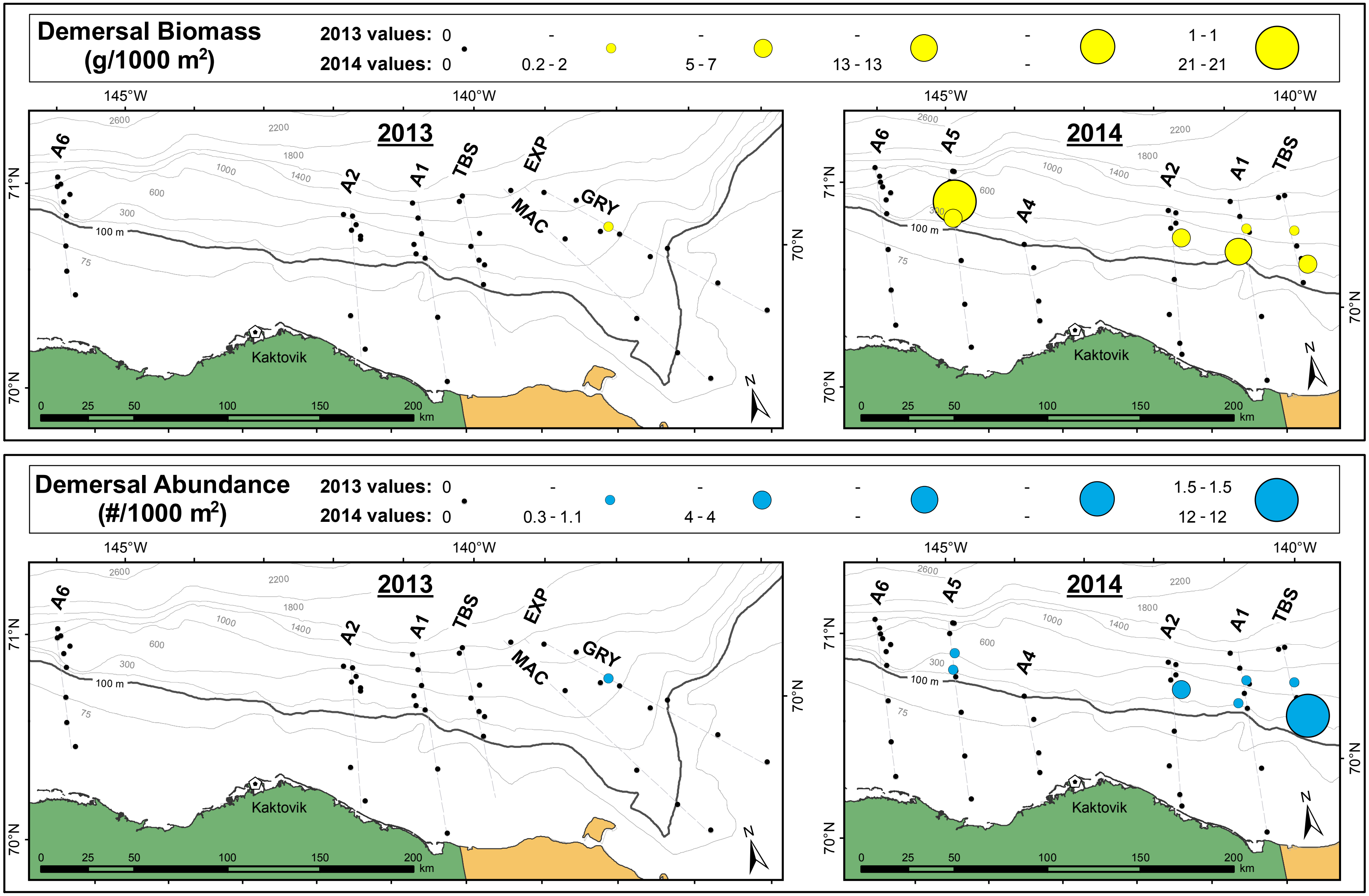
Appendix E3 Figure 40. Maps of demersal abundance, Zoarcidae: *Lycodes raridens*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts *Lycodes reticulatus* **Arctic Eelpout**



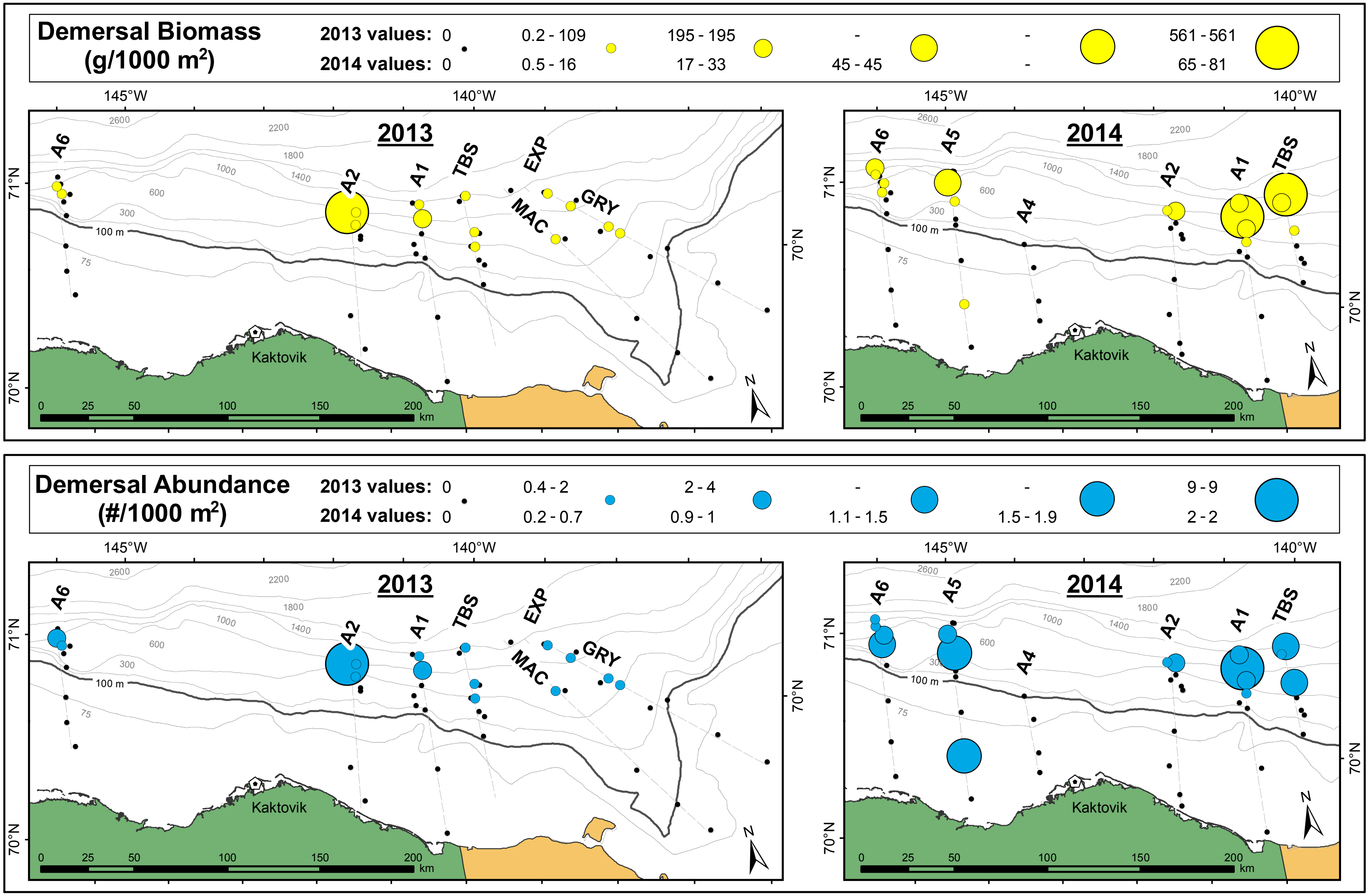
Appendix E3 Figure 41. Maps of demersal abundance, Zoarcidae: *Lycodes reticulatus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes rossi*** **Threespot eelpout**



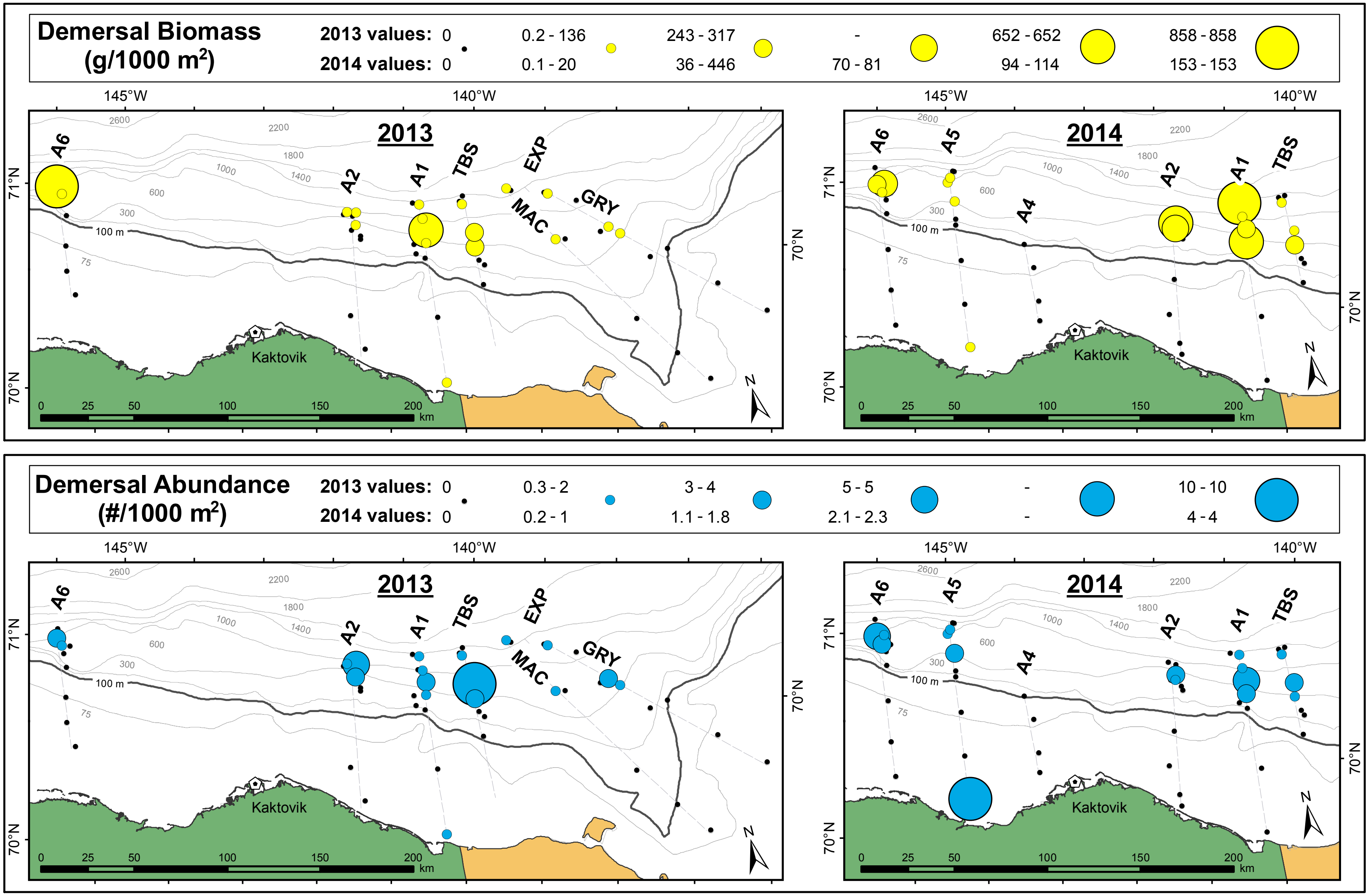
Appendix E3 Figure 42. Maps of demersal abundance, Zoarcidae: *Lycodes rossi*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes sagittarius*** **Archer Eelpout**



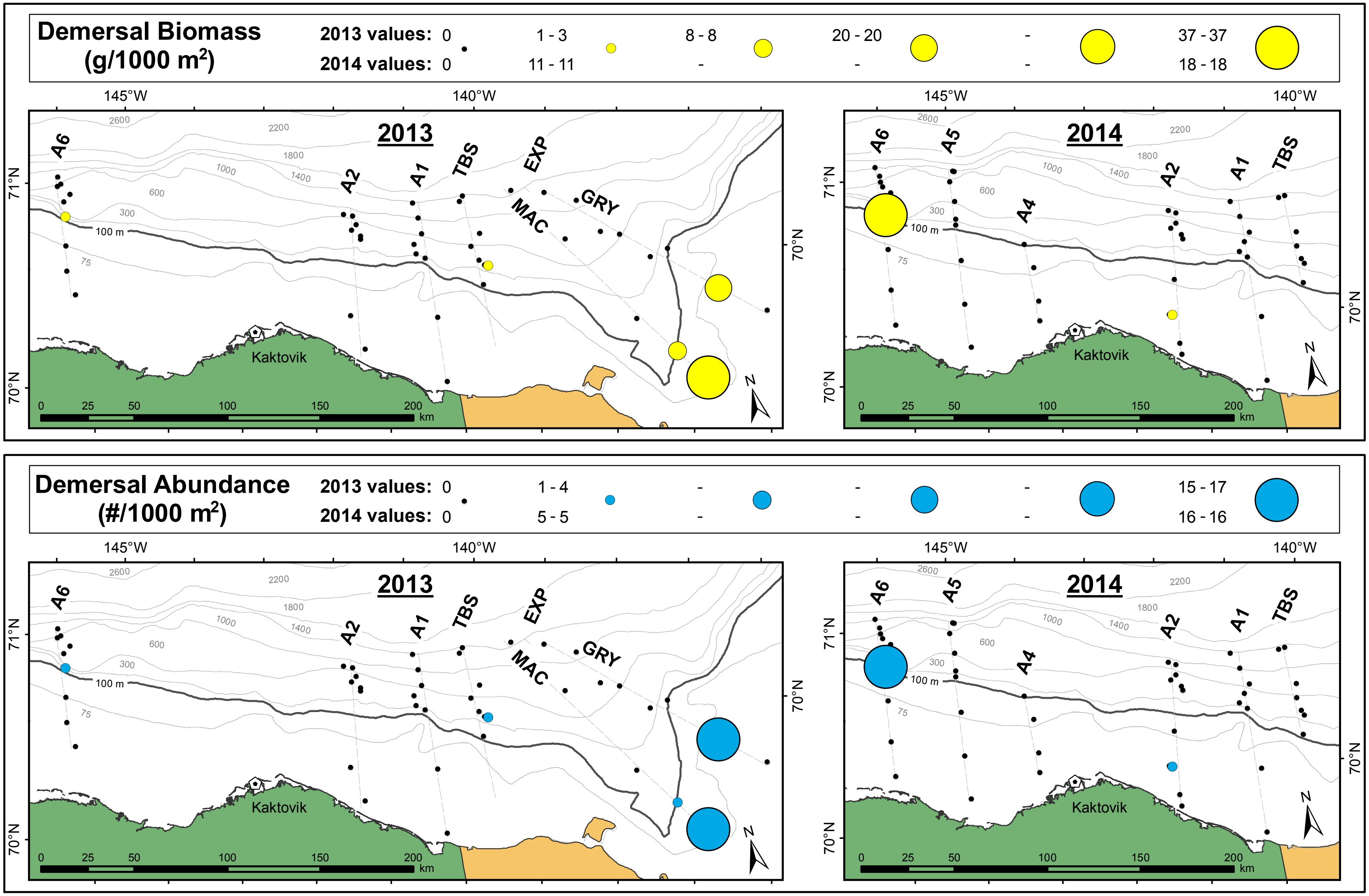
Appendix E3 Figure 43. Maps of demersal abundance, Zoarcidae: *Lycodes sagittarius*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Zoarcidae - Eelpouts ***Lycodes seminudus*** **Longear Eelpout**



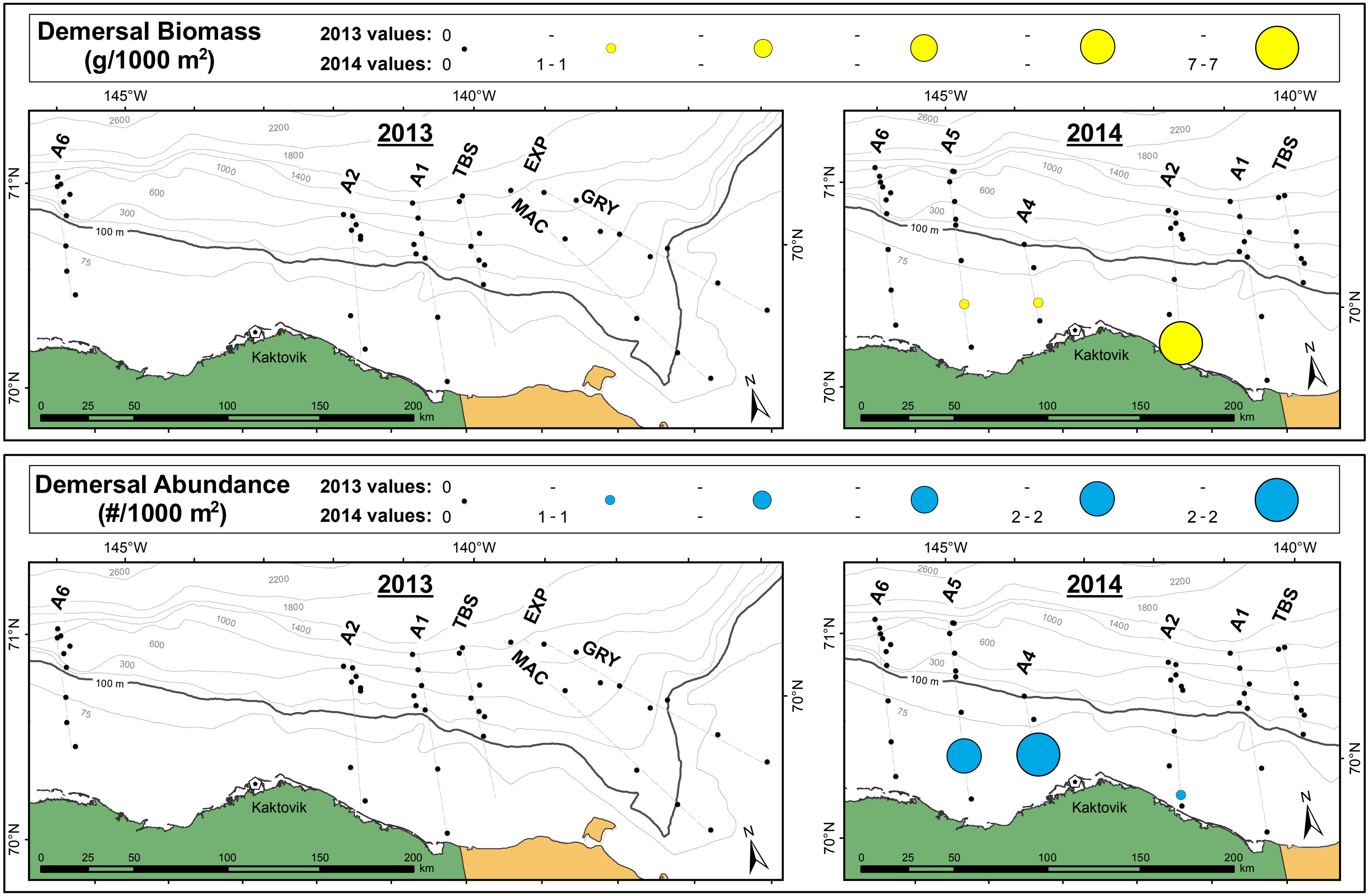
Appendix E3 Figure 44. Maps of demersal abundance, Zoarcidae: *Lycodes seminudus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Stichaeidae - Pricklebacks ***Anisarchus medius*** **Stout Eelblenny**



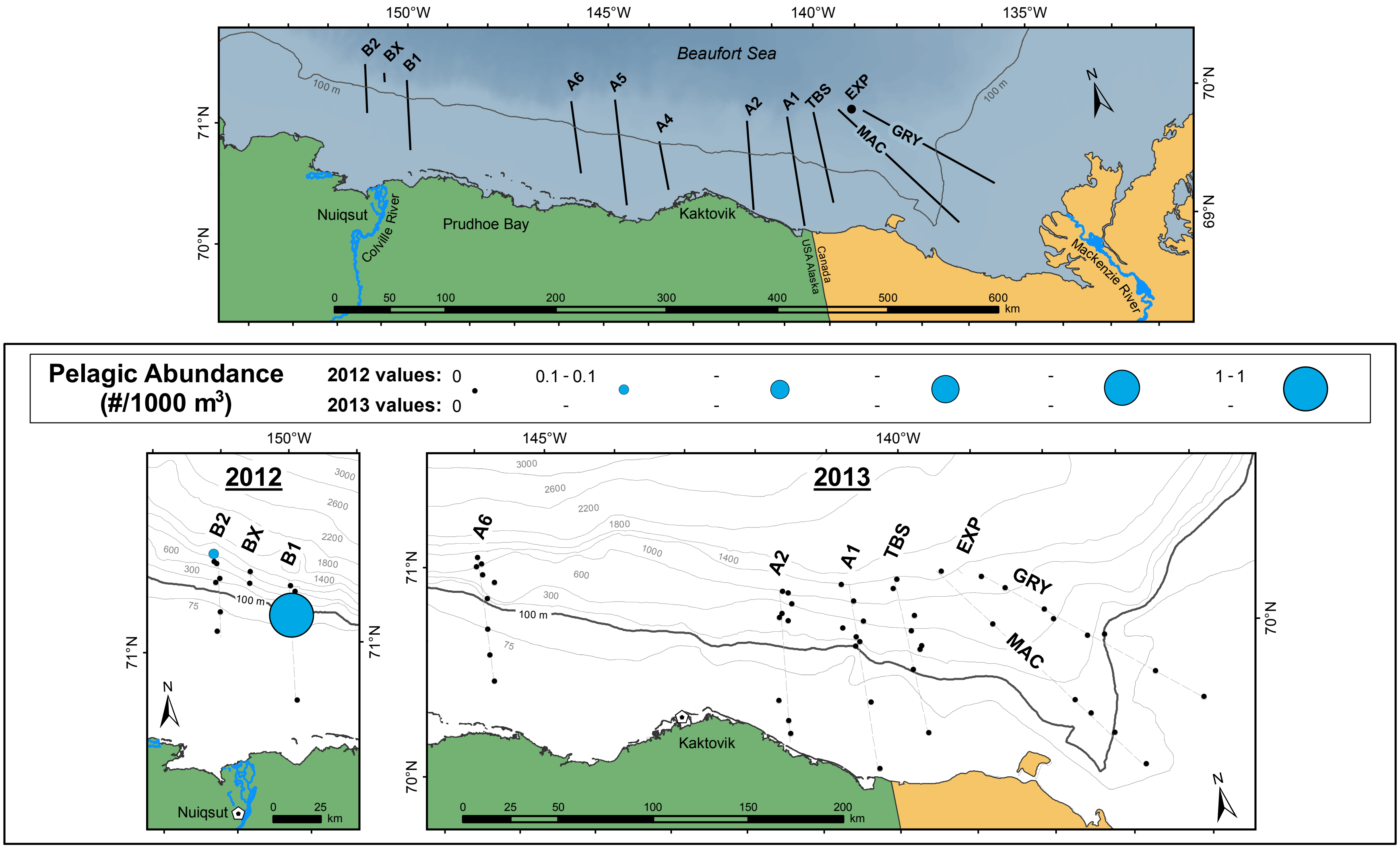
Appendix E3 Figure 45. Maps of demersal abundance, Stichaeidae, Lumpeninae: *Anisarchus medius*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. Pelagic abundance reported for subfamily Lumpeninae.

Stichaeidae - Pricklebacks ***Eumesogrammus praecisus*** **Fourline Snakeblenny**



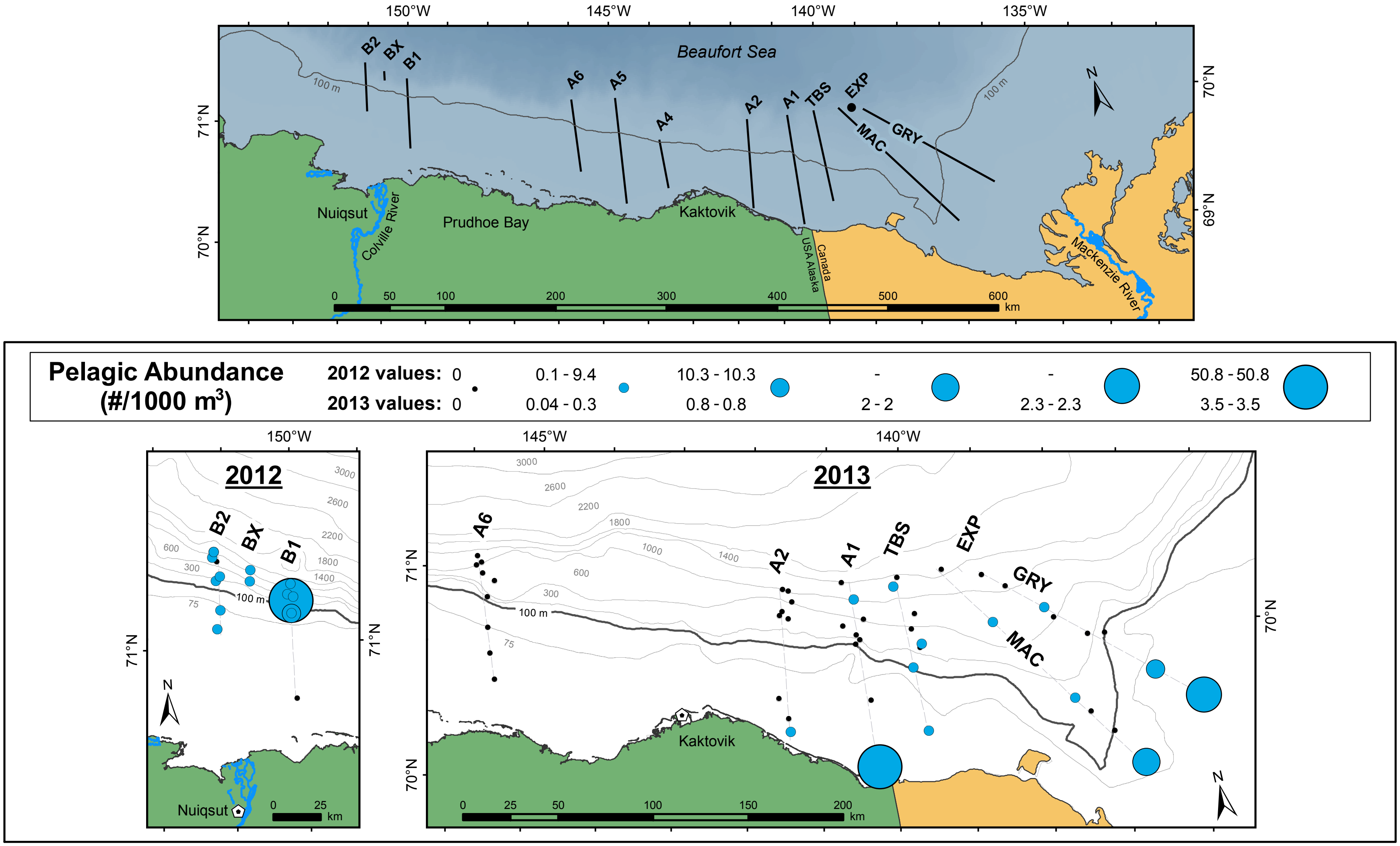
Appendix E3 Figure 46. Maps of demersal abundance, Stichaeidae: *Eumesogrammus praecisus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Stichaeidae - Pricklebacks *Leptoclinus maculatus* Daubed Shanny



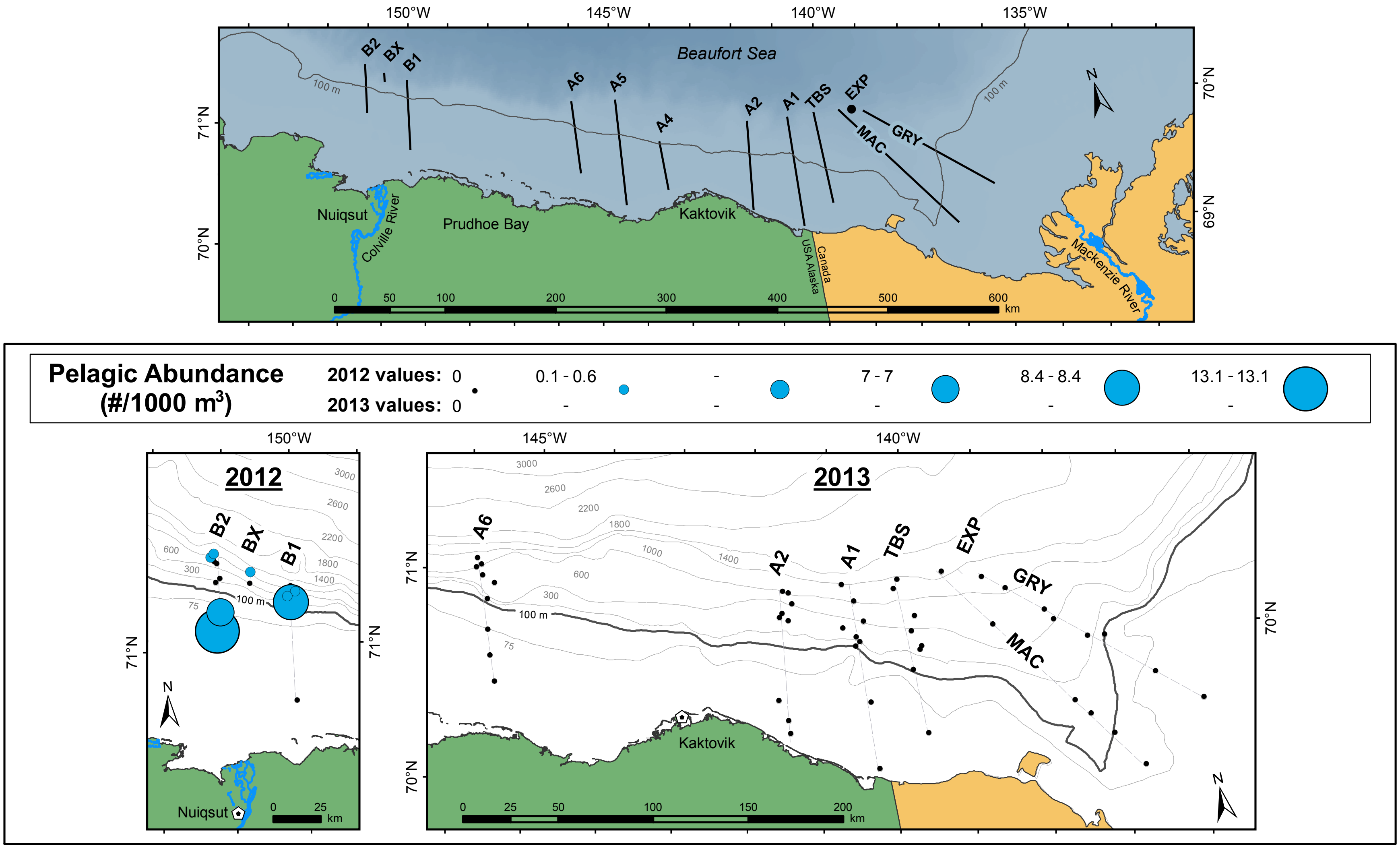
Appendix E3 Figure 47. Maps of pelagic abundance, Stichaeidae subfamily Lumpeninae: *Leptoclinus maculatus*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Stichaeidae - Pricklebacks Lumpeninae Stout or Slender Eelblenny or Daubed Shanny



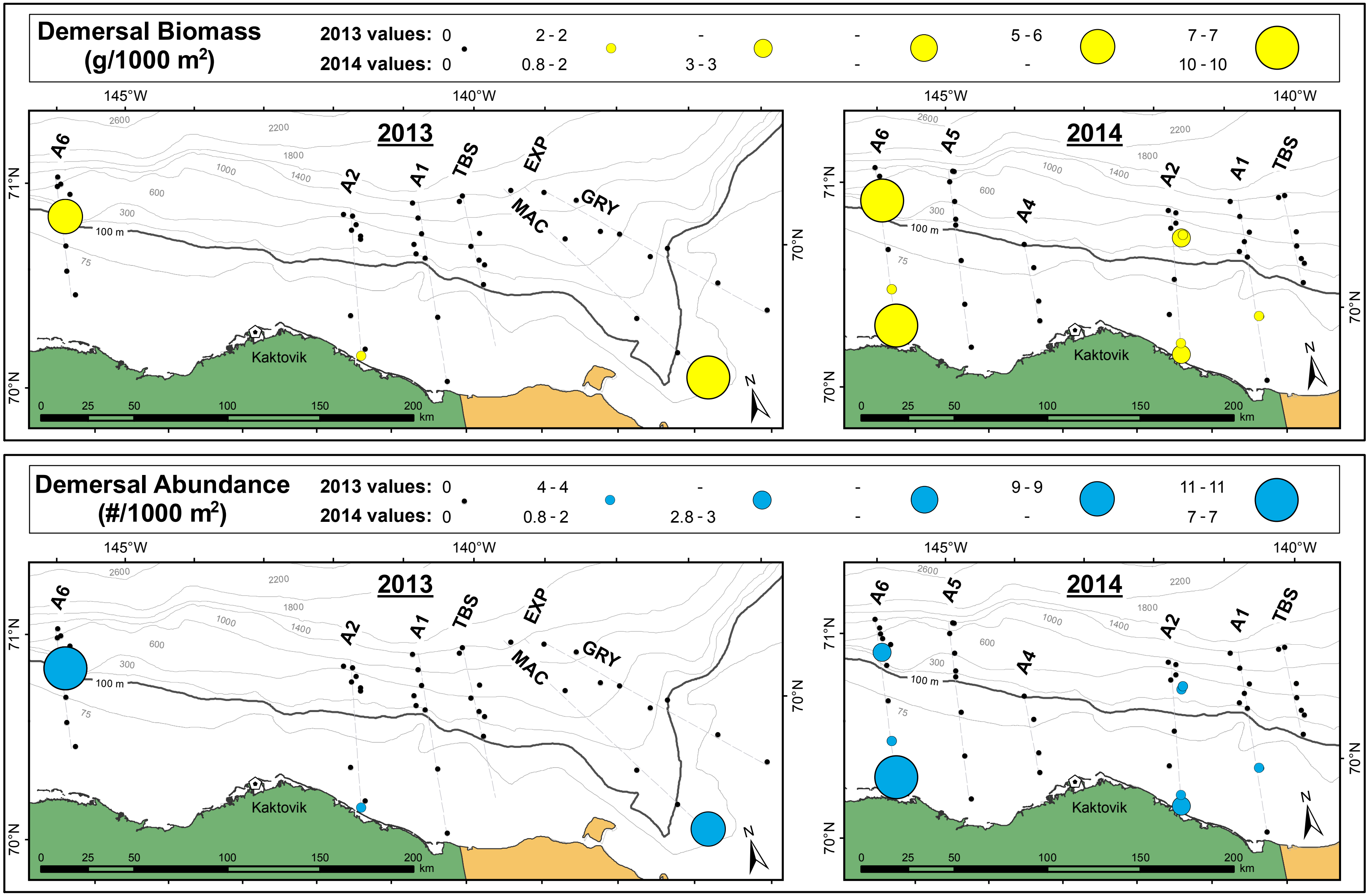
Appendix E3 Figure 48. Maps of pelagic abundance, Stichaeidae subfamily Lumpeninae: *Anisarchus medius*, *Leptoclinus maculatus* and *Lumpenus fabricii*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Stichaeidae - Pricklebacks ***Lumpenus fabricii*** **Slender Eelblenny**



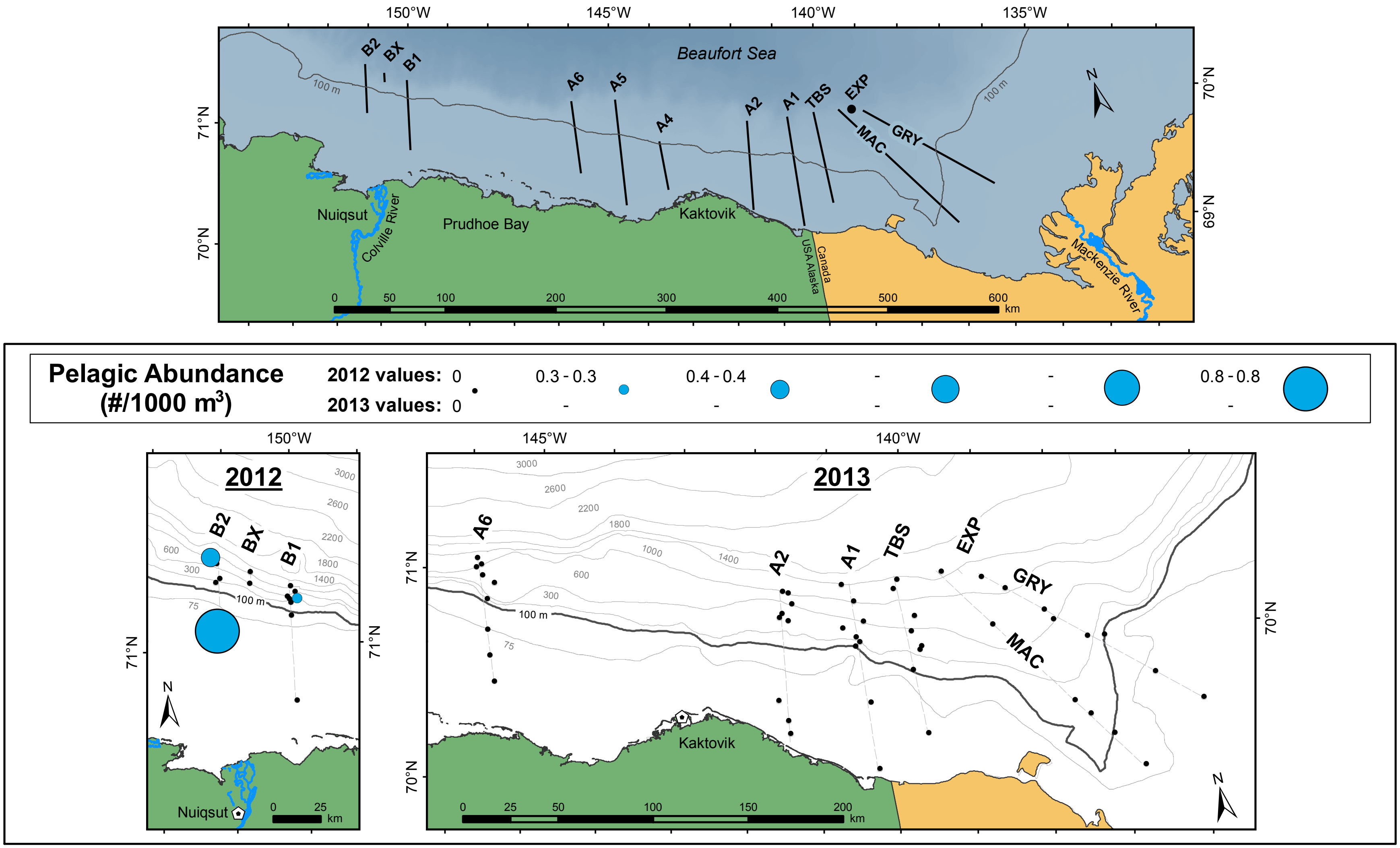
Appendix E3 Figure 49. Maps of pelagic abundance, Stichaeidae: Lumpeninae: *Lumpenus fabricii*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Stichaeidae - Pricklebacks ***Lumpenus fabricii*** **Slender Eelblenny**



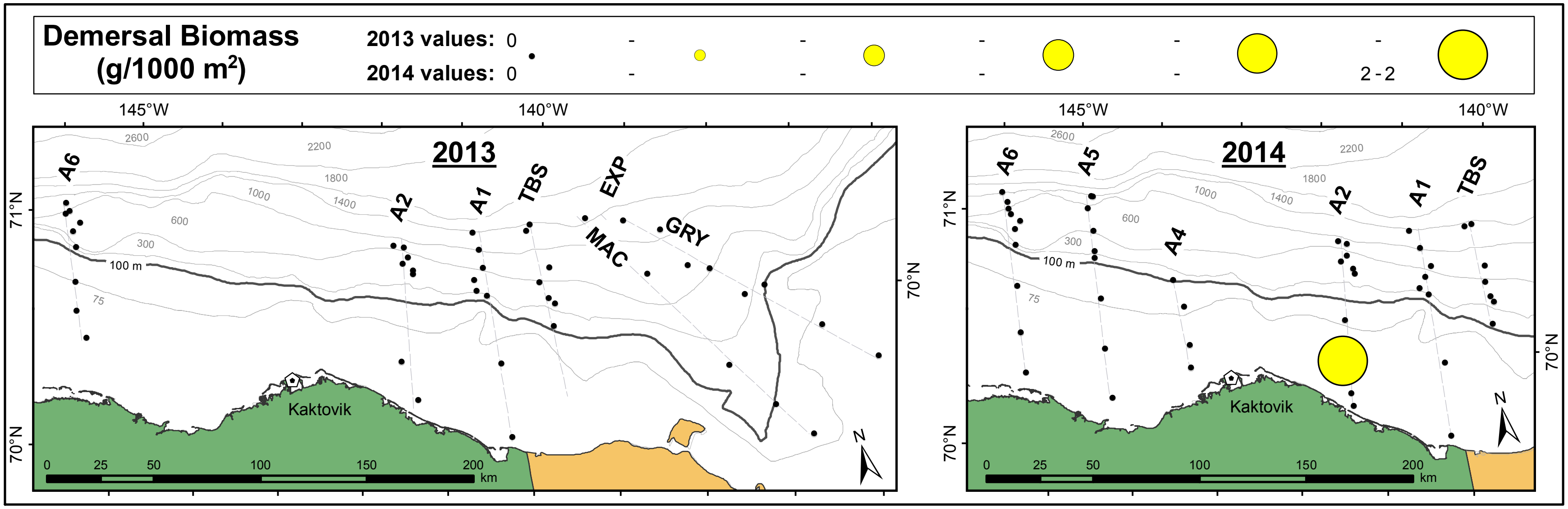
Appendix E3 Figure 50. Maps of demersal abundance, Stichaeidae, Lumpeninae: *Lumpenus fabricii*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

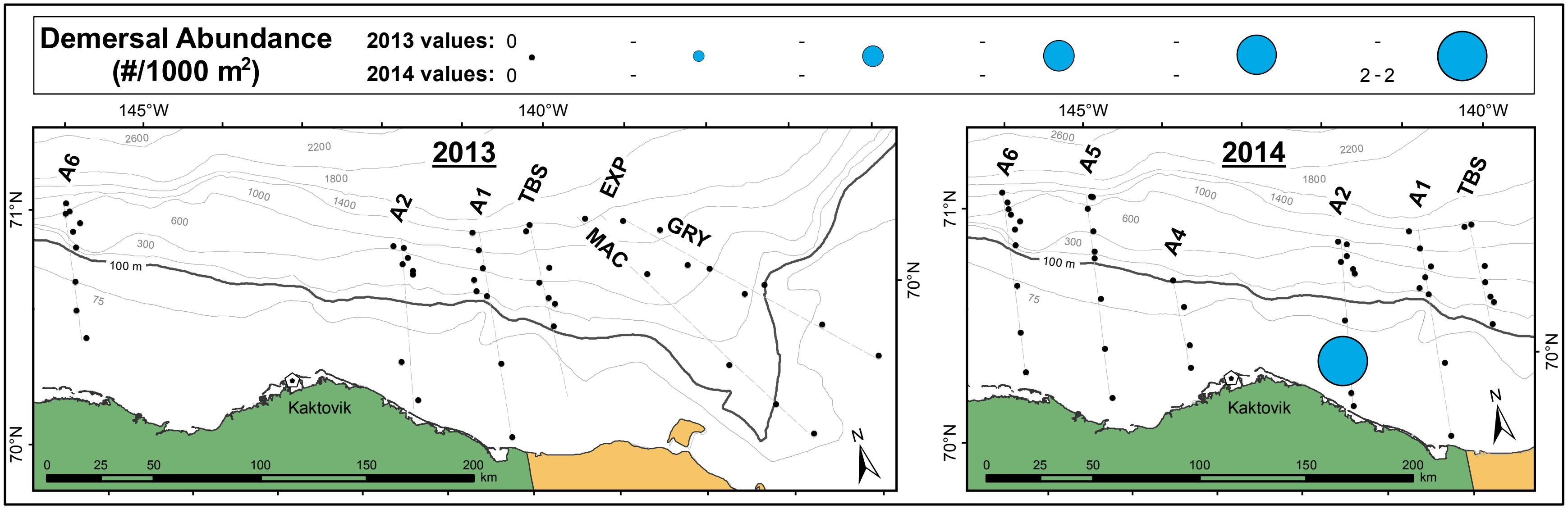
Stichaeidae - Pricklebacks ***Stichaeus punctatus*** **Arctic Shanny**



Appendix E3 Figure 51. Maps of pelagic abundance, Stichaeidae: *Stichaeus punctatus*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

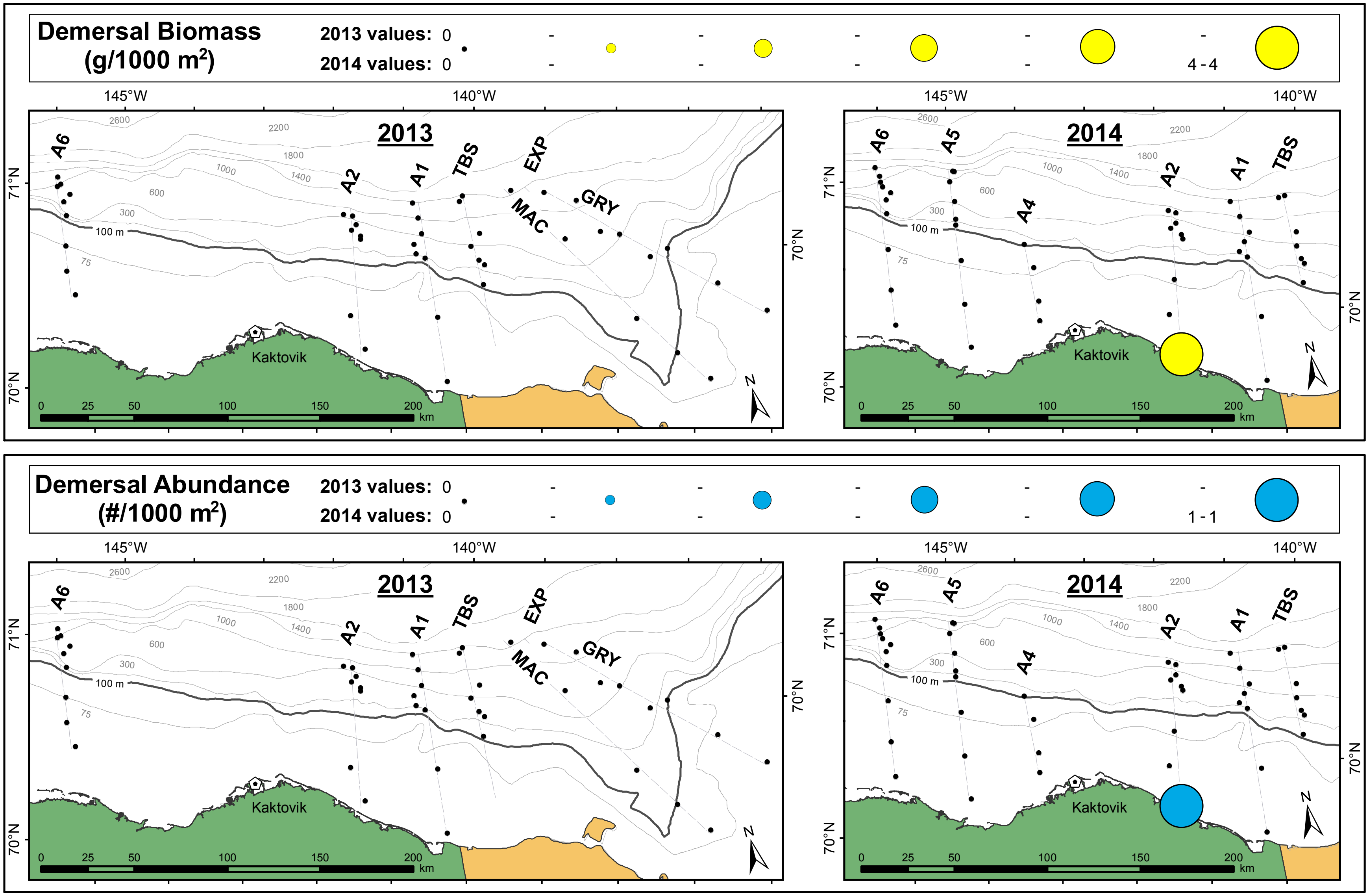
Stichaeidae - Pricklebacks ***Stichaeus punctatus*** **Arctic Shanny**





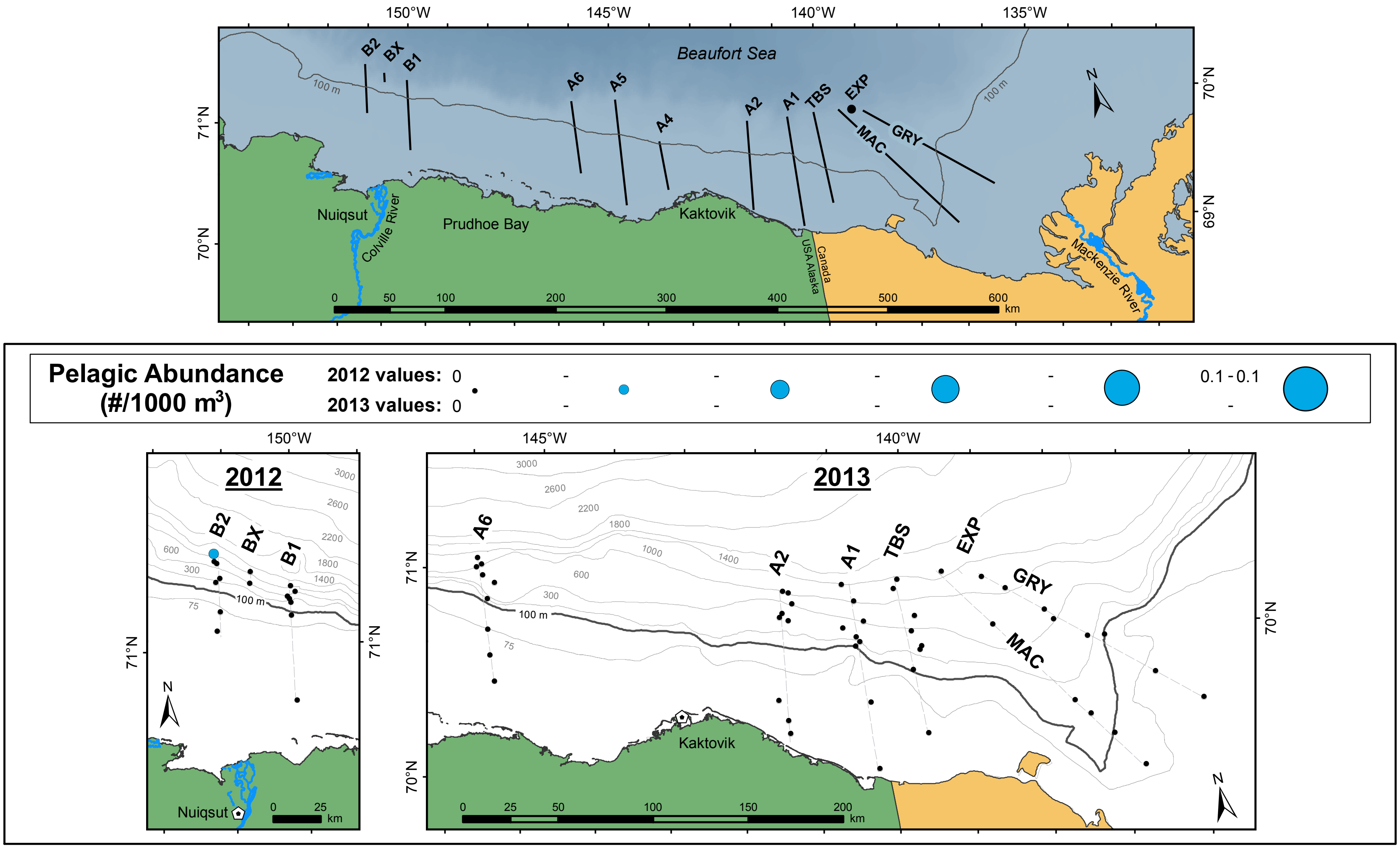
Appendix E3 Figure 52. Maps of demersal abundance, Stichaeidae: *Stichaeus punctatus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Ammodytidae - Sand lances ***Ammodytes hexapterus*** **Arctic Sand Lance**



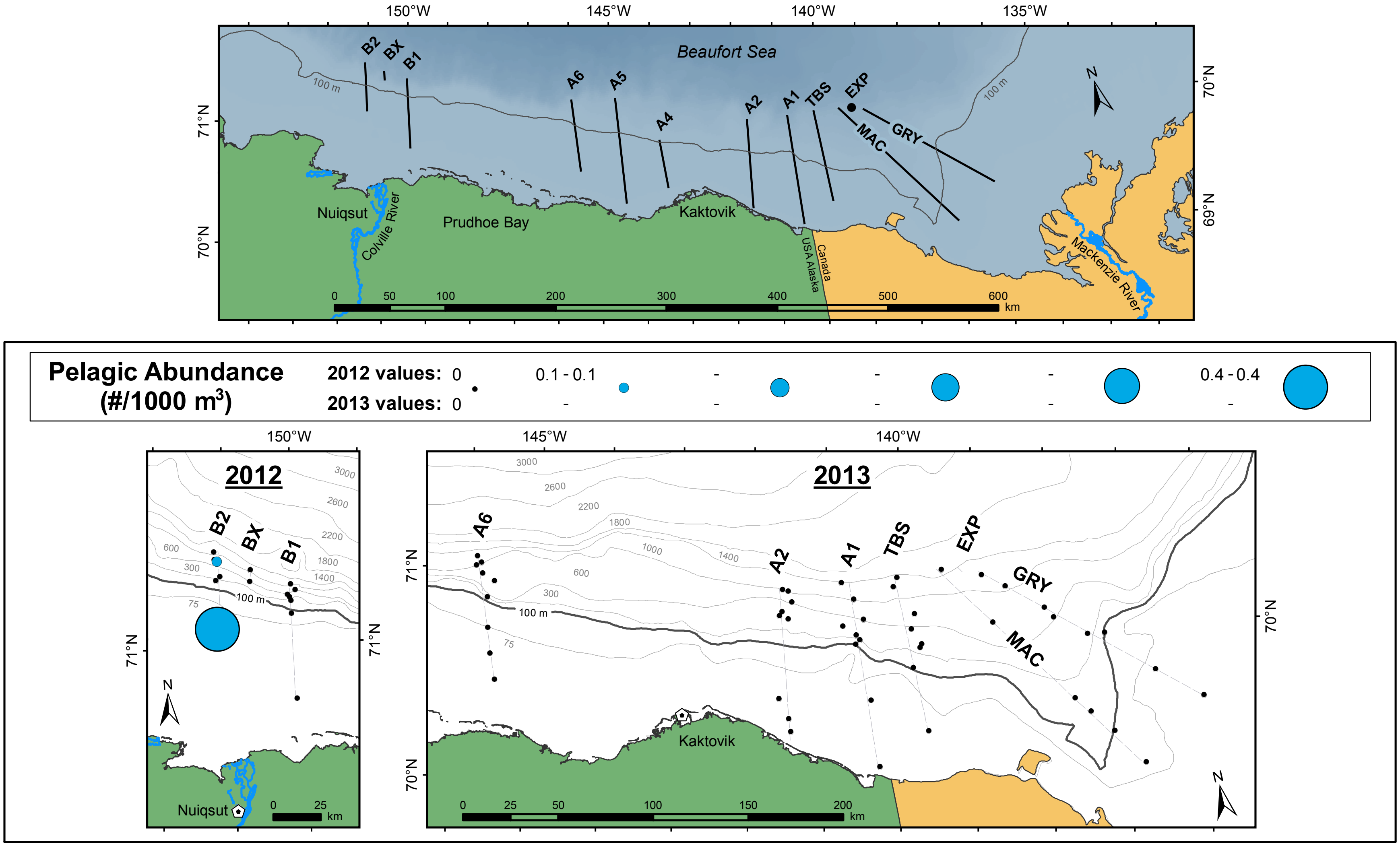
Appendix E3 Figure 53. Maps of demersal abundance, Ammodytidae: *Ammodytes hexapterus*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Pleuronectidae - Righteye flounders *Limanda proboscidea* Longhead Dab



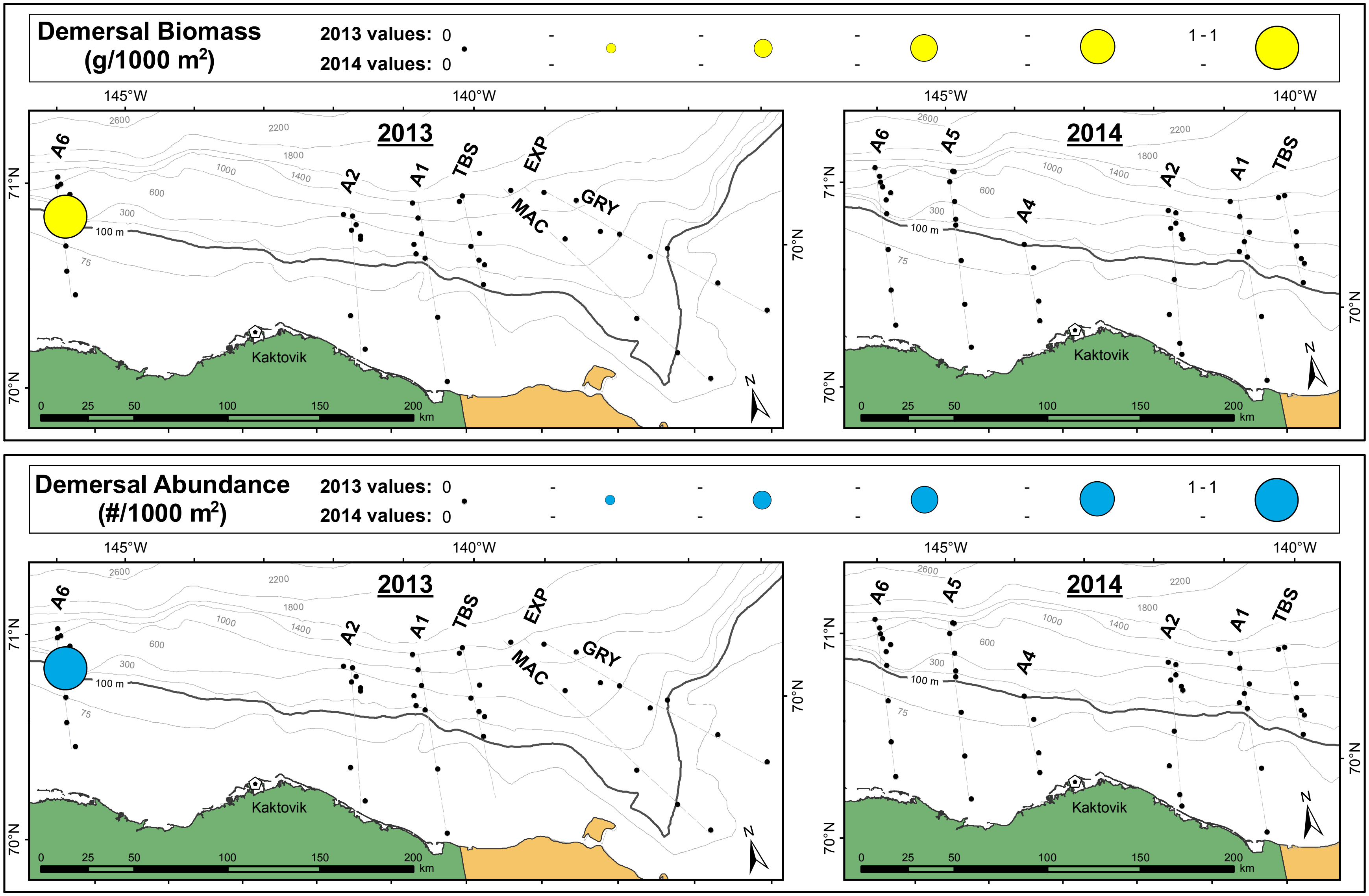
Appendix E3 Figure 54. Maps of pelagic abundance, Pleuronectidae: *Limanda proboscidea*. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in demersal habitat.

Pleuronectidae - Righteye flounders **Pleuronectidae larva**



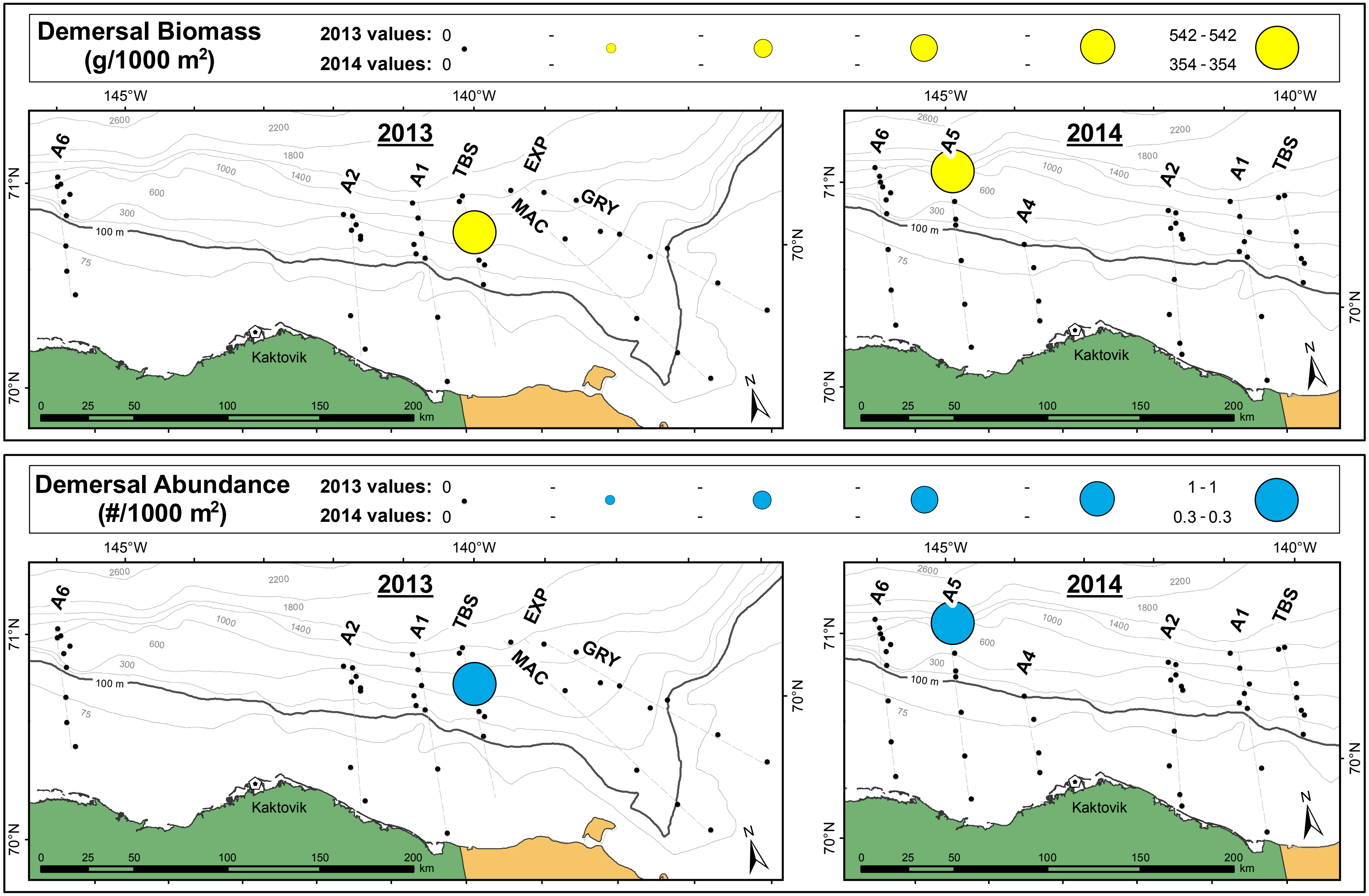
Appendix E3 Figure 55. Maps of pelagic abundance, Pleuronectidae: unidentified larvae. Stations and pelagic abundance from samples by Isaacs-Kidd Midwater Trawl during 2012–2013 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Pleuronectidae - Righteye flounders **Pleuronectidae larvae**



Appendix E3 Figure 56. Maps of demersal abundance, Pleuronectidae: unidentified larvae. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals.

Pleuronectidae - Righteye flounders ***Reinhardtius hippoglossoides*** **Greenland Halibut**



Appendix E3 Figure 57. Maps of demersal abundance, Pleuronectidae: *Reinhardtius hippoglossoides*. Stations and abundance from samples by beam trawl during 2013–2014 in the Beaufort Sea. Data ranges in each year are set to five equal intervals. None caught in pelagic habitat.

Appendix E3 Table 1. Mean abundance (± standard deviation) (per 1000 m^{-3}) of pelagic fishes caught by Isaacs-Kidd midwater trawl (IKMT) in the Central region (2012) and on the Eastern Shelf (≤100 m) and Eastern Slope (≥200 m) in 2013.

	2012 Central mean ± SD	2013 Shelf mean ± SD	2013 Slope mean ± SD
OSMERIDAE (smelts)			
Mallotus catervarius	0.1 ± 0.2	0	0
GADIDAE (cods)			
Boreogadus saida	5.6 ± 7.5	3.2 ± 3.7	0.6 ± 0.7
AGONIDAE (poachers)			
Aspidophoroides olrikii	0.6 ± 0.9	0.1 ± 0.2	<0.1 ± <0.1
COTTIDAE (sculpins)			
Gymnocanthus tricuspis	0.5 ± 0.8	0.1 ± 0.2	<0.1 ± <0.1
Icelus spp. ≤40 mm	0	0.1 ± 0.3	0
Myoxocephalus scorpius	<0.1 ± <0.1	0	0
Triglops pingelii	<0.1 ± 0.1	<0.1 ± 0.1	0
Cottidae unid. ≤50 mm	0.2 ± 0.4	0.4 ± 0.6	<0.1 ± <0.1
LIPARIDAE (snailfishes)			
Liparis fabricii	0	0	<0.1 ± <0.1
Liparis spp. unid. ≤50 mm	0.9 ± 1.0	0.7 ± 1.0	<0.1 ± 0.1
Liparis spp. unid. 51-140 mm	<0.1 ± <0.1	0	0
STICHAEIDAE (pricklebacks)			
Leptoclinus maculatus	0.1 ± 0.3	0	0
Lumpeninae unid. ≤51 mm	5.6 ± 12.5	0.5 ± 1.0	<0.1 ± <0.1
Lumpeninae unid. 53-67 mm	0.1 ± 0.2	0	0
Lumpenus fabricii	1.9 ± 4.0	0	0
Stichaeus punctatus	0.1 ± 0.2	0	0
PLEURONECTIDAE (righteye flounders)			
Limanda proboscidea	<0.1 ± <0.1	0	0
Pleuronectidae larvae	<0.1 ± 0.1	0	0
ALL TAXA	15.5 ± 22.9	5.0 ± 4.4	0.7 ± 0.8

Appendix E3 Table 2. Mean abundance (± standard deviation) (# 1000 m^{-2}) of demersal fishes caught by beam trawl on the shelf (≤100 m) and slope (≥200 m) in 2013 and 2014.

	2013 Shelf	2014 Shelf	2013 Slope	2014 Slope
	mean ± SD	mean ± SD	mean ± SD	mean ± SD
RAJIDAE	-	-	0.2 ± 0.5	<0.1 ± 0.1
MYCTOPHIDAE	-	-	-	<0.1 ± 0.1
GADIDAE				
Boreogadus saida	1.9 ± 2.4	10.7 ± 21.2	4.5 ± 8.1	3.6 ± 7.0
COTTIDAE				
Artediellus scaber	1.2 ± 3.1	5.6 ± 13.9	-	-
Cottidae unid. ≤50 mm	1.6 ± 4.5	0.2 ± 0.9	-	-
Gymnocanthus tricuspis	2.5 ± 3.3	11.6 ± 17.4	<0.1 ± 0.1	<0.1 ± 0.1
Icelus bicornis	-	2.4 ± 4.4	0.1 ± 0.3	0.1 ± 0.4
Icelus spatula	7.7 ± 9.2	6.5 ± 7.8	<0.1 ± 0.1	<0.1 ± 0.1
Icelus spp. all ≤40 mm	1.6 ± 3.1	9.0 ± 14.3	-	-
Myoxocephalus scorpius	-	0.1 ± 0.3	-	-
Triglops nybelini	-	0.1 ± 0.6	0.1 ± 0.2	0.3 ± 0.9
Triglops pingelii	3.2 ± 3.9	5.3 ± 8.0	0.4 ± 1.1	-
PSYCHROLUTIDAE				
Cottunculus microps	-	-	0.2 ± 0.5	0.1 ± 0.2
Psychrolutidae unid.	-	-	<0.1 ± 0.1	<0.1 ± <0.1
AGONIDAE				
Aspidophoroides olrikii	6.4 ± 8.4	7.0 ± 14.4	<0.1 ± 0.2	0.1 ± 0.2
Leptagonus decagonus	-	-	<0.1 ± 0.1	<0.1 ± 0.2
CYCLOPTERIDAE				
Cyclopteridae unid.	0.5 ± 1.1	-	-	-
Eumicrotremus derjugini	0.2 ± 0.6	0.2 ± 0.5	-	-
LIPARIDAE				
Careproctus lerikimae	-	-	0.2 ± 0.5	<0.1 ± 0.1
Liparis bathyarcticus	0.1 ± 0.4	-	<0.1 ± 0.2	-
Liparis fabricii	0.3 ± 0.6	0.1 ± 0.4	0.5 ± 0.9	0.2 ± 0.3
Liparis gibbus	-	-	0.1 ± 0.4	<0.1 ± 0.2
Liparis tunicatus	0.1 ± 0.3	0.1 ± 0.3	-	-
Liparis spp. all ≤50 mm	0.5 ± 1.2	0.9 ± 2.4	-	<0.1 ± 0.0
Liparis spp. unid. 51–110 mm	0.6 ± 1.5	0.2 ± 0.7	-	<0.1 ± 0.1
Paraliparis spp.	-	-	0.0 ± 0.1	<0.1 ± 0.1
Rhodichthys regina	-	-	0.1 ± 0.3	<0.1 ± 0.2
ZOARCIDAE				
Gymnelus hemifasciatus	1.7 ± 3.1	1.8 ± 2.4	-	-
Gymnelus spp. unid.	0.5 ± 1.4	-	-	-
Gymnelus viridis	0.3 ± 1.0	0.8 ± 1.5	-	-
Lycenchelys kolthoffi	-	-	0.0 ± 0.1	<0.1 ± <0.1
Lycodes adolfi	-	-	1.4 ± 2.3	0.9 ± 1.2
Lycodes eudipleurostictus	-	-	0.2 ± 0.5	0.2 ± 0.4
Lycodes frigidus	-	-	-	<0.1 ± 0.1

Appendiv E3 Table 2. continued.

	2013 Shelf	2014 Shelf	2013 Slope	2014 Slope
	mean ± SD	mean ± SD	mean ± SD	mean ± SD
ZOARCIDAE, continued				
Lycodes mucosus	<0.1 ± 0.2	0.3 ± 0.7	-	<0.1 ± 0.2
Lycodes pallidus	-	-	0.2 ± 0.6	<0.1 ± 0.1
Lycodes polaris	1.3 ± 1.6	1.3 ± 1.7	0.4 ± 1.7	<0.1 ± 0.1
Lycodes raridens	-	-	0.0 ± 0.2	<0.1 ± 0.1
Lycodes reticulatus	0.1 ± 0.3	-	0.1 ± 0.2	<0.1 ± 0.2
Lycodes rossi	-	0.7 ± 2.7	0.1 ± 0.3	0.1 ± 0.3
Lycodes sagittarius	-	0.1 ± 0.3	1.0 ± 1.9	0.6 ± 0.6
Lycodes seminudus	<0.1 ± 0.2	0.2 ± 0.9	1.6 ± 2.4	0.7 ± 0.8
Lycodes spp. unid.	-	0.2 ± 0.9	0.5 ± 0.9	0.3 ± 0.5
STICHAEIDAE				
Anisarchus medius	2.4 ± 5.4	1.0 ± 3.5	-	-
Eumesogrammus praecisus	-	0.2 ± 0.5	-	-
Leptoclinus maculatus	-	-	-	0.1 ± 0.3
Lumpeninae all ≤51 mm	0.6 ± 1.0	0.3 ± 0.7	-	-
Lumpenus fabricii	1.5 ± 3.6	0.8 ± 1.8	-	0.1 ± 0.6
Stichaeus punctatus	-	0.1 ± 0.5	-	-
AMMODYTIDAE				
Ammodytes hexapterus	-	<0.1 ± 0.2	-	-
PLEURONECTIDAE				
Reinhardtius hippoglossoides	-	-	<0.1 ± 0.2	<0.1 ± 0.1
Pleuronectidae larvae	0.1 ± 0.3	-	-	-
ALL TAXA	36.9 ± 22.9	67.7 ± 53.5	11.9 ± 9.5	7.7 ± 7.7

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix E4

Age Composition and Growth Rates of Arctic Cod in the Chukchi and Beaufort Seas

Author
Alyssa Frothingham

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Age Composition and growth rates of Arctic Cod in the Chukchi and Beaufort Seas

Alyssa Frothingham

ABSTRACT

Arctic Cod, *Boreogadus saida*, commonly dominates fish assemblages in the Arctic region and inhabits two hydrographically unique seas in the U.S. portion of the Arctic Ocean, the Beaufort and Chukchi seas. However, limited information exists about this species' life history. Due to the importance of Arctic Cod in the Arctic food web, establishing current benchmark information, such as growth rates, may provide a better understanding how this species will be affected by climate change. To investigate one aspect of Arctic Cod life history from two Arctic seas, growth rates were examined on the individual level using otolith measurements, and on a population level using a von Bertalanffy growth equation. Arctic Cod were collected from 2009 to 2014 from the southern and northern Chukchi Sea (SCS and NCS) and the western and eastern Beaufort Sea (WBS and EBS). Ages ranged from 0 to 5 years with highly variable sizes-at-age for all ages and regions. Arctic Cod collected in the NCS region reached the smallest average maximum achievable length (172 mm) at a slow rate (K= 0.46), whereas Arctic Cod collected from the SCS region reached the largest maximum achievable length of all four regions (275 mm) and at the fastest rate (K= 0.22). Growth rates and largest maximum achievable length were similar in the SCS and EBS, where EBS maximum achievable length reached 271 mm at a rate of K=0.29, which indicate that the eastern Beaufort Sea may be comparable to the nutrient rich Chukchi Sea for Arctic Cod growth. Heavily freshwater-influenced regions such as the EBS, may support larger, older populations of Arctic Cod. Contemporary growth rates of Arctic Cod in the Chukchi and Beaufort seas can be used in future comparisons to evaluate potential effects of increasing climate change and anthropogenic influences.

INTRODUCTION

Dramatic changes to the Arctic have highlighted the need for a greater understanding of the present Arctic ecosystem. Arctic sea surface temperatures have risen by 0.4°C over the past 150 years (IPCC, 2013). Additionally, from 1979 to 2012, Arctic annual average sea ice extent decreased roughly 3.8% per decade (IPCC, 2013). With the strong potential of an ice-free Arctic summer in the near future (Overland and Wang 2013), it is imperative to document the current state of Arctic marine biota. Arctic Cod, *Boreogadus saida,* is an abundant keystone species in the Arctic (Bradstreet and Cross 1982). Extensive research on Arctic Cod has been conducted in the Russian (Rass, 1968, Ponomarenko, 2000) and European Arctic (Falk-Petersen et al. 1986, Lønne and Gulliksen 1989). By comparison, only within the last 30 years has Arctic Cod research expanded to the western Arctic, providing a better understanding of the role of the species in the region. Understanding the effects of a changing environment on an Arctic species is nearly impossible without adequately characterizing a current life history benchmark. This project aims to gain further understanding of this important species by documenting length-at-age and comparing growth rates of Arctic Cod collected from the western Arctic.

Arctic Cod are abundant in two hydrographically unique seas offshore of Alaska: the Beaufort and Chukchi seas (Lowry and Frost 1981, Carmack and Wassmann 2006, Piatt and Springer 2007). The Chukchi Sea extends approximately 800 km northward from the Bering Strait to the shelf break of the Arctic Ocean (Weingartner 1997, Crawford et al. 2012; Figure 1). The Alaskan Coastal Current (warm, fresh, nutrient-poor), Anadyr Waters (cold, salty, nutrient-rich), and Bering Sea Water (characterized by properties in between the two) introduce an abundance of nutrients through the Bering Strait into the Chukchi Sea, increasing regional productivity (Grebmeier et al. 2006, Figure 1). To the east of the Chukchi Sea, the Beaufort Sea begins at Point Barrow and continues eastward into Canada. Waters from the Alaska Coastal Current in the Chukchi Sea flow create a strong and narrow coastal jet within the Beaufort Sea (Lukovich and Barber 2006). This combination mixes in the eastern Beaufort Sea with the outflow of the Mackenzie River, the third largest river in the Arctic, and spreads out across the shelf (Benoit et al. 2008). While the freshwater influence of the Mackenzie River increases primary productivity, the Beaufort Sea is typically not as biologically productive as the Chukchi Sea (Wong et al. 2013). Additionally, both the Chukchi and Beaufort seas are seasonally covered with sea ice. The distribution and timing of sea ice retreat typically begins in late July (Frey et al. 2015) but overall sea ice cover has decreased in recent years (Comiso et al. 2008, Overland and Wang 2013, Parkinson and Comiso 2013). Sea ice decline and the oceanographic differences between the Chukchi and Beaufort seas may affect the life history of Arctic Cod considerably.

The abundance and circumpolar distribution of Arctic Cod emphasize the importance of understanding the general life history of the species. Arctic Cod, a relatively short lived species (7-8 years), has evolved to thrive in the Arctic (Gradinger and Bluhm 2004, Geoffroy et al. 2011, David et al. 2015). Optimal spawn timing occurs in the late fall and early winter as buoyant eggs rise and settle beneath the ice-water interface (Hop and Graham 1995). Variations in spawn timing of Arctic Cod likely exist due to their broad spatial distribution, but may vary as a result of different environmental conditions such as temperature and salinity (Bouchard and Fortier 2011). Similar to spawn timing, hatch timing also must be adequately timed to increase survival. The timing of hatching events are often region specific (Bouchard and Fortier 2011). In the Beaufort Sea, hatching events between January and March favor juvenile growth and a greater chance of survival, compared to hatching events later in the season from March through July (Bouchard and Fortier 2011). Once hatched, Arctic cod typically concentrate to the epipelagic waters (< 100 m) where prey is abundant (Ponomarenko 2000, Geoffroy et al. 2015, Kono et al. 2016). Remaining in epipelagic waters is believed to be a strategy to avoid cannibalism from larger Arctic Cod (Rand et al. 2013) which are commonly found in deeper waters (Benoit et al. 2010). As Artic Cod become larger, pelagic juveniles often begin the descent to deeper (>100 m), offshore waters within the first year of hatching (Geoffroy et al. 2015). Understanding the life history of Arctic Cod and its adaptations to its present environment in the western Arctic is vital as habitat is expected to change dramatically.

While Arctic Cod commonly dominate fish assemblages in the Chukchi and Beaufort seas (Norcross et al. 2017), their growth rates in these regions are not fully understood. As the environmental characteristics of a habitat such as temperature and salinity can greatly affect this particularly important aspect of the life history (Craig et al. 1982, Falk-Petersen et al. 1986), understanding the growth of Arctic Cod from diverse habitats such as the Chukchi and Beaufort seas are imperative. Many Arctic fishes such as Arctic Cod are generally stenothermic, and typically grow faster at colder temperatures when compared to fishes from lower latitudes (Laurel et al. 2016). This stenothermic growth benefits high latitude fishes, but requires a narrow temperature range to prosper. Juvenile and adult Arctic Cod have been found in habitats with wide temperature (0° to 13.5°C) and salinity ranges (10 to 35) (Craig et al. 1982). The southern and northern regions of the Chukchi Sea experience spatial variability in environmental conditions due to the sea ice formation and melt timing, wind mixing, and the strength of the northward transport of the different water masses from the Bering Strait (Weingartner et al.

2005). In nearshore locations in the southern Chukchi Sea, a region heavily influenced by the warm, fresher Alaska Coastal Current, Arctic Cod were found to be larger on average at age, suggesting this region may be more favorable for growth (Gillespie et al. 1997). Similarly to the Chukchi Sea, temperature and salinity ranges fluctuate drastically in the western and eastern Beaufort Sea, as these regions experience strong freshwater influence from both the Colville and Mackenzie River (Kulikov et al. 1998). Evaluating Arctic Cod growth variation across two adjacent, hydrographically unique seas has not yet been conducted and will provide a useful benchmark for future comparison as a dramatically changing climate may potentially impact the circumpolar Arctic Cod habitat.

To quantify growth differences in the western Arctic, Arctic Cod were sampled across the Chukchi and Beaufort seas. Obtaining growth rates of Arctic Cod has become more feasible with their abundance in recent collections from the Beaufort and Chukchi seas, yet a comprehensive picture of growth differences in Arctic Cod has not been conducted at this scale. Length of the fish and the corresponding age are necessary components to best quantify growth. Age structure can be established utilizing the otoliths, calcified structures found in the inner ear of teleost fishes (Campana 1999). As somatic and otolith growth are highly correlated (Mossegard et al. 1988, Kelly Walker, personal communication), otolith-based age estimates and incremental ring width measurements have been shown to provide a good approach for reconstructing the growth of fishes at the population (Campana and Neilson, 1985) and individual levels (Wilson and Larkin, 1980; Chambers and Miller, 1995). Previous research has confirmed that Arctic Cod can be estimated for age through otolith analysis using the annuli, or closely spaced daily circuli, to determine one year of growth (Bouchard and Fortier 2011). Length-at-age is used to fit a von Bertalanffy growth equation to determine fish growth (Ricker 1975). While this model has been considered antiquated, it has proven useful in fisheries with limited stock information and provides a descriptive model of length-at-age data (Lester et al. 2004). Recently, growth rates of Arctic Cod were calculated using samples from the Arctic Ecosystem Integrated Survey (Arctic EIS), but were limited to the Bering Sea and southern Chukchi Sea (Helser et al. 2015). Identifying the age structure of an Arctic species such as Arctic Cod through otolith analysis has proven useful when age verifications via in situ observations of daily growth are impossible due to the Arctic's isolated nature and severe environmental conditions.

The main objectives for this project were to: 1) characterize length-at-age of Arctic Cod for each the Beaufort and Chukchi seas, 2) investigate regional individual Arctic Cod growth, 3) investigate interannual individual level Arctic Cod growth for the Eastern Beaufort Sea and finally, and 4) establish and compare population-level growth rates among seas. Based on nutrient availability and water temperature, I hypothesized that Arctic Cod will be larger at age and will grow at faster rates in the Chukchi Sea when compared to the Beaufort Sea. Additionally, I hypothesized that Arctic Cod captured in the southern Chukchi Sea and the eastern Beaufort Sea, which receive significant nutrient inputs from the Mackenzie River and Bering Strait, respectively, will be larger on average at age than fish captured in the western Beaufort and northern Chukchi seas, which do not receive such direct nutrient inputs. This information will increase the understanding of the potential biological responses to the changing environmental conditions that Arctic Cod will likely encounter in the near future and will provide a comprehensive look at the growth dynamics of Arctic Cod across a large spatial scale in the western Arctic.

METHODS

Sampling areas

Arctic Cod for this project were collected from 2009 to 2014 during the ice free months (August-September) from twelve cruises throughout the Beaufort and Chukchi seas (Figure 2). Arctic Cod were collected from the following Chukchi Sea cruises: the Russian-American Long-term Census of the Arctic (RUSALCA) from 2009 (Yun et al. 2014, Ershova et al. 2015, Mecklenburg and Steinke, 2015), the Alaska Monitoring and Assessment Program (AKMAP) from 2010 and 2011 (Gray et al. 2015, Gleason et al. 2015), Chukchi Sea Environmental Studies Program (CSESP) from 2009 and 2010 (WWW0902, WWW0904, WWW1003; Blanchard et al. 2013, Norcross et al. 2013), and the Arctic Ecosystem Integrated Survey project (ArcticEIS) from 2012 (Gray et al. 2015, Helser et al. 2015, De Robertis et al. 2017). From the Beaufort Sea, Arctic Cod were obtained from the following Beaufort Sea cruises: CSESP 2010 cruise (WWW1004), the Beaufish cruise from 2011 (Divine et al. 2015a, Gray et al. 2015, Ravelo et al. 2015), and the US-Canada-Transboundary (TB2012, TB2013, TB2014) cruises in 2012, 2013, and 2014 (Divine et al. 2015b, Bell et al. 2016, Smoot et al. 2016, Questel et al. 2016). The combined cruises from the Beaufort and Chukchi seas cover an area of nearly 1500 km habitat utilized by Arctic Cod.

For a more detailed understanding of spatial variations in Arctic Cod growth across their western Arctic distribution, the Chukchi and Beaufort seas were divided into regions (Figure 2). Based on sampling locations and hydrography (Weingartner et al. 2005), the Chukchi Sea was divided into Northern Chukchi Sea (NCS) and Southern Chukchi Sea (SCS) regions at 70°N where a semi-permanent front has been identified and to identify the influence of the less saline, warm Alaska Coastal Current in the southern Chukchi Sea (Weingartner et al. 2005, Divine et al. 2015a, Gray et al. 2015). Beaufort Sea sample sites were divided at 151.75°W, near the confluence of the Colville River, into the Western Beaufort Sea (WBS) and Eastern Beaufort Sea (EBS) based on previous demersal fish surveys (Rand and Logerwell 2011), comparable research in the region (Divine et al. 2015b, Gray et al. 2015) and to evaluate the impact of the Mackenzie River influence (Dunton et al. 2006, Logerwell et al. 2011).

A variety of bottom trawl gear was used in the Chukchi Sea. Bottom trawl nets included a standard plumb staff beam trawl (PSBT) (Gunderson and Ellis 1986) and an otter trawl net (OT). The PSBT had a 4.7 m headrope and 4.6 m footrope, 7 mm body mesh, 4 mm mesh codend liner, and a 1.3 m vertical opening, while the OT had a 9.1 m headrope, 38 mm body mesh, and 19 mm mesh in the codend was held open with two 61 x 122 cm (23 kg) doors. Additionally, a variety of a beam trawls were fished in the Chukchi Sea (3 m BT, 4 m BT, 5 m BT). Each net varied slightly in beam length, but were all fitted with a 12-mm codend liner. The different sizes of the beam trawls allowed researchers to target a broad size range of fish. Also a much larger bottom trawl, the 83-112 net was used; it had a body mesh of 102 mm and a codend mesh of 32 mm and 2.5 m vertical opening (Stauffer 2004).

Similar to the Chukchi Sea, a variety of sampling methods were used to collect Arctic Cod in the Beaufort Sea. Identical bottom trawl nets were used in the Beaufort Sea as in the Chukchi Sea, including the PSBT and OT. In the Beaufort Sea, the majority of the samples was caught with a PSBT or a modified plumb staff beam trawl (PSBT-A). The PSBT-A had rollers added to the footrope (Abookire and Rose 2005) to avoid boulders and rocks and muddy substrate that were frequently encountered in the Beaufort Sea. The Canadian beam trawl net (CBT) also had a 3-m beam to hold the mouth open, and roller gear on the footrope; it had a 4.2 m headrope and

4.2 m footrope, 10 mm mesh in body and 6 mm mesh as codend liner. In addition to the bottom trawl nets, two midwater nets were fished in the Beaufort Sea. The Isaacs-Kidd Midwater Trawl (IKMT) had a 3 mm body mesh size and codend attachment with dimensions of 1.5 m wide by 1.8 m high. An Aluette midwater net (AMT) had a length of 18 m, with a mouth opening of 8 m x 7 m, and 42 mm mesh at the mouth, 35 mm mesh at the intermediary, and 12 mm in the cod-end liner. Collectively, the range of nets utilized for sampling in the Beaufort and Chukchi seas covered a wide range of mesh, which reduced gear bias on size selectivity for Arctic Cod collection.

Laboratory Analysis

Following collection at sea, Arctic Cod were brought to the University of Alaska Fairbanks Fisheries Oceanography Lab for analysis. Total length was measured to the nearest millimeter (mm). After processing, twenty Arctic Cod were randomly selected per 10 mm increment bin range, per cruise collection, for age analysis. Ten millimeter increments were binned from 0-10 mm, 11-20 mm, 21-30 mm, and so on. Sagittal otoliths were removed, cleaned, and mounted in heated Crystalbond™ thermoplastic to a clear slide. Using a Buehler® isomet low speed saw, otoliths were transversely thin sectioned by grinding down the rostrum and then reheated to place the flat edge of the otolith onto the glass microscope slide. The exposed surface was then ground down until growth rings were visible under a compound microscope (Figure 3). If the first otolith was damaged during processing, the second otolith was prepared. A transmitted light photo of each otolith was taken with a camera-mounted dissecting microscope (Leica M165C). Two independent readers determined the age of the fish by using the photos to count annual growth rings. When readers disagreed on assessment of fish age, the readers re-aged the otoliths concurrently to assign a final age.

Length-at-age

Mean length at age was compared for Arctic Cod among regions. Total lengths (mm) of Arctic Cod with corresponding estimated ages were plotted using Sigma Plot software (v. 12.5, Systat Software Inc. 2011). A two-tailed t test was used to test for differences in mean total length between the seas. A series of one-way ANOVAs ($p < 0.05$) using Sigma Plot software was used to test for differences in average length at each age by region (SCS, NCS, WBS, and EBS). Differences among regions were detected using a Holm-Sidak multiple comparison. In age groups where sample sizes were not equal and the assumption of normality was not met using the Shapiro-Wilk test, a non-parametric Kruskal-Wallis one way ANOVA was used. When sample sizes were unequal, subsequent pairwise analyses were then completed using the Dunn's Method (Dunn 1961).

Individual Growth analysis

Annual growth of Arctic Cod collected from all four regions was estimated by measuring the distance between annuli from images of transversely sectioned otoliths using Leica Imaging Software. Growth from hatch to age-1 was difficult to accurately determine as the hatch ring was not easily discernable. Therefore, age-0 and age-1 were excluded from the analysis. Growth was measured in hundredths of millimeters between the first and second annuli to determine the growth between age-1 and age-2, the second and third annuli to determine growth between age-2 and age-3, and finally the third and fourth annuli to determine the growth between age-3 and age-4. Growth between these ages was compared across regions to determine differences in age using a one-way ANOVA (Chambers and Miller 1995). For example, the width of the growth zone between age-1 and age-2 was compared across all four regions (SCS, NCS, WBS, and EBS). In regions where sample sizes were not equal and the assumption of normality was not met, a non-parametric Kruskal-Wallis one-way ANOVA was used.

To test for interannual differences in growth within one region, the EBS region was selected for analysis because samples were available from five separate years (2010, 2011, 2012, 2013, and 2014). Samples from the SCS, NCS, and WBS regions included a maximum of three separate years of data collection, while the EBS region had five separate years to test for interannual growth differences. Differences in growth were only tested between age-1 and age-2 across five years of sampling efforts due to the small sample size of Arctic Cod age-3 and older collected from multiple years. Differences in mean increment width (growth) between age-1 and age-2 fish collected across five years were tested with a one-way ANOVA using Sigma Plot 12.5. Subsequent pairwise multiple comparisons were conducted using the Holm-Sidak method with a p-value less than 0.05 as significant.

Population Growth Analysis

The von Bertalanffy growth function (VBGF) was used to determine growth parameters of Arctic Cod using the following equation (Ricker, 1975):

$$L(t) = L_{\infty}[1 - e^{(-K*(t-t_0))}]$$

where L(t) is total fish length at age t, L_{∞} is the length at which the average fish reaches asymptotic length, t is age of fish in years, and t_0 is the theoretical age when L = 0. The rate of increase in length of the fish is a constant proportion (K) of the difference between the maximum and present length ($L\infty$ -L(t)). VBGF parameters were calculated using the FSA package (Ogle, 2016) in the statistical software R version 3.2.3 (R Core Team 2015).

RESULTS

Arctic Cod age and length frequency distributions

For this project, age and length were measured from a total of 2,709 Arctic Cod from four regions (Table 1): 481 from SCS, 1,025 from NCS, 253 from WBS, and 950 from EBS. Mean total length (mm) of Arctic Cod collected from the Chukchi Sea (96 ± 38 mm; n=1506; Table 2) were significantly different (t_{2707}=2.59, p= 0.01) from Arctic Cod collected from the Beaufort Sea (92 ±45 mm; n= 1203; Table 2). Within the Chukchi Sea, Arctic cod collected in the SCS region were on average larger (105 ± 42 mm) than NCS Arctic Cod sampled (91 ± 35 mm; Table 2). In the Beaufort Sea, the smallest Arctic Cod of all four regions were found in the WBS (77 ± 36 mm; Table 2) while the second largest Arctic Cod of all four regions were collected in the EBS (96 ± 46 mm; Table 2). T-tests used to compare average total length in each region were all significantly different from one another when compared by regions.

The age composition of Arctic Cod revealed similar trends across the Chukchi and Beaufort seas (Figure 4). Overall, ages estimated ranged from age-0 to age-5. The younger age classes were dominant in all regions with age 0, age-1 and age-2 collectively comprising 94% of the total samples collected. In the Chukchi Sea, ages ranged from age-0 to age-4 for both the NCS and SCS. In the Beaufort Sea, age ranged from age-0 to age-5, yet age-5 Arctic Cod were only found in the EBS and only made up 0.42% of the total samples collected in the region. In the

WBS region, 62% of all Arctic Cod were age-0. Age-4 and age-5 were far less common in this study and comprised only 2% of the total estimated samples.

All age classes of Arctic Cod had a wide spread of length-at-age (Figure 5). Overall, as Arctic Cod became older, the spread of length-at-age became wider. Age-0 and age-1 Arctic Cod collected from the Chukchi Sea had a smaller range in length when compared to the Beaufort Sea. For example, age-0 Arctic Cod in the Chukchi Sea were as small as 20 mm and as large as 105 mm while Arctic Cod from the Beaufort Sea were as small as 15 mm and as large as 139 mm. The older age classes (age-2, age-3, age-4) had wider length-at-age ranges in the Chukchi Sea than the Beaufort Sea as length-at-age. Age-2, age-3, age-4 Arctic Cod collected in the NCS region were consistently the smallest measured but the largest Arctic Cod for age-3 collected for this study was collected in the NCS.

Average length-at-age by region were all significantly different for age-0 (H=136.97, p=<0.001; age-1 (H=15.36, p=0.002;), age-2 (H=45.19, p=<0.001;), age-3 ($F_{(3,123)}$= 9.722, p<0.001; and age-4 (H=6.36, p=0.042; Table 3). No clear pattern could be detected when evaluating significant differences in length-at-age by region. Significant differences in length-at-age were found within the Chukchi Sea from the SCS and NCS regions for age-1, age-2, and age-3, yet differences were only detected within the Beaufort Sea from the WBS and EBS regions for age-0. Differences in length-at-age were detected from two regions with the greatest spatial distance between, the SCS and EBS, for all ages with the exception of age-2. Full results of the individual ANOVA tests are described in the Appendix from Table A-1 to Table A-5.

Individual growth analysis:

Annual growth varied among regions and ages. On average for all ages, growth, was smallest in the Chukchi Sea regions when compared to the Beaufort Sea regions. Growth was largest in the EBS region for all ages (Table 4). Growth between age-1 and age-2, age-2 and age-3, and age-3 and age-4 were all significantly different between the EBS and both Chukchi Sea regions (Table 5). No differences in growth within seas were detected. Full results of the individual ANOVA tests are described in the Appendix from Table A-6 to Table A-8.

A total of 242 otoliths were used to determine if interannual differences in growth existed (Table 6) between age-1 and age-2 for the EBS region across five consecutive years. Arctic Cod growth between age-1 and age-2, as measured as the distance between the first and second annuli, significantly differed for years 2010 to 2014 ($F_{(4,238)}$= 5.82, p<0.001; Table 7). Out of the five years, growth between age-1 and age-2 was smallest in 2011 and greatest in 2013 (Table 7). Pairwise multiple comparisons determined significant differences in growth between age-1 and age-2 from 2011 and 2013, 2012 and 2014, and finally 2013 and 2014 (Table 7).

Population Growth Analysis

The von Bertalanffy growth model indicated regional variation in growth and maximum achievable length. Arctic Cod sampled from the Chukchi Sea reached an overall smaller maximum achievable length (218 mm) compared to the Beaufort Sea (269 mm; Table 8). The growth parameter indicated faster growth in the Beaufort Sea (K= 0.25) than in the Chukchi Sea (K= 0.30; Table 8). Despite an overall smaller maximum achievable size in the Chukchi Sea when compared to the Beaufort Sea, the SCS region had the highest overall maximum achievable length (275 mm) and also displayed the fastest growth parameter (K= 0.22; Table 8) of the four regions. Arctic Cod from the NCS region reached the smallest overall maximum achievable length (172 mm), however this region did not have the lowest growth rate (K= 0.46).

The slowest growth parameter of the four regions was in the WBS region where Arctic Cod reached a maximum of 175 mm, with a K parameter of 0.49 (Table 8). The EBS region had a high maximum achievable length (271 mm), similar to the SCS region, yet calculated growth was faster in the SCS than in the EBS (Table 8).

DISCUSSION

Arctic Cod is an integral part of the Arctic ecosystem, due to the abundance throughout the Arctic region. This study utilized nearly 3,000 Arctic Cod otoliths providing a comprehensive look at age structure and growth rates from the western Arctic for this vital species. Differences in length-at-age were apparent between the Chukchi and Beaufort seas. Additionally, individual and population level growth rates differed among and between regions which both supported and refuted previous research conducted on these two systems.

Arctic Cod is a small, relatively short lived gadid species that were found to have similar age ranges in all four regions, yet the range in length-at-age varied greatly. With age-0 Arctic Cod ranging in size from 26 mm to 105 mm in the Chukchi Sea and 15 mm to 139 mm in the Beaufort Sea, food availability or spawn timing may be influencing the large length-at-age-0 in the Beaufort Sea. As Arctic Cod became older, larger lengths-at-age were observed in the Chukchi Sea for age-2 and age-3 when compared to the Beaufort Sea Acoustic signals taken in the Chukchi region have registered strong signals, likely Arctic Cod, in Barrow Canyon, an area fed by the nutrient rich Alaska Coastal Current (Crawford et al. 2012). Arctic Cod may have achieved a great deal of their early growth from the nutrient rich Chukchi Sea waters, and then transported to the Beaufort Sea. Age 1+ Arctic Cod size ranges were comparable to collection studies in the early 1980s, early 1990s and 2012 in the Chukchi Sea (Craig et al. 1982, Frost and Lowry, 1983, Gillispie et al. 1997, Hesler et al. 2015). The short-lived life history and the significant overlap in length-at-age indicate otolith analysis is a reliable tool to estimate age, rather than using length as an indicator of age.

Results of this study likely signify that the eastern Beaufort Sea is a complex, productive region than previously believed for Arctic Cod. This region is complex and productive region heavily influenced by freshwater input, predominantly the Mackenzie River (Dunton et al. 2006). Arctic Cod have been associated with freshwater-influenced areas including the eastern Beaufort Sea (Craig et al. 1982, Gradinger and Bluhm 2004). The freshwater influence not only lowers salinity but can also increase temperatures causing stratification in nearshore waters (Macdonald et al. 1999). The Beaufort Sea shelf is defined by its water masses: the Polar Mixed Layer (PML) which extends from the surface to approximately 50 m where temperatures and salinities greatly range any where from -1 to ~10, the Arctic Halocline Water (AHW) which begins roughly at 50 m depth and extends approximately to 200 m, characterized by temperatures < 0°C and high salinities (~34) and finally, the deepest water mass, the Atlantic Water (AW), a high saline (~34) and cold (> 0°C) water mass. The boundaries of these water masses vary spatially with the changes in wind, river flow, and ice conditions, but have been shown to produce elevated primary and secondary production compared to the coastal ocean water (Walkusz et al. 2010). In the summer months the PML typically settles into an upper layer that traps solar energy. Larvae Arctic Cod are often found in the upper water column, limited by body size to move into deeper waters (Geoffroy et al. 2015), while larger adults tend to prefer colder temperatures at depth (Benoit et al. 2010). When food is abundant, juvenile Arctic Cod thrive in temperatures in water temperatures from 3-8 °C (Laurel et al. 2016) and larvae and juvenile growth is accelerated in warmer temperatures (Bouchard and Fortier 2011). The distribution of juveniles in the upper warmer water column not only increases feeding opportunities but reduces interaction with adult Arctic Cod that may result in cannibalism (Benoit et al. 2010). Additionally, when compared to the WBS, NCS, and SCS, the average increment width was largest in the EBS for ages 1-4. This freshwater influence of the Mackenzie River plays a large role complexity of the region, and likely in the increase rate of growth and the overall survival potential in the EBS region.

Ideal growth conditions likely exist in the EBS and SCS as similar growth rates and maximum average achievable lengths occurred within both regions. The SCS region exhibited a larger achievable length when compared to the EBS, at similar growth rates, yet the Chukchi Sea is historically known to be a more productive region than the Beaufort Sea (Grebmeier, 2012). The Chukchi Sea, characterized by its broad shallow shelf (Weingartner et al. 2005), receives nutrients from the Bering Sea, and consequently experiences high benthic abundance and biomass. Comparatively, the Beaufort Sea's extensive ice coverage, narrow shelf, and currents limit primary production, and is more of a pelagic system (Grebmeier and Barry 1991). The largest and oldest Arctic Cod were collected in the Beaufort Sea. The Beaufort Sea receives a large input of terrestrial organic matter from the Mackenzie River (Guo et al. 2007) and is nutrient poor when compared to marine production from the Chukchi Sea (Dunton et al. 2012). Despite this, it has been recently shown that the input of terrestrial organic matter into the Beaufort Sea from the Mackenzie River provides high energetic value for higher marine trophic levels and drives the variation in marine trophic structure across the Beaufort shelf and slope (Bell et al. 2016). Not all of the Beaufort Sea proved beneficial for Arctic Cod. The samples from the WBS region had the smallest age range and slowest growth indicates less favorable conditions for growth in the region. Primary production available to marine consumers in the EBS region potentially has a higher energetic value than previously understood and suggests this region has the capacity to be equally as productive for Arctic Cod when compared to the Chukchi Sea.

This species is facing warmer sea temperatures in the near future (Overland and Wang 2013). The success of the population of Arctic Cod will be determined by temperature changes and declining sea ice, which may not benefit a species with a cold-water stenothermic growth response. Arctic cod are found in high abundance at 2–9 °C along thermal-salinity fronts such as in the Beaufort Sea (Moulton and Tarbox 1987). Arctic Cod may only briefly survive warm (>9°C) due to reduced growth potential and condition (Laurel et al. 2016). Recent temperatures collected around the Mackenzie River plume in the Beaufort Sea have been recorded 2.8°C warmer than the average from the previous twenty years of collected data (Arctic Data Archive System). It is important to document the current state of the species as vital habitat is changing.

Undoubtedly, the connectivity of the Chukchi and Beaufort seas may confound the interpretation of the results of this project. Nearly 3,000 Arctic Cod were utilized for this project and were collected from a broad spatial scale across multiple years. The transporation of Arctic Cod via current has likely occurred within the sample regions (Wyllie-Echeverria et al. 1997) and would be difficult to quantify. Fish collected in the Beaufort Sea may have been transported from the Chukchi Sea and thus early growth would not be representative of the Beaufort Sea. To remove any uncertainties of natal origin of Arctic Cod, trace element analysis of cores of fish otoliths should be examined. Unlike genetic markers that identify fish populations, trace element analysis can be useful in determining specific geographic regions occupied by fishes (Campana, 1999). An otolith chemical signature can reflect water mass occupation (Gleason et al. 2015), hence otolith microchemistry can be used to determine elemental signatures to differentiate natal origins of Arctic Cod from the Beaufort and Chukchi seas.

This study of Arctic Cod growth highlights the importance of understanding basic life history of this abundant fish species in the Arctic. Growth rates of Arctic Cod have been determined in laboratory studies (Jensen et al. 1991, Hop et al. 1995) but have not been extensively evaluated directly from the field for the Beaufort and Chukchi Seas until now. Based on the differences in length-at-age, growth, and maximum achievable length observed between the Chukchi and Beaufort seas, Arctic Cod are likely influenced by oceanographic currents, temperature, and riverine input. High-latitude seas, prime gadid habitat, are predicted to be the species most affected by increasing temperatures in the Arctic (Hurst et al. 2013). Results from this project will provide an encompassing view of Arctic Cod in the US Arctic and assist in the overall understanding of growth and subsequent survival of Arctic Cod.

LITERATURE REVIEW

Abookire AA, Rose CS. 2005. Modifications to a plumb staff beam trawl for sampling uneven, complex habitats. Fisheries research. 71(2): 247-254.

Bell LE, Bluhm BA, Iken K. 2016. Influence of terrestrial organic matter in marine food webs of the Beaufort Sea shelf and slope. Marine Ecology Progress Series 550:1-24.

Benoit D, Simard Y, Fortier L. 2008. Hydroacoustic detection of large winter aggregations of Arctic cod (*Boreogadus saida*) at depth in ice-covered Franklin Bay (Beaufort Sea). Journal of Geophysical Research: Oceans. 113(C6).

Benoit D, Simard Y, Gagné J, Geoffroy M, Fortier L. 2010. From polar night to midnight sun: photoperiod, seal predation, and the diel vertical migrations of polar cod (*Boreogadus saida*) under landfast ice in the Arctic Ocean. Polar Biology, 33(11), 1505-1520.

Blanchard, AL, Parris CL, Knowlton AL, Wade NR. 2013. Benthic ecology of the northeastern Chukchi Sea. Part I. Environmental characteristics and macrofaunal community structure, 2008–2010. Continental Shelf Research, 67, 52-66.

Bouchard C, Fortier L. 2008. Effects of polynyas on the hatching season, early growth and survival of polar cod *Boreogadus saida* in the Laptev Sea. Marine Ecology-Progress Series. 355: 247.

Bouchard C, Fortier L. 2011. Circum-arctic comparison of the hatching season of polar cod (*Boreogadus saida*): A test of the freshwater winter refuge hypothesis. Progress in Oceanography. 90(1): 105-116.

Bradstreet MS, Cross WE. 1982. Trophic relationships at high Arctic ice edges. Arctic: 1-12.

Campana SE. 1999. Chemistry and composition of fish otoliths: pathways, mechanisms and applications. Marine Ecology Progress Series. 188: 263-297.

Campana, SE, Neilson JD. 1985. Microstructure of fish otoliths. Canadian Journal of Fisheries and Aquatic Sciences. 42(5): 1014-1032.

Carmack E, Wassmann P. 2006. Food webs and physical–biological coupling on pan-Arctic shelves: unifying concepts and comprehensive perspectives. Progress in Oceanography. 71(2): 446-477.

Chambers RC, Miller TJ. 1995. Evaluating fish growth by means of otolith increment analysis: special properties of individual-level longitudinal data. Recent developments in fish otolith research:155-175.

Comiso JC, Parkinson CL, Gersten R, Stock L. 2008. Accelerated decline in the Arctic sea ice cover. Geophysical Research Letters 35.

Craig P, Griffiths W, Haldorson L, McElderry H. 1982. Ecological studies of Arctic cod (*Boreogadus saida*) in Beaufort Sea coastal waters, Alaska. Canadian Journal of Fisheries and Aquatic Sciences. 39(3): 395-406.

Crawford R, Vagle S, Carmack E. 2012. Water mass and bathymetric characteristics of polar cod habitat along the continental shelf and slope of the Beaufort and Chukchi seas. Polar Biology. 35(2): 179-190.

David C, Lange B, Krumpen T, Schaafsma F, van Franeker JA, Flores H. 2015. Under-ice distribution of polar cod *Boreogadus saida* in the central Arctic Ocean and their association with sea-ice habitat properties. Polar Biology: 1-14.

De Robertis A, Taylor K, Wilson CD, Farley EV. 2017. Abundance and distribution of Arctic cod (*Boreogadus saida*) and other pelagic fishes over the US Continental Shelf of the Northern Bering and Chukchi Seas. *Deep Sea Research Part II: Topical Studies in Oceanography*, *135*, 51-65.

Divine LM, Bluhm BA, Mueter FJ, Iken K. 2015a. Diet analysis of Alaska Arctic snow crabs (*Chionoecetes opilio*) using stomach contents and δ 13 C and δ 15 N stable isotopes. Deep Sea Research Part II: Topical Studies in Oceanography.

Divine LM, Iken K, Bluhm BA. 2015b. Regional benthic food web structure on the Alaska Beaufort Sea shelf. Marine Ecology Progress Series 531:15-32.

Dunn OJ. 1961. Multiple comparisons among means. Journal of the American Statistical Association 56:52-64.

Dunton, KH, Weingartner T, Carmack EC. 2006. The nearshore western Beaufort Sea ecosystem: Circulation and importance of terrestrial carbon in arctic coastal food webs. Progress in Oceanography 71(2–4): 362-378.

Dunton KH., Schonberg SV, Cooper LW. 2012. Food web structure of the Alaskan nearshore shelf and estuarine lagoons of the Beaufort Sea. Estuaries and Coasts 35:416-435.

Ershova EA., Hopcroft RR., Kosobokova, KN. 2015. Inter-annual variability of summer mesozooplankton communities of the western Chukchi Sea: 2004–2012. *Polar Biology*, *38*(9), 1461-1481.

Falk-Petersen IB., Frivoll V, Gulliksen B and Haug T. 1986. Occurrence and size/age relations of polar cod, *Boreogadus saida* (Lepechin), in Spitsbergen coastal waters. Sarsia. 71(3-4): 235-245.

Frost KJ, Lowry, LF. 1983. Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort Seas, 1976-77. US Department of Commerce, NOAA, National Marine Fisheries Service.

Geoffroy M, Robert D, Darnis G, Fortier L. 2011. The aggregation of polar cod (*Boreogadus saida*) in the deep Atlantic layer of ice-covered Amundsen Gulf (Beaufort Sea) in winter. Polar biology 34:1959-1971.

Geoffroy M, Majewski A, LeBlanc M, Gauthier S, Walkusz W, Reist JD, Fortier L. 2015. Vertical segregation of age-0 and age-1+ polar cod (Boreogadus saida) over the annual cycle in the Canadian Beaufort Sea. Polar biology:1-15.

Gillespie, JG., Smith RL, Barbour E, Barber WE. 1997. Distribution, abundance, and growth of Arctic cod in the Northeastern Chukchi Sea. Pages 81-89 in J. Reynolds, editor. Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, Maryland.

Gleason CM, Norcross BL, Spaleta KJ. 2015. Otolith chemistry discriminates water mass occupancy of Arctic fish in the Chukchi Sea. Marine and Freshwater Research.

Gradinger RB, Bluhm BA. 2004. In-situ observations on the distribution and behavior of amphipods and Arctic cod (*Boreogadus saida*) under the sea ice of the High Arctic Canada Basin. Polar Biology. 27(10): 595-603.

Grebmeier JM, Barry JP. 1991. The influence of oceanographic processes on pelagic-benthic coupling in polar regions: a benthic perspective. Journal of Marine Systems, 2(3-4), 495-518.

Grebmeier JM, Cooper LW, Feder HM, Sirenko BI. 2006. Ecosystem dynamics of the Pacific-influenced northern Bering and Chukchi Seas in the Amerasian Arctic. Progress in Oceanography.;71(2):331-61.

Gunderson DR., Ellis IE. 1986. Development of a plumb staff beam trawl for sampling demersal fauna. Fisheries Research, 4(1), 35-41.

Guo L, Ping CL., Macdonald RW. 2007. Mobilization pathways of organic carbon from permafrost to arctic rivers in a changing climate. Geophysical Research Letters, 34(13).

Helser TE, Colman JR., Anderl DM., Kastelle CR. 2015. Growth dynamics of saffron cod (*Eleginus gracilis*) and Arctic cod (*Boreogadus saida*) in the Northern Bering and Chukchi Seas. Deep Sea Research Part II: Topical Studies in Oceanography.

Hop H., Trudeau VL, Graham M. 1995. Spawning energetics of Arctic cod (*Boreogadus saida*) in relation to seasonal development of the ovary and plasma sex steroid levels. Canadian Journal of Fisheries and Aquatic Sciences. 52(3): 541-550.

IPCC 2013: Climate Change 2013. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate. Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

Jensen T, Inne Ugland K, Anstensrud M. 1991. Aspects of growth in Arctic cod, *Boreogadus saida* (Lepechin 1773). Polar Research. 10(2).

Kono Y, Sasaki H, Kurihara Y, Fujiwara A, Yamamoto J, Sakurai Y. 2016. Distribution pattern of Polar cod (*Boreogadus saida*). Polar Biology, 39(6), 1039-1048.

Kulikov, E. A., Carmack, E. C., & Macdonald, R. W. 1998. Flow variability at the continental shelf break of the Mackenzie Shelf in the Beaufort Sea. Journal of Geophysical Research: Oceans, 103(C6), 12725-12741.

Laurel BJ, Spencer M, Iseri P, Copeman LA. 2016. Temperature-dependent growth and behavior of juvenile Arctic cod (*Boreogadus saida*) and co-occurring North Pacific gadids. Polar biology:1-9.

Lester N, Shuter B, Abrams P. 2004. Interpreting the von Bertalanffy model of somatic growth in fishes: the cost of reproduction. Proceedings of the Royal Society of London B: Biological Sciences. 271(1548): 1625-1631.

Lønne OJ, Gulliksen, B. 1989. Size, age and diet of polar cod, Boreogadus saida (Lepechin 1773), in ice covered waters. Polar Biology, 9(3), 187-191.

Lowry LF, Frost KJ 1981. Distribution, growth, and foods of Arctic cod (*Boreogadus saida*) in the Bering, Chukchi, and Beaufort seas. The Canadian field-naturalist. 95 (1981).

Lukovich, J. and D. Barber. 2006. Atmospheric controls on sea ice motion in the southern Beaufort Sea. Journal of Geophysical Research: Atmospheres. 111(D18).

Macdonald, R., E. Carmack, F. McLaughlin, K. Falkner and J. Swift. 1999. Connections among ice, runoff and atmospheric forcing in the Beaufort Gyre.

Mecklenburg CW, Steinke D. 2015. Ichthyofaunal baselines in the Pacific Arctic region and RUSALCA study area. Oceanography.28(3):158-89.

Mossegard H., Svedäng H., Taberman K, 1988. Uncoupling of somatic and otolith growth rates in Arctic char (*Salvelinus alpinus*) as an effect of differences in temperature response. Can. J. Fish. Aquat. Sci. 45, 1514–1524,

Moulton LL, Tarbox KE. 1987. Analysis of Arctic cod movements in the Beaufort Sea nearshore region, 1978-79. Arctic:43-49.

Norcross BL, Holladay BA, Apsens SJ, Edenfield LE, Gray BP, Walker KL. 2017. Central Beaufort Sea Marine Fish Monitoring. BOEM OCS Final Report 2017-034, Springfield VA

Norcross BL, Raborn SW, Holladay BA, Gallaway BJ, Crawford ST, Priest JT, Edenfield LE, Meyer R. 2013. Northeastern Chukchi Sea demersal fishes and associated environmental characteristics, 2009–2010. Continental Shelf Research 67:77-95.

Overland JE. Wang M. 2013. When will the summer Arctic be nearly sea ice free? Geophysical Research Letters. 40(10): 2097-2101.

Ogle DH. 2016. Introductory Fisheries Analyses with R. Chapman & Hall/CRC, Boca Raton, FL.

Parkinson CL, Comiso, JC. 2013. On the 2012 record low Arctic sea ice cover: Combined impact of preconditioning and an August storm.Geophysical Research Letters,40(7), 1356-1361.

Piatt J, Springer A. 2007. Marine ecoregions of Alaska. Long-term ecological change in the Northern Gulf of Alaska. 522-526.

Ponomarenko V. 2000. Eggs, larvae, and juveniles of polar cod *Boreogadus saida* in the Barents, Kara, and White Seas. Journal of Ichthyology. 40(2): 165-173.

Questel JM., Blanco-Bercial L, Hopcroft RR., Bucklin A. 2016. Phylogeography and connectivity of the Pseudocalanus (Copepoda: Calanoida) species complex in the eastern North Pacific and the Pacific Arctic Region. Journal of plankton research.

R Core Team 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rand KM., Whitehouse A., Logerwell EA, Ahgeak E, Hibpshman R., Parker-Stetter S. 2013. The diets of polar cod (*Boreogadus saida*) from August 2008 in the US Beaufort Sea. Polar biology, 36(6), 907-912.

Rass TS. 1968. Spawning and development of polar cod. Rapp PV Reun Cons Perm Int Explor Mer, 158, 135-137.

Ricker WE. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can. 191: 382.

Smoot CA, Hopcroft, RR. 2016. Depth-stratified community structure of Beaufort Sea slope zooplankton and its relations to water masses. Journal of Plankton Research.

Stauffer G. 2004. NOAA protocols for groundfish bottom trawl surveys of the nation's fishery resources. NOAA Tech. Memo. NMFS-F/SPO-65.

Systat Software Inc., 2011. Sigma Plot version for Windows.

Walkusz, W., J. E. Paulić, S. Kwaśniewski, W. J. Williams, S. Wong and M. H. Papst. 2010. Distribution, diversity and biomass of summer zooplankton from the coastal Canadian Beaufort Sea. Polar biology. 33(3): 321-335.

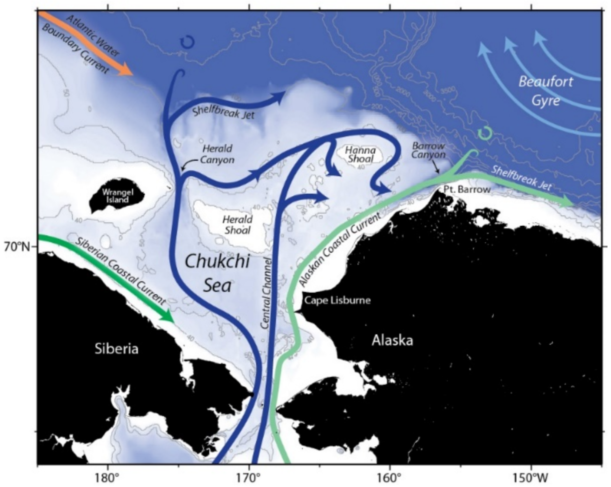
Weingartner K. Aagaard, R. Woodgate, S. Danielson, Y. Sasaki and D. Cavalieri. 2005. Circulation on the north central Chukchi Sea shelf. Deep Sea Research Part II: Topical Studies in Oceanography. 52(24): 3150-3174.

Weingartner TJ. 1997. A review of the physical oceanography of the northeastern Chukchi Sea. Fish ecology in Arctic North America. American Fisheries Society Symposium.

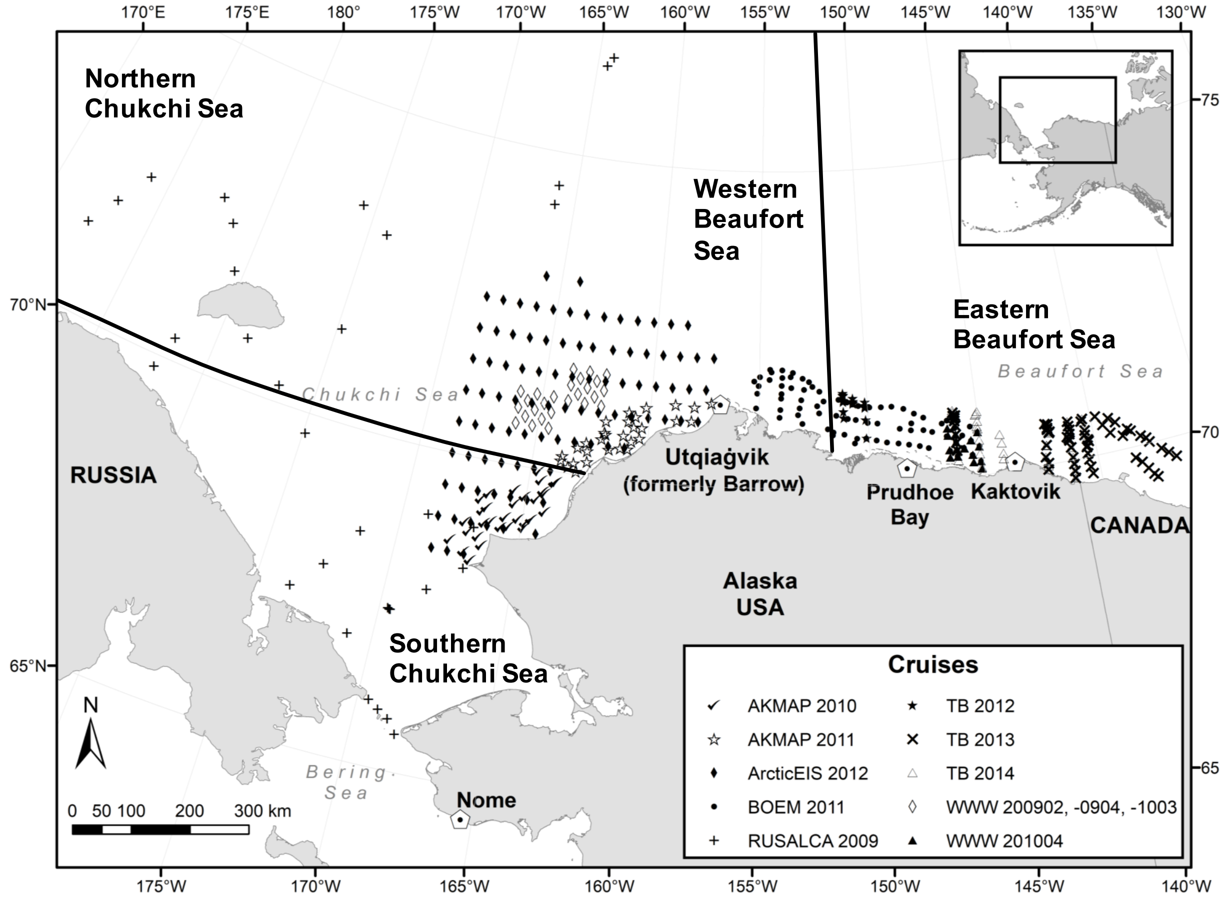
Wong S, Walkusz W, Hanson M, Papst MH. 2013. The influence of the Mackenzie River plume on distribution and diversity of marine larval fish assemblages on the Canadian Beaufort Shelf. Journal of Marine Systems 127: 36-45.

Woodgate RA., Weingartner TJ and Lindsay R. 2012. Observed increases in Bering Strait oceanic fluxes from the Pacific to the Arctic from 2001 to 2011 and their impacts on the Arctic Ocean water column. Geophysical Research Letters. 39(24).

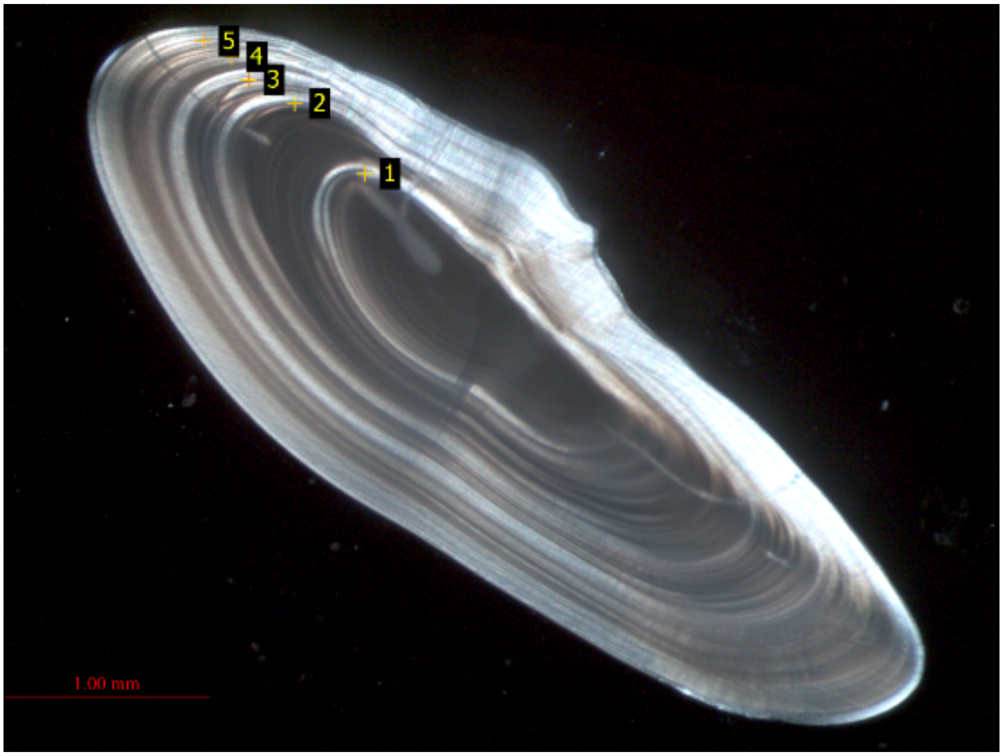
Wyllie-Echeverria T, Barber WE, Wyllie-Echeverria S. 1997. Water masses and transport of age-0 Arctic cod and age-0 Bering flounder into the Northeastern Chukchi Sea. Fish ecology in Arctic North America. American Fisheries Society Symposium.



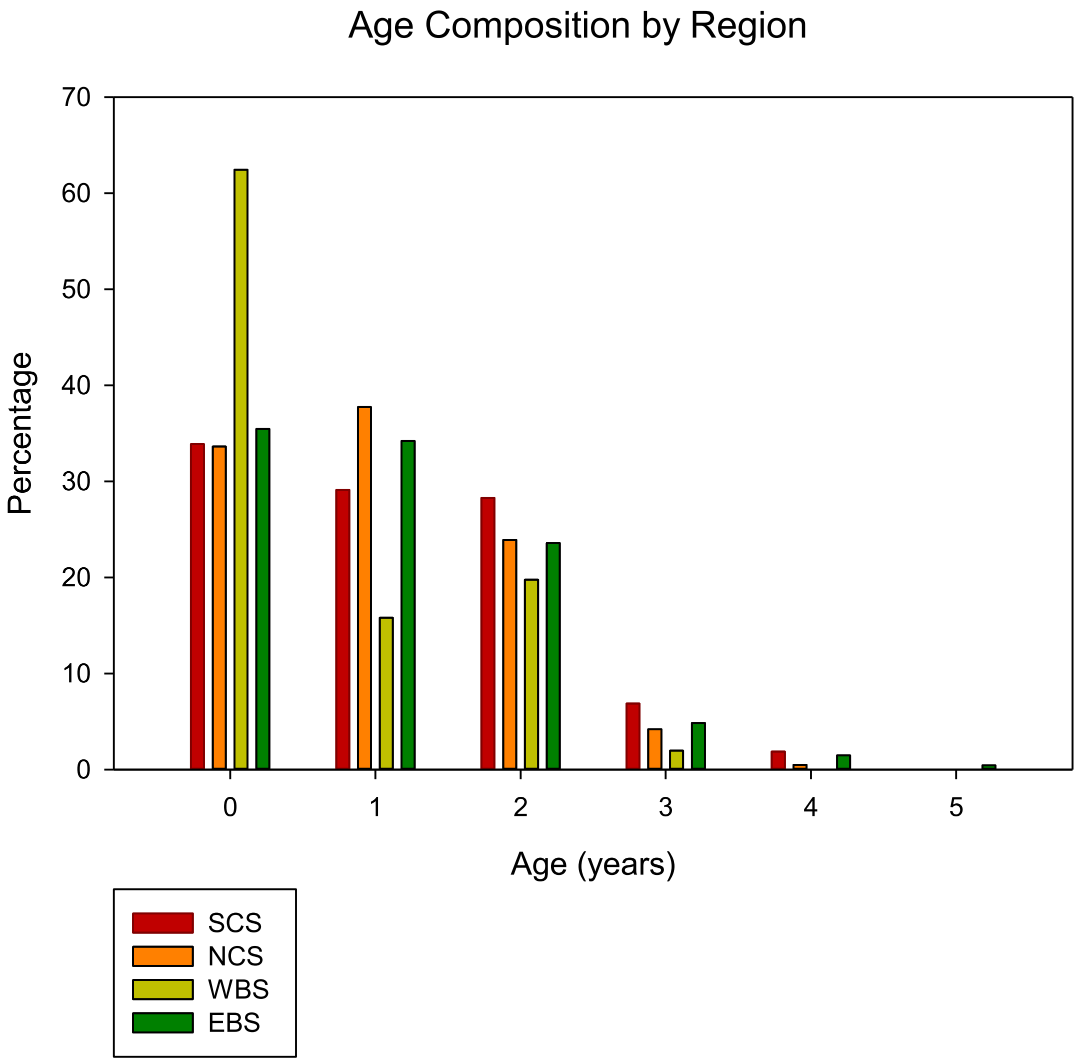
Appendix E4 Figure 1: Currents of the Chukchi (west of Pt. Barrow) and the Beaufort (east of Pt. Barrow) seas. Source: http://arcticspring.org/dispatches/ocean-action



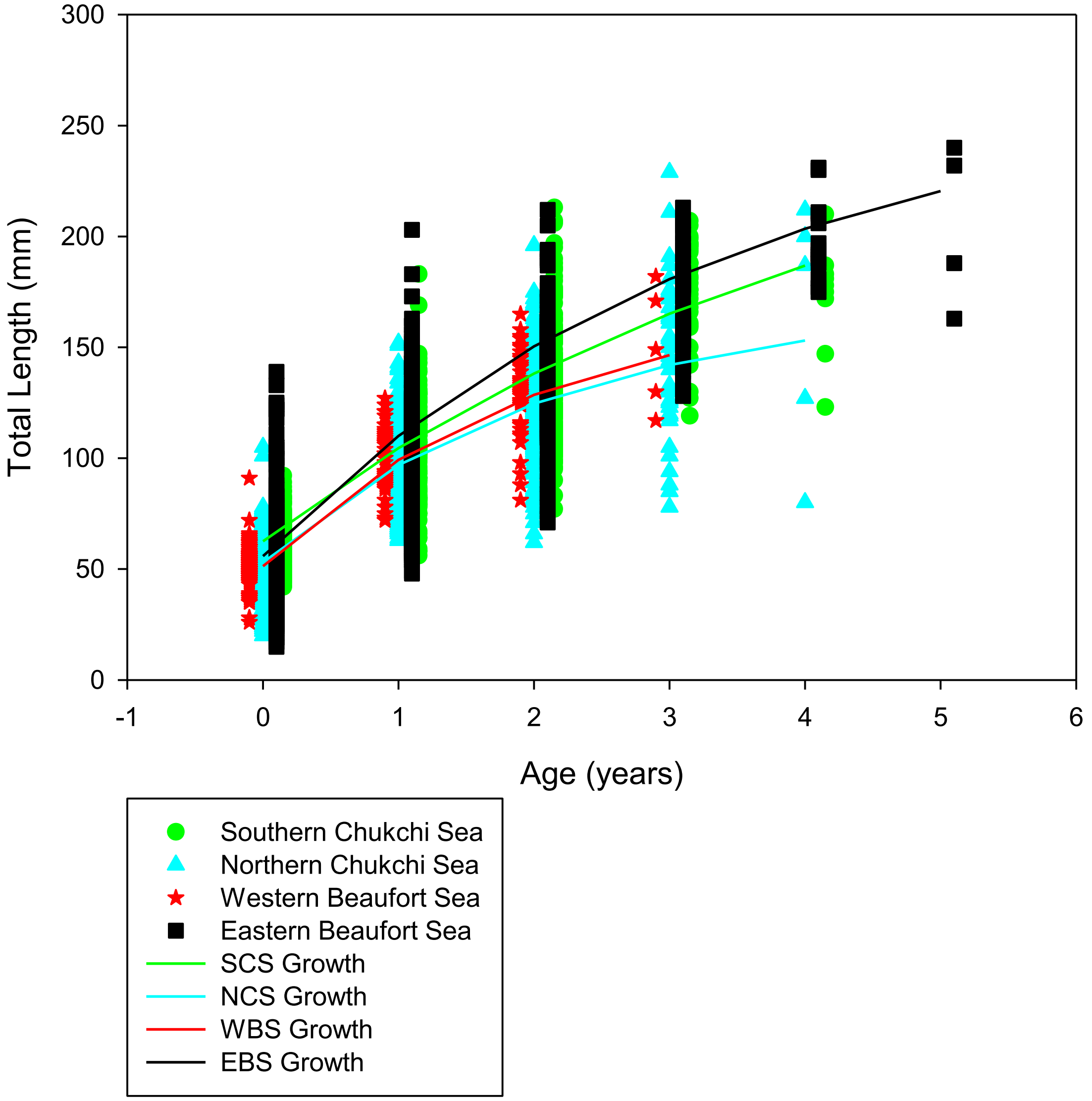
Appendix E4 Figure 2: The study area of the Chukchi and Beaufort seas. Symbols represent different cruises.



Appendix E4 Figure 3: Photo of a transversely sectioned age-5 Arctic Cod otolith. The opaque bands are enumerated to estimate age.



Appendix E4 Figure 4: Age composition by regions: Northern Chukchi Sea (NCS), Southern Chukchi Sea (SCS) regions divided at 70°N and the Western Beaufort Sea (WBS) and Eastern Beaufort Sea divided at 151.75°W



Appendix E4 Figure 5: Age at length by region designated by color. Best fit growth curve based on calculated Von Bertalanffy parameters is fit to each region.

Appendix E4 Table 1: Scientific cruise listed by region, year and latitude range.

Region	Year	Latitude Range
Southern Chukchi Sea		
RUSALCA 2009	2009	65.68°−73.34°N
AKMAP 2010	2010	68.43°−69.96°N
Arctic Eis 2012	2012	68.50°−73.00°N
Northern Chukchi Sea		
WWW0902	2009	70.64°−71.30°N
WWW0904	2009	70.64°−71.49°N
WWW1003	2010	70.64°−71.98°N
RUSALCA 2009	2009	65.68°−73.34°N
AKMAP 2011	2011	70.05°−71.30°N
Arctic Eis 2012	2012	68.50°−73.00°N
Western Beaufort Sea		
Beaufish 2011	2011	155.22°− 145.08°W
Eastern Beaufort Sea		
WWW1004	2010	146.43°− 145.09°W
Beaufish 2011	2011	155.22°− 145.08°W
TB-2012-US	2012	151.1°−136.67°N
TB-2013-US	2013	151.1°−136.67°N
TB-2014-US	2014	151.1°−136.67°N

Appendix E4 Table 2: Sample size, minimum and maximum, and average total length (mm) ± standard deviation (SD) of Arctic Cod estimated for age collected by sea, then by region.

Sea	**Sample Size**	**Min Length (mm)**	**Max Length (mm)**	**Avg Length (mm)**
Chukchi Sea	1506	20	229	96 ±38
Beaufort Sea	1203	15	240	92 ±45
Region				
Southern Chukchi Sea	**481**	42	213	105 ±41
Age-0	163	42	92	62 ±11
Age-1	140	56	183	105 ±22
Age-2	136	77	213	135 ±28
Age-3	33	119	207	176 ±23
Age-4	9	123	210	173 ±25
Northern Chukchi Sea	**1025**	20	229	91 ±35
Age-0	345	20	105	53 ±12
Age-1	387	63	152	98 ±17
Age-2	245	62	196	124 ±22
Age-3	43	78	229	144 ±33
Age-4	5	80	212	161 ±56
Western Beaufort Sea	**253**	26	182	77 ±36
Age-0	158	26	91	52 ±8
Age-1	40	72	127	100 ±15
Age-2	50	81	165	129 ±17
Age-3	5	117	182	150 ±27
Eastern Beaufort Sea	**950**	15	240	96 ±46
Age-0	337	15	139	49 ±21
Age-1	325	48	203	100 ±23
Age-2	224	71	212	137 ±23
Age-3	46	128	213	165 ±22
Age-4	14	175	231	198 ±18
Age-5	4	163	240	206 ±37

Appendix E4 Table 3: Results of Dunn's multiple comparison determining significant differences in average length-at-age for five different age classes among regions.

	SCS vs NCS	**SCS vs WBS**	**SCS vs EBS**	**NCS vs WBS**	**NCS vs EBS**	**EBS vs WBS**
Age-0	$p<0.05$	$p<0.05$	$p<0.05$		$p<0.05$	$p<0.05$
Age-1		$p<0.05$	$p<0.05$			
Age-2	$p<0.05$				$p<0.05$	
Age-3[a]	$p<0.05$		$p<0.05$			
Age-4			$p<0.05$			

[a] Holm-sidak multiple comparison used for age-3 because assumption of normality met

Appendix E4 Table 4: Average growth of otoliths (millimeters), standard deviation and (sample size) by region for the southern and northern Chukchi Sea (SCS and NCS), and the western and eastern Beaufort Sea (WBS and EBS) between three ages of Arctic Cod. Growth was calculated by measuring the width of the otolith growth zone between annuli.

	Average Growth (mm) ± SD (n)		
Region	***Age 1-2***	***Age 2-3***	***Age 3-4***
SCS	0.20±0.05 (105)	0.12±0.04 (28)	0.10±0.04 (6)
NCS	0.19±0.05 (192)	0.11±0.05 (25)	0.11±0.05 (3)
WBS	0.21±0.05 (54)	0.13±0.04 (5)	
EBS	0.23±0.06 (243)	0.15±0.05 (54)	0.11±0.03 (17)

Appendix E4 Table 5: Summary results of the Kruskal-Wallis (H) one-way ANOVA to determine differences in annual growth of otoliths between ages 1-2, ages 2-3, and ages 3-4 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

	Region					
Growth	SCS vs NCS	SCS vs WBS	SCS vs EBS	NCS vs WBS	NCS vs EBS	EBS vs WBS
Age 1-2	$p<0.05$		$p<0.05$		$p<0.05$	
Age 2-3	$p<0.05$		$p<0.05$			
Age 3-4			$p<0.05$		$p<0.05$	

Appendix E4 Table 6: Sample size (n) and average growth of otoliths (thousandths of millimeters) as measured using the width of the otolith growth zone between age-1 age-2 of Arctic Cod collected in the Eastern Beaufort Sea (EBS) for years 2010-2014.

Eastern Beaufort Sea growth between age-1 and age-2

Year	n	mean
2010	9	0.229
2011	19	0.201
2012	98	0.237
2013	45	0.244
2014	72	0.203

Appendix E4 Table 7: Results of the one-way ANOVA to determine differences in annual growth of otoliths between age-1 and age-2 from the Eastern Beaufort Sea for years 2010-2014. Subsequent pairwise multiple comparisons were conducted using the Holm-Sidak method with alpha level α=0.05*.

ANOVA Growth Between Ages 1-2

Source of Variation	df	SS	MS	F	p-value
Between Groups	4	0.0759	0.019	5.82	**<0.001**
Residual	238	0.776	0.00326		
Total	242	0.852			
Pairwise Test			**Difference of Means**	**t**	**p**
2010 vs 2011			0.0278	1.202	0.852
2010 vs 2012			0.0082	0.411	0.898
2010 vs 2013			0.0156	0.748	0.912
2010 vs 2014			0.0255	1.262	0.753
2011 vs 2012			0.0360	2.512	0.085
2011 vs 2013			0.0434	2.777	*0.046
2011 vs 2014			0.0023	0.156	0.876
2012 vs 2013			0.0074	0.722	0.852
2012 vs 2014			0.0337	3.799	*0.002
2013 vs 2014			0.0411	3.787	*0.002

Appendix E4 Table 8: Calculated von Bertalanffy parameters by sea and region. Von Bertalanffy parameters including L_∞ (the length the average fish reaches asymptotic length), K, (the constant rate of increase in length of the fish) and t_0 (theoretical age when length is 0).

Sea	**L∞ (mm)**	**K**	**t0**
Chukchi	218	0.30	-0.98
Beaufort	269	0.25	-0.83
Region			
Southern Chukchi Sea	275	0.22	-1.17
Northern Chukchi Sea	172	0.46	-0.8
Western Beaufort Sea	175	0.49	-0.71
Eastern Beaufort Sea	271	0.29	-0.8

Appendix A

Table A-1: Results of the Kruskal-Wallis (H) one way ANOVA ($p < 0.05$) to test for differences in average fish length (mm) at age-0 by region. Subsequent pairwise analyses reported as Dunn's (Q) method.

Kruskal-Wallis One Way ANOVA Age-0

Region	N	Mean	H	p
			136.968	<0.001
SCS	163	62		
NCS	345	53		
WBS	158	52		
EBS	337	49		

Pairwise Test for Age-0	**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS	321.66	11.638	p<0.05
SCS vs WBS	223.45	6.909	p<0.05
SCS vs NCS	195.92	7.116	p<0.05
NCS vs EBS	125.74	5.667	p<0.05
NCS vs WBS	27.53	0.989	NS
WBS vs EBS	98.21	3.516	p<0.05

Table A-2: Results of the Kruskal-Wallis (H) one way ANOVA to test for differences in average length at age-1 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

Kruskal-Wallis One Way ANOVA Age-1						
Region	N	Mean	H	p		
			15.361	0.002		
SCS	140	105				
NCS	386	98				
WBS	40	100				
EBS	325	100				
Pairwise Test for Age-1				**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS				97.49	3.840	p<0.05
SCS vs WBS				82.22	3.160	p<0.05
SCS vs NCS				54.13	1.173	NS
NCS vs EBS				43.36	1.014	NS
NCS vs WBS				28.09	0.651	NS
WBS vs EBS				15.27	0.788	NS

Table A-3: Results of the Kruskal-Wallis (H) one way ANOVA to test for differences in average length at age-2 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

Kruskal-Wallis One Way ANOVA Age-2						
Region	N	Mean	H	p		
			45.186	< 0.001		
SCS	136	134				
NCS	245	124				
EBS	224	137				
WBS	50	129				
Pairwise Test for Age-2				**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS				44.52	2.164	NS
SCS vs WBS				22.02	0.703	NS
SCS vs NCS				71.89	3.553	p<0.05
NCS vs EBS				116.40	6.654	p<0.05
NCS vs WBS				49.87	1.698	NS
WBS vs EBS				66.53	2.248	NS

Table A-4: Results of the one way ANOVA to test for differences in average length at age-3 by region. Subsequent pairwise analyses reported using the Holm-Sidak method.

ANOVA Age-3	**N**	**Mean**	**F**	**p-value**
Between Regions			9.722	<0.001
SCS	33	176		
NCS	43	144		
WBS	5	149		
EBS	46	165		

Pairwise Test for Age-3	**Difference of Means**	**t**	**p<0.05**
SCS vs EBS	10.10	1.667	p<0.05
SCS vs WBS	25.72	2.017	NS
SCS vs NCS	31.35	5.099	p<0.05
NCS vs EBS	21.5	3.770	NS
NCS vs WBS	5.63	0.449	NS
WBS vs EBS	15.61	1.248	NS

Table A-5: Results of the Kruskal-Wallis (H) one way ANOVA (p < 0.05) to test for differences in average length at age-4 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

Kruskal-Wallis One Way ANOVA Age-4				
Region	N	Mean	H	p
			6.357	0.042
SCS	9	173		
NCS	5	161		
EBS	14	198		

Pairwise Test for Age-4	**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS	8.69	2.474	p<0.05
EBS vs NCS	5.35	1.248	NS
NCS vs SCS	3.34	0.729	NS

Table A-6: Results of the Kruskal-Wallis (H) one-way ANOVA to determine differences in annual growth of otoliths between ages 1-2 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

Kruskal-Wallis One Way ANOVA growth between 1-2 years							
Region	N	Median	H	p			
			32.169	< 0.001			
SCS	105	0.204					
NCS	192	0.190					
WBS	54	0.212					
EBS	243	0.222					
Pairwise Test					**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS					58.792	2.933	p<0.05
SCS vs WBS					28.427	0.989	NS
SCS vs NCS					33.331	1.600	NS
NCS vs EBS					92.123	5.559	p<0.05
NCS vs WBS					61.758	2.336	NS
WBS vs EBS					30.365	1.176	NS

Table A-7: Results of the Kruskal-Wallis one-way ANOVA to determine differences in annual growth of otoliths between ages 2-3 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

Kruskal-Wallis One Way ANOVA growth between 2-3 years							
Region	N	Median	H	p			
			16.758	< 0.001			
SCS	28	0.108					
NCS	25	0.104					
WBS	5	0.123					
EBS	54	0.142					
Pairwise Test					**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS					20.58	2.722	p<0.05
SCS vs WBS					7.732	0.490	NS
SCS vs NCS					9.13	1.021	NS
NCS vs EBS					29.71	3.782	p<0.05
NCS vs WBS					16.86	1.060	NS
WBS vs EBS					12.85	0.847	NS

Table A-8: Results of the Kruskal-Wallis one-way ANOVA to determine differences in annual growth of otoliths between ages 3-4 by region. Subsequent pairwise analyses reported using the Dunn's (Q) Method.

One Way ANOVA growth between 3-4 years				
Region	N	Median	H	p
			16.758	< 0.001
SCS	6	0.108		
NCS	3	0.104		
EBS	17	0.142		

Pairwise Test	**Difference of Ranks**	**Q**	**p<0.05**
SCS vs EBS	20.58	2.722	p<0.05
SCS vs WBS	7.73	0.490	NS
SCS vs NCS	9.13	1.021	NS
NCS vs EBS	29.71	3.782	p<0.05
NCS vs WBS	16.86	1.060	NS
WBS vs EBS	12.85	0.847	NS

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

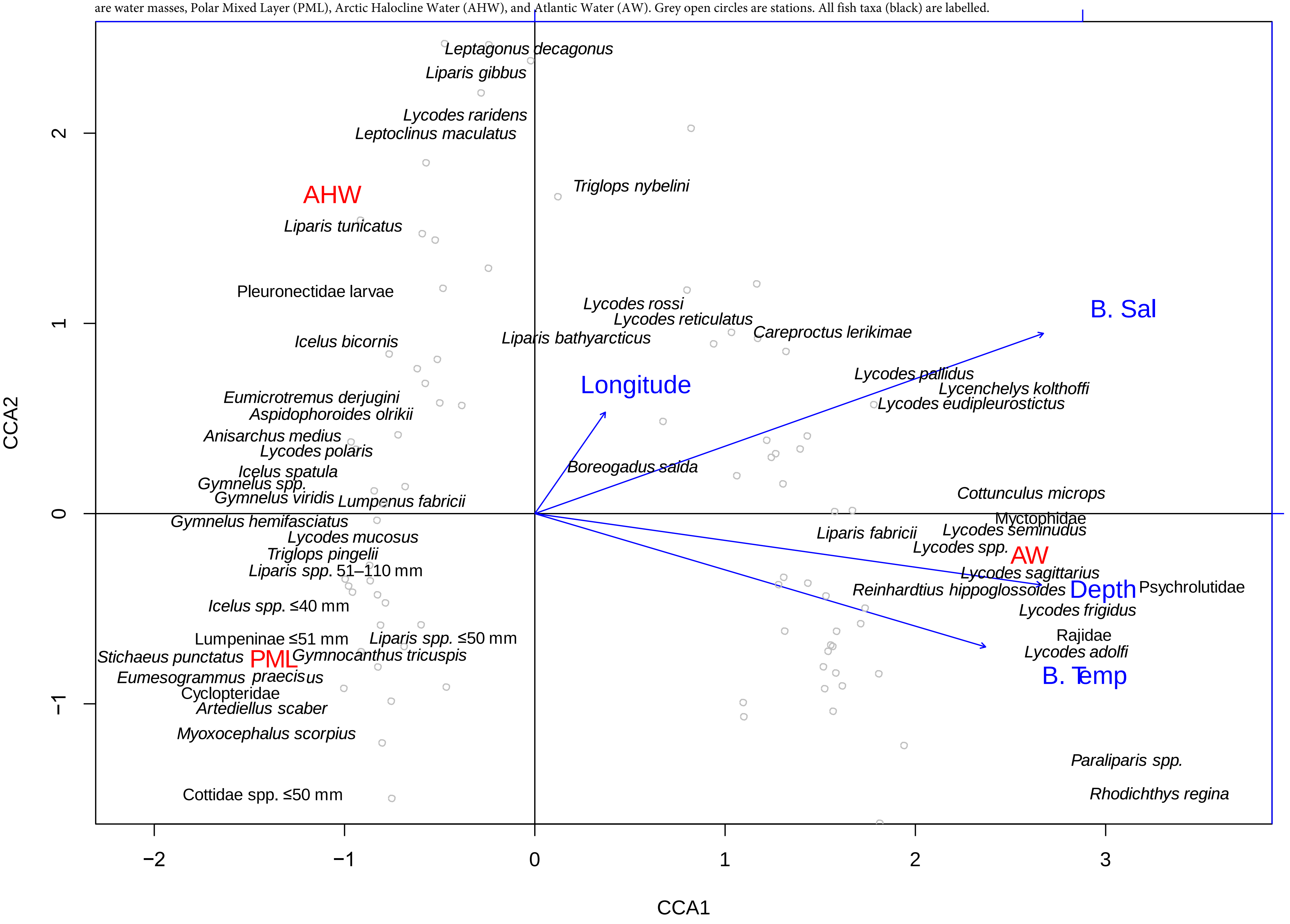
BOEM 2017-034 Appendix E5

CCA Ordination Relating Demersal Fish Abundance in Beam Trawls During 2013 and 2014

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Appendix E5 Figure 1. Canonical correspondence analysis (CCA) ordination relating demersal fish abundance in beam trawls during 2013 and 2014 to selected environmental variables at 89 stations. Continuous environmental variables (blue) denoted by vectors are bottom depth (Depth), bottom salinity (B. Sal), bottom temperature (B. Temp), and longitude. Categorical variables (red) are water masses, Polar Mixed Layer (PML), Arctic Halocline Water (AHW), and Atlantic Water (AW). Grey open circles are stations. All fish taxa (black) are labelled.



US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix F

Diet of Arctic Cod in the US Beaufort Sea

Author
Ben Gray

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Table of Contents

Diet of Arctic Cod in the US Beaufort Sea

Introduction

Arctic Cod is one of the most abundant forage fishes throughout its distribution (Lowry and Frost 1981; Welch et al. 1992; Mecklenburg et al. 2011) and has consistently dominated trawl survey catches in the western Arctic (Barber et al. 1997; Norcross et al. 2013). It is an important prey species for marine mammals, seabirds, and other fishes (Lowry and Frost 1981; Welch et al. 1992; Walkusz et al. 2011), linking lower trophic levels to higher level predators (Welch et al. 1992). Arctic Cod is primarily regarded as an open-water, pelagic, ice-associated forage fish (Lønne and Gullikson 1989) but is found throughout the water column in ice-free areas as well (Walkusz et al. 2011; Norcross et al. 2013). Although past research has documented the ecological importance of this species, further study is needed to document its role in Arctic food webs (Walkusz et al. 2011).

Likely owed to its ubiquity throughout high-latitude marine systems, Arctic Cod is considered to be one of the dominant zooplanktivores in Arctic food webs (Welch et al. 1992; Walkusz et al. 2011). It is typically a pelagic predator (Lowry and Frost 1981) that feeds on calanoid copepods, ice-associated amphipods, hyperiid amphipods, euphausiids, and other fishes (Lowry and Frost 1981; Craig et al. 1982; Coyle et al. 1997; Rand et al. 2013). However, its food habits are flexible, which allows Arctic Cod to inhabit shallower regions (Bluhm and Gradinger 2008) and to feed on bottom-associated (i.e., benthic and epibenthic) prey such as amphipods, cumaceans, and mysids (Craig et al. 1982; Coyle et al. 1997; Cui et al. 2012).

In this study, we examined variability in Arctic Cod diet composition using fish collected over the 2012 (TB-2012-US), 2013 (TB-2013-US), and 2014 (TB-2014-US) Transboundary cruises using both demersal and pelagic trawling methods. Sampling was conducted from 20 to 100 m on the shelf and 200 to 1000 m on the slope, the two depth strata used for statistical analysis. Transects from TB-2012-US, TB-2013-US, and TB-2014-US were binned into regions based on their geographic locations, which allows for a spatial analysis as the western region was only sampled in 2012 and the eastern regions were sampled in both 2013 and 2014. Transects are grouped and presented from the most western region, B1-B2-BX (sampled in 2012) to two eastward transect groups, A4-A5-A6 at Camden Bay and A1-A2-TBS at the Canadian border (sampled in 2013 and 2014), to the most eastern transect group in Canadian waters, GRY-MAC at the Mackenzie River (sampled in 2013) (Figure 2.1). These strata provide for a robust interannual and spatial analysis.

Arctic Cod diet composition is expected to differ interannually (i.e., between cruise years) and by region of the water column inhabited, transect groups, and depth categories (each is a proxy for habitat-related diet differences). Both interannual variability and habitat features are known to create diet variability (Scharf et al. 2000; Renaud et al. 2012), but the degree to which they affect Arctic Cod diets has not been well described. Interannually, prey availability and the size of prey available to Arctic Cod could differ due to a variety of reasons such as variability in the timing of sea ice retreat, water mass formation, and terrestrial hydrographic conditions (Walkusz et al. 2013). These factors would, in turn, affect conditions within and between the region (transect groups) and depth categories, which could also be influenced by differences in biological productivity, prey composition, and oceanographic processes. Arctic Cod inhabiting shallower regions inshore of the shelf break may be consuming different prey, including some benthic and epibenthic prey groups absent from diet compositions further offshore.

Within the Beaufort Sea study regions and depth categories, ontogenetic shifts in diet and mouth gape size likely influence the size range of prey eaten by Arctic Cod (Werner and Gilliam 1984; Rand et al. 2013) and thus affect diet complexity. As fishes grow larger, they become more proficient at eating larger, more energetically-profitable prey (Werner and Hall 1974). Such shifts in prey use are documented in Arctic Cod populations; larval Arctic Cod consume smaller stages of calanoid copepods (Walkusz et al. 2011), while juvenile and adult Arctic Cod consume larger prey, including calanoid copepods, amphipods, mysids, and other fishes (Lowry and Frost 1981; Craig et al. 1982; Jensen et al. 1991).

Variation in Arctic Cod diet has the potential to create differences in energy flows from Arctic Cod to higher trophic level consumers. In the western Arctic, a lack of region-specific, quantitative diet data available for use in food web models (Whitehouse et al. 2014) perpetuates the gap in our ecological knowledge of this species. Comparatively less information is available regarding Arctic Cod diet compositions in the western Beaufort Sea; therefore, comprehensive diet data will be of great importance in parameterizing any food web model designed for these regions. While this study does not directly contribute to the implementation of food web models, the results enhance the current understanding of Arctic Cod ecology and provide essential data to inform food web models in the western Beaufort Sea. The objectives of this research were to determine whether Arctic Cod diet composition varied by years, regions of water column inhabitance, transect groups (i.e., regions), depth categories, and throughout ontogeny. These objectives were accomplished through statistical analyses of Arctic Cod diet composition. This information adds to our current knowledge of Arctic Cod ecology by documenting intraspecific diet variability across a large spatial scale.

Methods

Laboratory methods

Initial Arctic Cod length and weight measurements, along with all processes associated with stomach contents analysis, took place at the University of Alaska (UAF) fisheries oceanography laboratory. Arctic Cod were thawed, individually blotted with tissue paper, weighed to the nearest 0.01 g, and measured for total length in millimeters. Whole stomachs (defined as esophagus to pyloric valve) were removed, placed in petri dishes, and frozen in fresh water until examined. Stomachs were opened and prey was identified using a dissecting microscope. At 6x to 100x magnification, all recognizable prey were identified to the lowest taxonomic level using keys (Barnard 1969; Gardner and Szabo 1982; Vassilenko and Petryashov

2009) or through consultation with invertebrate specialists. Once identified, the wet weight of each prey item was recorded to the nearest 0.0001 g.

Due to the diversity of prey consumed by Arctic Cod, all identifiable prey was aggregated into course prey groups based on common taxonomic characteristics and overall contribution to diets by percent mean weight (%MW), percent mean number (%MN), and percent occurrence (%O). Taxonomically-similar groups that contributed to at least 3% of the overall diet by %MW, %MN, or %O were included as a prey category in statistical comparisons. Overall, 14 prey groups were included in this analysis: amphipods, calanoid copepods, chaetognaths, cladocerans, copepod nauplii, cumaceans, cyclopoid copepods, euphausiids, fish prey, hyperiid amphipods, isopods, mysids, ostracods, and "other prey" (Appendix F Table 1). The "other prey" group was composed of rare diet items (e.g., bivalve veligers, polychaetes, or shrimps). Unidentifiable animal fragments and tissues were removed from analyses because they could not be definitively classified as prey.

Prey items were in various stages of digestion, which was a potential source of error in determining the importance, by weight, of those prey items to Arctic Cod diet. To address this potential error, we determined average weight-at-length values of all prey taxa consumed by Arctic Cod throughout the Beaufort Sea study area (Appendix F Table 1). This was accomplished using prey count, length, and weight data from all available UAF fisheries oceanography laboratory studies that focused on Arctic Cod diet. The taxa-specific averages were then multiplied by prey counts to assign prey weights to all Arctic Cod stomachs used in this diet study.

Some prey items eaten by Arctic Cod were very small, i.e., <0.5 mm, and thus did not register a weight value on a 0.0001 g mass balance. This scenario was particularly noticeable in the diets of juvenile, i.e., <50 mm, Arctic Cod. If an individual fish ate enough of the same, small prey taxa, it was possible to develop an average weight value per individual from their combined weight in a stomach. When this was not possible, we assigned a weight to a prey item using values from peer-reviewed literature (Appendix F Table 1). These methods allowed for a more accurate representation of the importance of small prey, by weight, in juvenile Arctic Cod diet.

Diet analysis methods

Stomach contents analysis, i.e., the dissection of fish stomachs and identification of resulting prey items, forms the base of this diet comparison study. This method was chosen because it is useful in understanding trophic linkages within natural ecosystems (Pinnegar et al. 2003), and it offers greater taxonomic resolution than other methods, including analysis of stable isotopes or fatty acids (Kolts et al. 2013). Fish diet compositions can be quantified in many ways (Hyslop 1980; Baker et al. 2014). Here we use a combination of gravimetric, numeric, and occurrence-based calculations, along with univariate and multivariate statistical methods, to characterize and compare Arctic Cod diets.

To characterize Arctic Cod diets, we chose three diet indices: percent mean weight (%MW), percent mean number (%MN), and percent occurrence (%O). Percent mean weight was calculated as: $\%MW_i = 1/P \times (\sum[W_{ij}/\sum W_{ij}]) \times 100$, where $\%MW_i$ is the percent mean weight of prey *i* consumed by a predator, W_{ij} is the weight of prey *i* in the stomach of a single predator *j*, and ΣW_{ij} is the sum of all prey weights in the stomach of a single predator *j*. The sums of this calculation for each prey item over the entire sample are then divided by the number of fish with food in their stomachs (P). Percent mean number (%MN) was calculated similarly. Percent occurrence (%O) was calculated as: $\%O=[O_i/P] \times 100$, where %O is defined as the occurrence of a prey group *i* divided by the sum of non-empty stomachs (ΣP).

Each diet index offers different information about fish diet composition within a category of interest (e.g., region, size class, etc.). Percent mean weight values can be used as an indicator of the energetic importance of prey types to a fish population (Hyslop 1980; Chipps and Garvey 2007). Alternatively, %MN gives information about the numerical importance of prey in the diets, and %O indicates the percentage of individuals in the sampled population that ate a specific prey type (Hyslop 1980; Chipps and Garvey 2007; Baker et al. 2014). While useful in characterizing fish diets, each of these methods have been criticized. Percent mean weight can, at times, can inflate the importance of rarer, larger, and less-digested prey (e.g., fish), whereas %MN can overvalue the importance of numerically-abundant, but smaller prey (e.g., copepod nauplii; Hyslop 1980; Chipps and Garvey 2007). Similarly, percent occurrence documents the frequency that a particular prey item was eaten by a population but gives no indication as to that prey's importance to the population (Chipps and Garvey 2007). Because of these issues, compound indices that take into account %MW, %MN, and %O (e.g., the index of relative importance, IRI) have been proposed as methods to standardize fish diet characterizations (Hyslop 1980; Cortes 1997). However, compound methods are criticized for being non-additive indices that lack biological interpretability (Chipps and Garvey 2007). Additionally, compound indices are affected by study designs that use different taxonomic prey resolutions (Hansson 1998). Because of these issues, we chose to use %MW, %MN, and %O, rather than a compound index, to characterize Arctic Cod diet throughout the study area. Although there is controversy with %MW (Baker et al. 2014), this index was used in statistical comparisons because %MW is most useful in indicating prey energetic importance in the absence of the actual energy content of major prey types (Chipps and Garvey 2007).

Experimental strata and data analyses

Strata chosen for Arctic Cod diet comparisons included cruise (i.e., year), transect group, and depth category; determining whether or not to further stratify by gear type and size class required multivariate data analysis methods. The cruise category included three levels: TB-2012-US, TB-2013-US, and TB-2014-US; transect groups, four levels: B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC; and depth category included two levels: $\leq$100 m or >100 m. Cruise year was used to facilitate interannual comparisons, transect group data provided regionally similar combinations of transects to compare within or between other transect groups, and depth categories were created for across shelf break comparisons of Arctic Cod diets. Stratification by gear and size class was determined using non-parametric analysis of variance (hereafter, NP MANOVA). NP MANOVA is a permutation-based version of MANOVA that uses a Bray-Curtis distance matrix to partition variance; it is considered a robust alternative to parametric

MANOVA and parametric ordination methods (Legendre and Anderson 1999). We chose this method because the diet data sets contained a multitude of zeroes, which made it difficult to meet the distributional assumptions of parametric MANOVA (Quinn and Keough 2002). Using the function adonis in the vegan package of R, version 2.15.2, NP MANOVA was used to simultaneously compare all prey eaten by bottom and mid-water Arctic Cod to determine whether stratification by water column inhabitance was necessary. Similarly, NP MANOVA was used to develop Arctic Cod size classes by comparing diet compositions between 10 mm increments (e.g., 20 mm vs. 30 mm) using all diet data available. If there was a significant difference between a 10 mm increment, a size class was made at this break. If there was not a significant difference between two 10 mm increments, a NP MANOVA model that compared multiple 10 mm increments (e.g., 20 mm vs. 30 mm vs. 40 mm, etc.) was applied with increments being added until a significant difference in diet compositions was identified. A size class was then made from the first 10 mm bin in the comparison up to the bin previous to the one that created the significant difference. These analyses provided evidence in favor of stratifying between bottom and mid-water fish (hereafter, demersal and pelagic, respectively) and for creating size classes for both demersal (39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm) and pelagic Arctic Cod (39 mm, 40–59 mm, and ≥60 mm). To facilitate comparisons between demersal and pelagic Arctic Cod, we qualitatively standardized size classes at ≤40 mm, 41–50 mm, 51–60 mm, and 61–132 mm, with 132 mm being the largest individual Arctic Cod collected from pelagic trawling gear.

The same NP MANOVA method was used for all multivariate comparisons between strata, but univariate methods, i.e., one-way analysis of variance (ANOVA) or a Kruskal-Wallis one-way ANOVA, were needed to determine which of the 14 prey groups were responsible for significant differences in Arctic Cod diet compositions. For comparisons with larger sample sizes, we used a one-way ANOVA, along with Tukey's method of multiple comparisons to determine which prey groups explained the significant difference. This method was deemed appropriate because ANOVA is robust to the assumptions of normality and equal variance when sample sizes are large (e.g., n>30). For comparisons involving smaller sample sizes, a Kruskal-Wallis one-way ANOVA was considered more appropriate because its assumptions of normality and equal variance are more relaxed. When it was necessary to use a Kruskal-Wallis one-way ANOVA, corresponding %O values of prey taxa were used to approximate the size class responsible for the significant difference in prey use. Because ontogenetic shifts were of interest, only key comparisons of adjacent size classes from the Tukey matrix or %O values from the Kruskal-Wallis tables were presented here. The ANOVA models and Tukey multiple comparisons were conducted in R commander version 1.9–6. Kruskal-Wallis one-way ANOVA models were conducted in SigmaPlot Version 12.0 (Systat Software, Inc. 2011).

Cumulative prey curves were generated to determine how adequately Arctic Cod diets were described using our processed stomach samples. This method plots the occurrence of novel prey against a running total of examined stomachs (Chipps and Garvey 2007). Fish diet diversity is said to be adequately described when the curve is close to an asymptote. Cumulative prey curves were constructed using the species-accumulation plot function in PRIMER v6 multivariate statistics package. Following the methods outlined in Hallett and Daley (2011), we randomized the Arctic Cod stomach contents data across 999 permutations using a bootstrap method that removed any biases associated with plotting the accumulation of prey types by sample order. Cumulative prey curves were calculated at both low and coarse taxonomic levels to determine the effect of aggregating lower-level taxonomic prey into coarse groups. Cumulative prey curves were generated separately for demersal and pelagic Arctic Cod by size classes and transect groups. This allowed for examining any major trends across all transect groups and size classes.

To investigate the overall distribution of prey sizes in Arctic Cod diet, all intact prey items were measured to the nearest 0.5 mm and divided into four size classes: small (<5 mm), medium (5–9.5 mm), large (10–19.5 mm), and extra-large (≥20 mm). The percent, by number of small, medium, large, and extra-large prey sizes in Arctic Cod diets were then plotted against the corresponding fish size classes to identify overall patterns in prey consumption by Arctic Cod.

To begin our analyses, we completed an initial assessment of diet variability for both demersal and pelagic Arctic Cod, by transect groups and size classes, to provide an overview of diet differences. This was followed by finer-scaled analyses by years, regions of water column inhabitance, transect groups, depth categories, and size classes. These analyses included a characterization of demersal and pelagic Arctic Cod diets by %MW, %MN, and %O, pooling all other strata into transect groups and then size classes. Cumulative prey curves were then generated for both demersal and pelagic Arctic Cod to determine how well our sample sizes described diets within transect groups and size classes as well as to measure diet diversity. Further, an analysis of percent number of prey size in the diets of Arctic Cod at our specific size classes was included for the overall characterization. It should be noted that some comparisons by all strata used very small sample sizes. In these cases, it is possible that Arctic Cod diets may not have been adequately described. Because little is known about how environmental characteristics affect Arctic Cod diets, we chose to include all comparisons between years, regions of water column inhabitance, transect groups, depth categories, and size classes at our discretion.

Results

Initial diet characterization and analyses by transect groups

A total of 1,439 Arctic Cod with identifiable prey in their stomachs were used in diet comparisons. Overall analysis by NP MANOVA indicated that demersal Arctic Cod diet compositions differed significantly by cruise (years), transect groups, depth categories, and size classes considered as separate strata or as interactions between strata (Appendix F Table 2). Pelagic Arctic Cod diet compositions differed significantly by cruise (year), transect groups, and size classes when considered as separate strata. While depth categories were not a significant factor, both interactions involving depth categories were significant (Appendix F Table 3).

Our initial characterization of Arctic Cod diets by transect groups indicated prey taxa varied in importance by %MW, %MN, and %O for demersal (Appendix F Table 4) and pelagic (Appendix F Table 5) fish alike. Throughout transect groups, major contributors to demersal and pelagic Arctic Cod diets included calanoid copepods, hyperiid amphipods, and chaetognaths. Demersal fish consumed more hyperiid amphipods and chaetognaths by each index (Appendix F Table 4), and pelagic fish consumed more calanoid copepods by each index (Appendix F Table 3). Of the calanoid copepods identified to species, *Calanus glacialis*, *C. hyperboreus*, and *Eurytemora* spp. contributed most notably to Arctic Cod diets in the B1-B2-BX, A1-A2-TBS, and GRY-MAC transect groups, respectively. *Themisto libellula* was the most important hyperiid amphipod and contributed most to demersal and pelagic Arctic Cod diets in A4-A5-A6 and the demersal fish diet at GRY-MAC (Appendix F Tables 4 and 5). Very small prey (<0.5 mm) such as cladocerans, copepod nauplii, and cyclopoid copepods were, at times, large contributors to pelagic Arctic Cod diet by %MN and %O but not by %MW (Appendix F Tables 4 and 5).

In general, the cumulative prey curves generated for demersal (Appendix F Figures 1A and 1B) and pelagic (Appendix F Figures 2A and 2B) Arctic Cod within transect groups each attained an asymptote faster (i.e., diets were better described) using coarse taxonomic prey groups (Appendix F Figures 1B and 2B) than using all taxa consumed (Appendix F Figures 1A and 2A). Additionally, our analysis showed that demersal Arctic Cod (Appendix F Figure 1) consumed more unique prey taxa and groups than pelagic conspecifics (Appendix F Figure 2). Consequently, characterization of demersal Arctic Cod diet within transect groups required a greater sample size of stomachs than needed for pelagic conspecifics. Demersal Arctic Cod in the A4-A5-A6 transect group showed the most diet diversity in terms of cumulative prey taxa (Appendix F Figure 1A) and prey groups (Appendix F Figure 1B) consumed. Demersal Arctic Cod diet in the GRY-MAC transect group was not as well described as for other transect groups as indicated by the cumulative prey curve not reaching an asymptote (Appendix F Figure 1). Because pelagic conspecifics consumed less diverse diets, fewer stomach content samples per transect group were needed to adequately describe diet, regardless of how prey were grouped (Appendix F Figure 2). Pelagic fish in A1-A2-TBS consumed the most diverse diet followed by individuals in transect groups A4-A5-A6, B1-B2-BX, and GRY-MAC. All pelagic fish diet cumulative prey curves attained asymptotes except for the A4-A5-A6 transect group (Appendix F Figure 2). It is important to note that rare prey taxa and rare prey groups were included in these analyses. If these prey were removed, cumulative prey curves for both the transect groups and size classes would likely asymptote at a smaller stomach sample size, meaning Arctic Cod diets would be more adequately described by fewer stomachs.

Analysis by one-way ANOVA of demersal and pelagic Arctic Cod diets within transect groups indicated that demersal Arctic Cod diet compositions differed among 13 of 14 prey groups throughout all transect groups (Appendix F Table 6), while pelagic Arctic Cod diet compositions were different among 5 of 8 prey groups throughout all transect groups (Appendix F Table 7). Subsequent analysis by Tukey's method of multiple comparisons showed that in each transect group, demersal Arctic Cod consumed specific prey groups in great enough %MW to create significant differences with conspecifics in all other transect groups. Relative to all other transect groups, demersal Arctic Cod consumed significantly more chaetognaths in B1-B2-BX, amphipods, mysids, and ostracods in A4-A5-A6, calanoid copepods in A1-A2-TBS, and cladocerans and euphausiids in GRY-MAC (Appendix F Table 6, Figure 3). All other significant differences in prey groups varied between transect groups for demersal fish (Appendix F Table 6, 5 Figure 3). Similarly, pelagic Arctic Cod in the B1-B2-BX transect group consumed significantly more chaetognaths, while A4-A5-A6 pelagic Arctic Cod consumed significantly more hyperiid amphipods (Appendix F Table 7, Figure 4). Other significant differences were due to differences in cladocerans (consumed most by pelagic Arctic Cod in A1-A2-TBS and GRY-MAC), copepod nauplii (A1-A2-TBS), and cyclopoid copepods (A1-A2-TBS; Appendix F Table 7, Figure 4). The ANOVA model for pelagic Arctic Cod by transect groups found a significant difference in calanoid copepods between transect groups. However, Tukey's method of multiple comparisons found only a weak significance between pelagic Arctic Cod diet in groups A1-A2-TBS and GRY-MAC (Appendix F Table 7, Figure 4).

Initial diet characterization and analyses by size classes

We examined the size classes by cumulative prey curves before examining by one-way ANOVA and %N size of prey by size class analysis. Similar to the transect group analysis, cumulative prey curves for demersal (Appendix F Figures 5A and 5B) and pelagic (Appendix F Figures 6A and 6B) Arctic Cod diets reached an asymptote sooner when prey taxa were aggregated into taxonomically-coarse prey groups, although it was only a slight difference for pelagic Arctic Cod (Appendix F Figure 6). Demersal Arctic Cod diet was again more varied than pelagic Arctic Cod diet (Appendix F Figures 5 and 6); however, cumulative prey curves for demersal and pelagic Arctic Cod at lengths ≤39 mm appeared to asymptote at a similar stomach sample size regardless of region of water column inhabitance or taxonomic clarity of the prey curves (Appendix F Figures 5 and 6). Of the demersal size classes, 80–169 mm fish showed the most diet diversity (Appendix F Figure 5). All cumulative prey curves except for that of 60–79 mm and 170–240 mm demersal fish attained an asymptote with less than 100 stomachs when considering taxonomically-coarse prey groups (Appendix F Figure 5B). For the pelagic size classes, both ≤39 mm and 40–59 mm fish attained an asymptote in less than 20 stomachs (Appendix F Figure 6) regardless of the taxonomic clarity of the curves. Cumulative prey curves for pelagic Arctic Cod ≥60 mm did not reach an asymptote; consequently, this size class may have been underrepresented by our sample sizes.

Size class comparisons by ANOVA and %N of prey size in diet indicated strong differences in demersal and pelagic Arctic Cod diet compositions when considering both prey groups and prey sizes consumed. Demersal Arctic Cod diet compositions were significantly different by all 14 prey groups (Appendix F Table 8), and five prey groups were significantly different between pelagic Arctic Cod diets (Appendix F Table 9). Although significantly different by the overall ANOVA of demersal Arctic Cod diet, euphausiids, mysids, ostracods, and other prey did not have significant differences between adjacent size classes as determined by Tukey's method of multiple comparisons (Appendix F Table 8). In both the demersal (Appendix F Figure 7) and pelagic (Appendix F Figure 8) prey size analyses, as Arctic Cod body size increased, differences in diets were driven by a general decline in smaller prey eaten and a subsequent increase in larger prey eaten. This pattern was observed in the ANOVA analyses for both demersal (Appendix F Table 8) and pelagic (Appendix F Table 9) Arctic Cod. For demersal Arctic Cod, the smallest prey, i.e., cladocerans, copepod nauplii, and cyclopoid copepods (each <0.5 mm) were eaten in largest amounts by ≤39 mm fish (Appendix F Figure 9). Similar size pelagic Arctic Cod consumed mostly cladocerans (Appendix F Figure 10) and other prey (mostly <0.5 mm bivalve veligers). In both demersal and pelagic analyses, 40–49 mm Arctic Cod consumed the highest %MW of calanoid copepods (Appendix F Figures 9 and 10). As pelagic fish increased in size (≥60 mm), larger prey such as chaetognaths and hyperiid amphipods were consumed in higher amounts (Appendix F Figure 10). Similarly, for larger demersal Arctic Cod, chaetognaths and hyperiid amphipods, along with amphipods, cumaceans, and fish prey created significant differences in diets (Appendix F Table 8). Cumaceans and chaetognaths were consumed in highest amounts by 60–79 mm fish, hyperiid amphipods were consumed in highest amounts by 80–169 mm fish, and amphipod and fish prey were consumed in highest amounts by 170–240 mm fish (Appendix F Figure 9).

Comparisons within the B1-B2-BX transect group (2012 only)

NP MANOVA analysis of demersal Arctic Cod diet composition within the B1-B2-BX transect group indicated significant differences within ≤100 m and >100 m depth categories (Df=5, F=8.545–11.352, p<0.001) and between depth strata by size classes (Df=11, F=9.644, p<0.001). Subsequent analyses by Kruskal-Wallis one-way ANOVA of diet compositions within the ≤100 m group (Appendix F Table 10), within the >100 m group (Appendix F Table 11), and between ≤100 m and >100 m groups (Appendix F Table 12) all showed significant differences due to calanoid copepods, chaetognaths, cumaceans, and hyperiid amphipods. This varied slightly by depth category, with ≤100 m Arctic Cod diets also being significantly different by cumaceans and ostracods (Appendix F Table 10) and Arctic Cod diets within both depths also significantly differing due to fish prey (Appendix F Tables 10 and 11). In general, calanoid copepods were highest by %O in diets of <80 mm Arctic Cod and occurred in slightly higher amounts in >100 m depths. Chaetognaths occurred mostly in 60–169 mm Arctic Cod diets with a slightly higher occurrence in ≤100 m depths, cumaceans were eaten mostly by 60–79 mm Arctic Cod in ≤100 m depths, fish prey was eaten in higher amounts by 80–240 mm Arctic Cod in ≤100 m depths, and hyperiid amphipods in slightly higher amounts by 80–240 mm Arctic Cod in >100 m depths (Appendix F Tables 10–12).

There were no fish collected by mid-water gears in ≤100 m depths in the B1-B2-BX transect. Within the sampled >100 m depth category, NP MANOVA found Arctic Cod diet compositions to be significantly different between size classes (Df=2, F=6.5069, p=0.002). Further analysis by Kruskal-Wallis one-way ANOVA found Arctic Cod diet compositions significantly differed by calanoid copepods, copepod nauplii, cyclopoid copepods, hyperiid amphipods, ostracods, and other prey (Appendix F Table 13). Percent occurrence analysis showed copepod nauplii, cyclopoid copepods, ostracods, and other prey (bivalve veligers) were eaten nearly exclusively by ≤39 mm Arctic Cod, while hyperiid amphipods occurred only in ≥60 mm Arctic Cod (Appendix F Table 13). Calanoid copepods were higher in %O in the diets of Arctic Cod <60 mm (Appendix F Table 13).

Demersal and pelagic Arctic Cod consumed significantly different diets within >100 m depths (Df=7, F=8.6266, p<0.001). Further analysis by Kruskal-Wallis one-way ANOVA determined that their diets differed due to calanoid copepods, chaetognaths, copepod nauplii, hyperiid amphipods, and other prey (Appendix F Table 14). Of these prey types, calanoid copepods were taken in overall higher amounts by all size classes of pelagic Arctic Cod, and chaetognaths were eaten in slightly higher amounts by 51–132 mm demersal Arctic Cod. Copepod nauplii, cyclopoid copepods and other prey (bivalve veligers) were eaten nearly exclusively by pelagic ≤40 mm Arctic Cod, while hyperiid amphipods occurred in highest amounts in 61–132 mm pelagic fish (Appendix F Table 14).

Comparisons within the A4-A5-A6 transect group (2013–2014)

Within the A4-A5-A6 transect group, only bottom trawl comparisons were possible due to very small sample sizes of pelagic Arctic Cod. In 2013, there were not enough stomachs available to analyze demersal Arctic Cod diets in the ≤100 m depths. There were enough stomachs for analysis within the >100 m depths, however, NP MANOVA did not find a significant difference among size classes (Df=2, F=0.8995, p=0.586). For 2014 Arctic Cod, there was no significant difference between diet compositions in the ≤100 m depth category (Df=4, F=1.9298, p=0.100); however, NP MANOVA did indicate a significant difference between Arctic Cod diet compositions in >100 m depths (Df=5, F=4.9540, p<0.001) and between ≤100 m and >100 m depths (Df=10, F=4.6911, p<0.001). Further analysis by Kruskal-Wallis one-way ANOVA found that diets of Arctic Cod (by size classes) within the >100 m (Appendix F Table 15) and between ≤100 m and >100 m depths (Appendix F Table 16) were significantly different due to calanoid copepods, copepod nauplii, cyclopoid copepods, and hyperiid amphipods. Copepod nauplii and cyclopoid copepods were highest in occurrence in ≤49 mm Arctic Cod diets, with higher %O in >100 m depths; calanoid copepods were high in %O throughout all size groups but slightly higher in ≤100 m, and hyperiid amphipods occurred in higher amounts in the diets of 50–169 mm Arctic Cod in >100 m depths (Appendix F Tables 15 and 16).

Interannual comparisons were only possible between 2013 and 2014 Arctic Cod diets for size classes within the >100 m depth categories. Diet compositions were found significantly different by NP MANOVA (Df=8, F=2.9714, p<0.001). Analysis by Kruskal-Wallis one-way ANOVA found Arctic Cod diets to differ by calanoid copepods, copepod nauplii, and cyclopoid copepods, all of which occurred in highest amounts in 2014 Arctic Cod ≤59 mm in length (Appendix F Table 17).

Comparisons within the A1-A2-TBS transect group (2013–2014)

In 2013, within the A1-A2-TBS transect group at ≤100 m depths, Arctic Cod diets were not significantly different (Df=2, F=1.5022, p=0.160); however, NP MANOVA indicated significant differences between Arctic Cod diet compositions in >100 m depths (Df=2, F=2.7301, p=0.014) and between ≤100 m and >100 m depths (Df=5, F=1.8025, p=0.041). Further analysis by Kruskal-Wallis one-way ANOVA found that within the >100 m category Arctic Cod diets were significantly different due to calanoid copepods and fish prey (Appendix F Table 18) and, between the two depths, in addition to calanoid copepods and fish prey, Arctic Cod diets were also significantly different due to cladocerans and cyclopoid copepods (Appendix F Table 19). Calanoid copepods occurred in diets in fairly similar amounts regardless of size and depth of inhabitance, while cladocerans and cyclopoid copepods occurred only in the diets of ≤39 mm Arctic Cod in depths ≤100 m. Fish prey was eaten by one 170–240 mm Arctic Cod in >100 m depths (Appendix F Table 19).

In 2014, Arctic Cod diet compositions were significantly different within ≤100 m depths (Df=4, F=6.4677, p=0.023), >100 m depths (Df=5, F=18.207, p<0.001), and between ≤100 m and >100 m depths (Df=10, F=46.922, p<0.001). Analysis by Kruskal-Wallis one-way ANOVA of Arctic Cod diets in ≤100 m (Appendix F Table 20), >100 m (Appendix F Table 21), and between ≤100 m and >100 m (Appendix F Table 22) indicated that Arctic Cod diets were consistently significantly different by calanoid copepods and hyperiid amphipods; however, there was some variation between depth categories, with euphausiids and fish prey creating significant differences in diets within ≤100 m depths (Appendix F Table 20), amphipods, copepod nauplii, and cyclopoid copepods creating significant differences in >100 m depths (Appendix F Table 21), and ostracods being significantly different when compared between depths (Appendix F Table 22). In general, throughout all depths, calanoid copepods were eaten rather uniformly, with a slightly higher %O in ≤100 m Arctic Cod diets. Amphipods occurred in slightly higher amounts in ≥80 mm fish in >100 m depths, euphausiids occurred in nearly similar amounts in both ≤100 m and >100 m 80–169 mm Arctic Cod, copepod nauplii and cyclopoid copepods were highest by %O in ≤59 mm Arctic Cod in >100 m depths, hyperiid amphipods and ostracods occurred highest in 60–169 mm fish in >100 m depths, and fish prey was highest by %O in 80–169 mm Arctic Cod diets in ≤100 m depths.

Although there were no significant differences within ≤100 m diets in 2013, the diet compositions of Arctic Cod collected in 2013 and 2014 were significantly different (Df=5, F=2.109, p=0.042) when compared interannually and by similar size classes (i.e., ≤39 mm, 60–79 mm, and 80–169 mm). Further analysis by Kruskal-Wallis one-way ANOVA indicated calanoid copepods, cladocerans, cyclopoids, euphausiids, and hyperiid amphipods were causing the significant difference between years (Appendix F Table 23). Calanoid copepods were eaten by all size classes but occurred slightly less in the diet of 2014, 80–169 mm Arctic Cod. Cladocerans occurred most in the diets of 2013, ≤39 mm Arctic Cod, and euphausiids and hyperiid amphipods occurred in highest amounts in 2013, 80–169 mm Arctic Cod (Appendix F Table 23). Additionally, Arctic Cod diets in 2013 and 2014 in >100 m depths were significantly different (Df=5, F=5.6564, p<0.001). Comparing by similar size classes (i.e., 60–79 mm, 80–169 mm, and 170–240 mm), Kruskal-Wallis one-way ANOVA found that diet compositions of Arctic Cod size classes differed between 2013 and 2014 by amphipods, calanoid copepods, fish prey, hyperiid amphipods, and ostracods (Appendix F Table 24). Amphipod occurrence was highest in the diets of Arctic Cod ≥80 mm collected in 2014, calanoid copepods and hyperiid amphipods were higher in occurrence in the diets of 2013, ≤169 mm Arctic Cod, and ostracods were higher in occurrence in 2014, ≤169 mm Arctic Cod. Fish prey occurred highest in occurrence in the diet of the single 170–240 mm Arctic Cod collected in 2013; however, fish prey also occurred in trace amounts in the diets of 80–169 conspecifics in 2013 and 2014 (Appendix F Table 24).

For pelagic Arctic Cod diets in the A1-A2-TBS transect group, NP MANOVA did not find a significant difference within or between ≤100 m and >100 m depths in 2013 (Df=1–4, F=0.309–0.346, p=0.346–0.498). Similarly, there was no significant difference in Arctic Cod diet composition within or between ≤100 m and >100 m depth categories in 2014 collections (Df=1–4, F=0.997–2.91, p=0.077–1.000). When compared interannually, NP MANOVA did not find a significant difference between 2013 and 2014 Arctic Cod at ≤100 m (Df=3, F=0.5778, p=0.447), but did find a difference in Arctic Cod diet composition between 2013 and 2014 pelagic fish collected at depths >100 m. Further analysis by Kruskal-Wallis one-way ANOVA indicated that diet compositions differed between year and size class due to calanoid copepods, chaetognaths, cladocerans, copepod nauplii, and cyclopoid copepods (Appendix F Table 25). Calanoid copepods were consumed in fairly similar amounts by size classes in both years, cladocerans were consumed by ≤59 mm Arctic Cod only in 2013, and copepod nauplii and cyclopoid copepods occurred mostly in diets of ≤59 mm Arctic Cod in 2014 (Appendix F Table 25).

When comparing the diet compositions of demersal and pelagic Arctic Cod collected in 2013 by standardized size classes, NP MANOVA found no significant difference in diets in ≤100 m depths (Df=3, F=1.7877, p=0.167); however, NP MANOVA did find a significant difference between demersal and pelagic Arctic Cod diet compositions in >100 m depths (Df=3, F=6.0853, p=0.001). Further analysis by Kruskal-Wallis one-way ANOVA indicated that diet compositions between demersal and pelagic Arctic Cod size classes significantly differed due to cladocerans, copepod nauplii, cyclopoid copepods, euphausiids, and hyperiid amphipods (Appendix F Table 26). The ≤40 mm and 41–50 mm size classes were only collected in mid-water trawls; consequently, cladocerans, copepod nauplii, and cyclopoid copepods only occurred in the diets of ≤50 mm pelagic Arctic Cod, while euphausiids and hyperiid amphipods only occurred in 61–132 mm demersal Arctic Cod diet (Appendix F Table 26). In 2014, there were not enough stomachs for a comparison between ≤100 m demersal and pelagic Arctic Cod diets; however NP MANOVA did find a significant difference between Arctic Cod size classes in >100 m depths (Df=6, F=8.5375, p<0.001). Further analysis by Kruskal-Wallis one-way ANOVA indicated diets differed by calanoid copepods, copepod nauplii, cyclopoid copepods, hyperiid amphipods, ostracods, and other prey (Appendix F Table 27). Calanoid copepods were important by %O to each size class. Copepod nauplii and cyclopoid copepods occurred in high amounts in fish ≤50 mm but were slightly higher in %O in pelagic fish, hyperiid amphipods and ostracods occurred most in demersal 61−132 mm diets, and other prey was highest by %O in ≤40 mm fish and occurred most in demersal Arctic Cod diets (Appendix F Table 27).

Comparisons within the GRY-MAC transect group (2013 only)

Samples from the GRY-MAC transect group were taken in 2013 in both bottom and mid-water trawls. Bottom trawls did not produce enough samples to run analyses between ≤100 m depths, additionally, Arctic Cod diet compositions between size classes were not significantly different within the >100 m depth category (Df=2, F=2.0054, p=0.082). Mid-water trawls did not produce enough stomachs for analyses within ≤100 m depths; additionally, NP MANOVA did not find a significant difference between pelagic Arctic Cod diet compositions within the >100 m depth category (Df=2, F=0.8938, p=0.249). When comparing demersal and pelagic Arctic Cod diets by standardized size classes, there were not enough samples for comparisons within ≤100 m; however, NP MANOVA indicated a significant difference in demersal and pelagic Arctic Cod diets within the >100 m depth category (Df=5, F=6.9345, p<0.001). Further analysis by Kruskal-Wallis one-way ANOVA found that demersal and pelagic Arctic Cod diets differed significantly by cladocerans, cyclopoid copepods, hyperiid amphipods, and ostracods (Appendix F Table 28). Cladocerans and cyclopoid copepods were highest by %O in ≤50 mm fish diets, occurring slightly higher in pelagic fish diets, while hyperiid amphipods and ostracods were consumed exclusively by 61−132 mm demersal Arctic Cod (Appendix F Table 28).

Discussion

Arctic Cod diet proved to be quite variable throughout the Transboundary study area. Our research examined Arctic Cod diet variability using aggregated prey groups based on taxonomic likeness. Demersal and pelagic Arctic Cod collected during the 2012, 2013, and 2014 Transboundary cruises demonstrated noticeable differences in diet diversity within different habitats (i.e., transect groups and depth categories) and displayed ontogenetic shifts in both type and proportion of prey consumed. Arctic Cod are generalist zooplanktivores (Renaud et al. 2012) whose diets may differ by body size (Lowry and Frost 1981) and food availability within different habitats (Lønne and Gullikson 1989). This study found that within-habitat Arctic Cod diet variability was explained by processes related to differences in body sizes, while interannual and between-habitat variability was more likely driven by the effects of large-scale differences in physical and biological oceanography on habitat.

As demersal and pelagic Arctic Cod body size increased with ontogeny, their diets became increasingly varied in both prey taxa and size of prey consumed. Increased variability in diet associated with larger predator body sizes is common among fishes (Labropoulou and Eleftheriou 1997). As fish grow larger, they become more proficient at handling larger, more profitable prey (Werner and Hall 1974). Smaller Arctic Cod consume mostly calanoid copepods, while larger individuals in the Beaufort Sea integrate larger prey into their diets such as amphipods, euphausiids, fishes, mysids, and shrimps (Lowry and Frost 1981; Craig et al. 1982). We observed a similar pattern in this study. In both demersal and pelagic habitats, the smallest Arctic Cod (i.e., ≤59 mm fish) consumed mostly calanoid and cyclopoid copepods, including naupliar stages of each. Larger individuals in both areas of the water column consumed various pelagic zooplankton, and, depending on the region and depth of their habitat, larger demersal Arctic Cod ultimately integrated benthic and epibenthic crustaceans and fishes into their diets. Because larger, demersal Arctic Cod were feeding on both demersal and pelagic prey groups, they were able to exploit a broader prey base than pelagic conspecifics, which consumed exclusively pelagic zooplankton.

Interannual differences in demersal Arctic Cod diets were difficult to detect due to low sample sizes; however, significant differences were found for pelagic fish in the A1-A2-TBS transect group between cruise years 2013 and 2014. Cladocerans as a prey group were eaten in high amounts by Arctic Cod in 2013, while this prey was absent from diets in 2014 in favor of copepod nauplii and cyclopoid copepods. In the same year, cladocerans were eaten in high amounts by conspecifics in the GRY-MAC transect group. Marine cladocerans tend to be abundant at stations having low salinities and warmer temperatures (Onbe et al. 1996). Stations in both A1-A2-TBS and GRY-MAC transect groups were closest to the Mackenzie River, which is responsible for less saline and warmer waters extending as far as 400 km into the Arctic Ocean (Walkusz et al. 2013). The shift from cladocerans to copepod nauplii and cyclopoid copepods in the A1-A2-TBS transect confirms the generalist nature of juvenile Arctic Cod and provides evidence that their diet composition is likely a function of body size morphology-related feeding constraints and prey availability rather than selective foraging.

Between transect groups, the differences in Arctic Cod diet composition that stood out most were chaetognaths being of major importance to ≥50 mm Arctic Cod in the 2012 B1-B2-BX transect group, while cladocerans and copepods (*Eurytemora* spp.) were consumed exclusively by juvenile Arctic Cod in the 2013 A1-A2-TBS and GRY-MAC transect groups. A surprising lack of data is available on chaetognath production and distribution throughout this region of the western Beaufort Sea; however, research in the North Pacific and the Gulf of Alaska found chaetognath distributions to be greatly influenced by water mass salinity and water-current patterns (Nishiuchi et al. 1997). Additionally, it appears that high interannual variability in chaetognath production may exist within the B1-B2-BX transect group; (Gray et al. 2015) found this prey type to be nearly absent from Arctic Cod diets in essentially the same region in 2011. *Eurytemora* spp., similar to the euryhaline cladocerans, tend to thrive in warmer, less-saline waters (Lee 1999) making areas adjacent to the Mackenzie River (represented in the 2013 A1-A2-TBS and GRY-MAC transect groups) prime habitat for these cladocerans and copepods and apparently important feeding grounds for juvenile Arctic Cod.

The ≤100 m and >100 m depth categories, developed to demark the Beaufort Sea shelf break, appeared to drive Arctic Cod diet variability within transect groups; but, small samples sizes in the ≤100 m depth categories hindered across-shelf comparisons. However, when such comparisons were possible, there was an evident pattern of benthic and epibenthic crustaceans, mostly cumaceans and mysids, in the diets of demersal Arctic Cod collected in ≤100 m depths, regardless of transect group. Similarly, Craig et al. (1982) found nearshore Arctic Cod in the western Beaufort Sea to regularly consume these prey groups. Arctic Cod food habits may become bottom-associated in shallow shelf areas (Bluhm and Gradinger 2008) as documented in other regions of the Arctic such as the Bering (Cui et al. 2012) and Chukchi Seas (Coyle et al. 1997; Gray et al. 2015). Pelagic Arctic Cod diets appeared to be less influenced by depth and fish primarily consumed pelagic zooplankton with some variation associated with the region in which they were collected.

The findings presented here could contribute to the future implementation of food web models specific to the western Beaufort Sea. Our study concurs with others that found Arctic Cod diet varies depending on local prey availability (Craig et al. 1982; Lønne and Gulliksen 1989; Renaud et al. 2012) and fish body size (Lowry and Frost 1981); however, this study also demonstrated that year, region, and depth can increase variability. Because Arctic Cod is a vital link in the Arctic food chain, parameterizing a model that accounts for these factors could enhance our knowledge of trophic pathways throughout this vast system.

Our research showed that demersal and pelagic Arctic Cod diet differed interannually, within and between habitats, and varied according to body size. Variability within habitats was related year and depth, along with ontogenetic shifts in body size and morphology that allowed larger demersal and pelagic fish to consume larger demersal and pelagic prey. However, these factors were likely not the only source of within-habitat diet variability. Smaller spatial scale processes, such as the effects of regional oceanographic and topographic characteristics (Lønne and Gullikson 1989; Blanchard and Feder 2014) on invertebrate assemblages (Ashjian et al. 2005; Blanchard et al. 2013) also could have attributed to the overall diet variability documented here. There was high variability in Arctic Cod diet composition throughout this study, which probably reflected a combination of factors acting on regionally available prey communities. These findings provide insight into the role of Arctic Cod as a predator in the Arctic and suggest that the importance of secondary prey items (i.e., not calanoid copepods) varies depending on year, habitat, and body size.

References

Ashjian, C.J., R.G. Campbell, H.E. Welch, M. Butler, and D. Van Keuren. 2003. Annual cycle in abundance, distribution, and size in relation to hydrography of important copepod species in the western Arctic Ocean. Deep-Sea Research Part I: Oceanographic Research Papers 50(10–11):1235–1261.

Baker, R., A. Buckland, and M. Sheaves. 2014. Fish gut content analysis: robust measures of diet composition. Fish and Fisheries 15(1):170–177.

Barber, W.E., R.L. Smith, M. Vallarino, and R.M. Meyer. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fishery Bulletin 95:195–209.

Barnard, J.L. 1969 The families and genera of marine gammaridean Amphipoda. Smithsonian Institution Press, Washington.

Blanchard A.L., C.L Parris, A.L. Knowlton, and N.R. Wade. 2013. Benthic ecology of the northeastern Chukchi Sea. Part I. Environmental characteristics and macrofaunal community structure, 2008–2010. Continental Shelf Research 67:52–66.

Blanchard, A.L. and H.M. Feder. 2014. Interactions of habitat complexity and environmental characteristics with macrobenthic community structure at multiple spatial scales in the northeastern Chukchi Sea. Deep-Sea Research Part II: Topical Studies in Oceanography 102:132–143.

Bluhm, B.A. and R. Gradinger. 2008. Regional variability in food availability for arctic marine mammals. Ecological Applications 18(sp2): S77–S96.

Castellani, C., X. Irigoien, D.J. Mayor, R.P. Harris, and D. Wilson. 2008. Feeding of *Calanus finmarchicus* and *Oithona similis* on the microplankton assemblage in the Irminger Sea, North Atlantic. Journal of Plankton Research 30(10):1095–1116.

Chipps, S.R. and J.E. Garvey. 2007. Assessment of diets and feeding patterns. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland. pp 473–514.

Cortes, E. 1997. A critical review of methods of studying fish feeding based on analysis of stomach contents: application to elasmobranch fishes. Canadian Journal of Fisheries and Aquatic Sciences 54(3):726–738.

Coyle, K.O., J.A. Gillispie, R.L. Smith, and W.E. Barber. 1997. Food habits of four demersal Chukchi Sea fishes. American Fisheries Society Symposium: Fish Ecology in Arctic North America 19:310–318.

Craig, P.C., W.B. Griffiths, L. Haldorson, and H. McElderry. 1982. Ecological studies of Arctic cod (*Boreogadus saida*) in Beaufort Sea coastal waters, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 39(3):395–406.

Cui, X., J.M. Grebmeier, and L.W. Cooper. 2012. Feeding ecology of dominant groundfish in the northern Bering Sea. Polar Biology 35(9):1407−1419.

Gardner, G.A. and I. Szabo. 1982. British Columbia pelagic marine Copepoda: an identification manual and annotated bibliography. Vol. 62. Department of Fisheries and Oceans, Canada.

Gray, B.P. 2015. Comparisons of Arctic Cod (*Boreogadus saida*), Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*), and Shorthorn Sculpin (*Myoxocephalus scorpius*) diets across the northeastern Chukchi and western Beaufort Seas. MS Thesis, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

Gray, B.P., B.L. Norcross, A.L. Blanchard, A.H. Beaudreau, and A.C. Seitz. 2015. Variability in the summer diets of juvenile polar cod (*Boreogadus saida*) in the northeastern Chukchi and western Beaufort Seas. Polar Biology 39(6):1069–1080.

Hallett, C.S. and R.K. Daley. 2011. Feeding ecology of the southern lanternshark (*Etmopterus baxteri*) and the brown lanternshark (*E. unicolor*) off southeastern Australia. ICES Journal of Marine Science 68(1):157–165.

Hansson, S.1998. Methods of studying fish feeding: a comment. Canadian Journal of Fisheries and Aquatic Sciences 55(12):2706–2707.

Hyslop, E.J. 1980. Stomach contents analysis—a review of methods and their application. Journal of Fish Biology 17(4):411–429.

Jensen, T., K.I. Ugland, and M. Anstenrud. 1991. Aspect of growth in Arctic cod, *Boreogadus saida* (Lepechin 1773). In: Sakshaug E., C.C.E. Hopking, and N.A. Oritsland (eds.) Proceedings of the Pro Mare Symposium on Polar Marine Ecology, Trondheim, 12–16, May 1990. Polar Research 10(2):547–552.

Kolts, J.M., J.R. Lovvorn, C.A. North, J.M. Grebmeier, and L.W. Cooper. 2013. Relative value of stomach contents, stable isotopes, and fatty acids as diet indicators for a dominant invertebrate predator (*Chionoecetes opilio*) in the northern Bering Sea. Journal of Experimental Marine Biology and Ecology 449: 274–283.

Labropoulou, M. and A. Eleftheriou. 1997. The foraging ecology of two pairs of congeneric demersal fish species: importance of morphological characteristic in prey selection. Journal of Fish Biology 50(2):324−340.

Lee, C.E. 1999. Rapid and repeated invasions of fresh water by the copepod *Eurytemora affinis*. Evolution 53(5):1423–1434.

Legendre, P. and M.J. Anderson. 1999. Distance-based redundancy analysis: testing multispecies responses in multifactorial ecological experiments. Ecological Monographs 69(1):1–24.

Lønne, O.J. and B. Gulliksen. 1989. Size, age and diet of polar cod, *Boreogadus saida* (Lepechin 1773), in ice covered waters. Polar Biology 9(3):187–191.

Lowry, L.F. and K.J. Frost. 1981. Distribution, growth, and foods of Arctic cod (*Boreogadus saida*) in the Bering, Chukchi, and Beaufort seas. The Canadian Field-Naturalist 95(2):186–191.

Mecklenburg, C., P. Møller, and D. Steinke. 2011. Biodiversity of arctic marine fishes: taxonomy and zoogeography. Marine Biodiversity 41(1):109–140.

Nishiuchi, K., N. Shiga, and S. Takagi. 1997. Distribution and abundance of chaetognaths along 180˚ longitude in the northern North Pacific Ocean during the summers of 1982 through 1989. Plankton Biology and Ecology 44(1/2):55–70.

Norcross, B.L., S.W. Raborn, B.A. Holladay, B.J. Gallaway, S.T. Crawford, J.T. Priest, L.E. Edenfield, and R. Meyer. 2013. Northeastern Chukchi Sea demersal fishes and associated environmental characteristics, 2009–2010. Continental Shelf Research 67:77−95.

Onbe, T., A. Tanimura, M. Fukuchi, H. Hattori, H. Sasaki, and O. Matsuda. 1996. Distribution of marine cladocerans in the northern Bering Sea and the Chukchi Sea. Proceedings of the NIPR Symposium on Polar Biology 9:141–152.

Parker-Stetter, S.L., J.K. Horne, and T.J. Weingartner. 2011. Distribution of polar cod and age-0 fish in the U.S. Beaufort Sea. Polar Biology 34(10):1543−1557.

Pinnegar, J.K., V.M. Trenkel, A.N. Tidd, W.A. Dawson, and M.H. Du Buit. 2003. Does diet in Celtic Sea fishes reflect prey availability? Journal of Fish Biology 23(1):197−212.

Scharf, F.S., F. Juanes, and R.A. Rountree. 2000. Predator size-prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic-niche breadth. Marine Ecology Progress Series 208:229–248.

Quinn, G.P. and M.J. Keough. 2002. Experimental design and data analysis for biologists. Cambridge University Press, Cambridge. pp 467–469.

Rand, K.M., A. Whitehouse, E.A. Logerwell, E. Ahgeak, R. Hibpshman, and S. Parker-Stetter. 2013. The diets of polar cod (*Boreogadus saida*) from August 2008 in the U.S. Beaufort Sea. Polar Biology 36:907–912.

Renaud, P.E., J. Berge, Ø. Varpe, O. Lønne, J. Nahrgang, C. Ottesen, I. Hallanger. 2012. Is the poleward expansion by Atlantic Cod and Haddock threatening native polar cod, *Boreogadus saida*? Polar Biology 35(3):401–412.

Vassilenko, S.V. and V.V. Petryashov. 2009. Illustrated keys to free-living invertebrates of Eurasian Arctic seas and adjacent deep waters. Vol. 1. Alaska Sea Grant. Fairbanks: University of Alaska Fairbanks.

Walkusz, W., J.E. Paulic, W.J. Williams, S. Kwasniewski, and M.H. Papst. 2011. Distribution and diet of larval and juvenile Arctic cod (*Boreogadus saida*) in the shallow Canadian Beaufort Sea. Journal of Marine Systems 84(3–4):78–84.

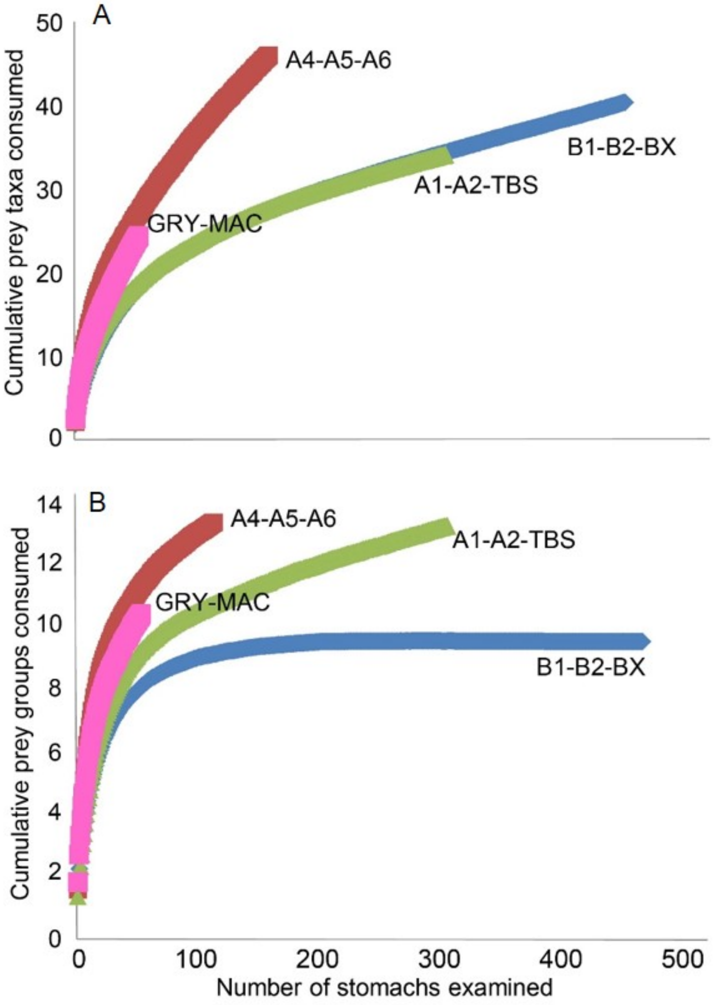
Walkusz, W., A. Majewski, and J.D. Reist. 2013. Distribution and diet of the bottom dwelling Arctic cod in the Canadian Beaufort Sea. Journal of Marine Systems 127:65–75.

Welch, H.E., M.A. Bergmann, T.D. Siferd, K.A. Martin, M.F. Curtis, R.E. Crawford, R.J. Conover, and H. Hop. 1992. Energy flow through the marine ecosystem of the Lancaster Sound region, Arctic Canada. Arctic 45(4):343–357.

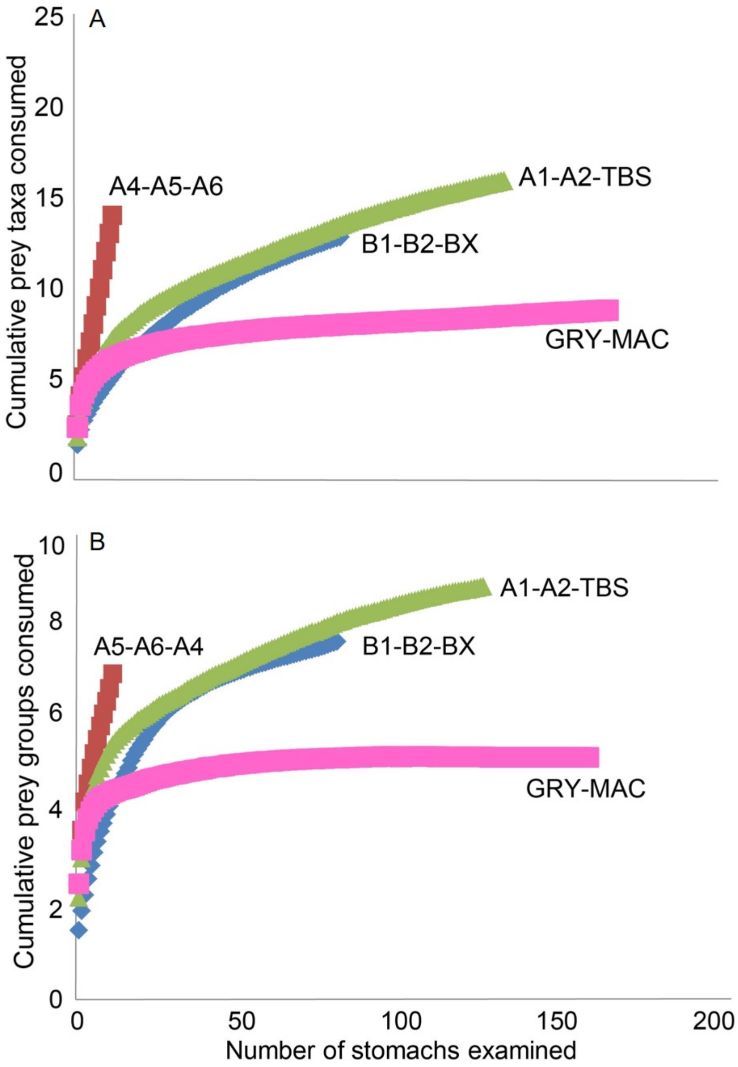
Werner, E.E. and D.J. Hall. 1974. Optimal foraging and the size selection of prey by the Bluegill Sunfish (*Lepomis macrochirus*). Ecology 55(5):1042–1052.

Werner, E.E. and J.F. Gilliam. 1984. The ontogenetic niche and species interaction in size-structured populations. Annual Review of Ecological Systems 15:393–425.

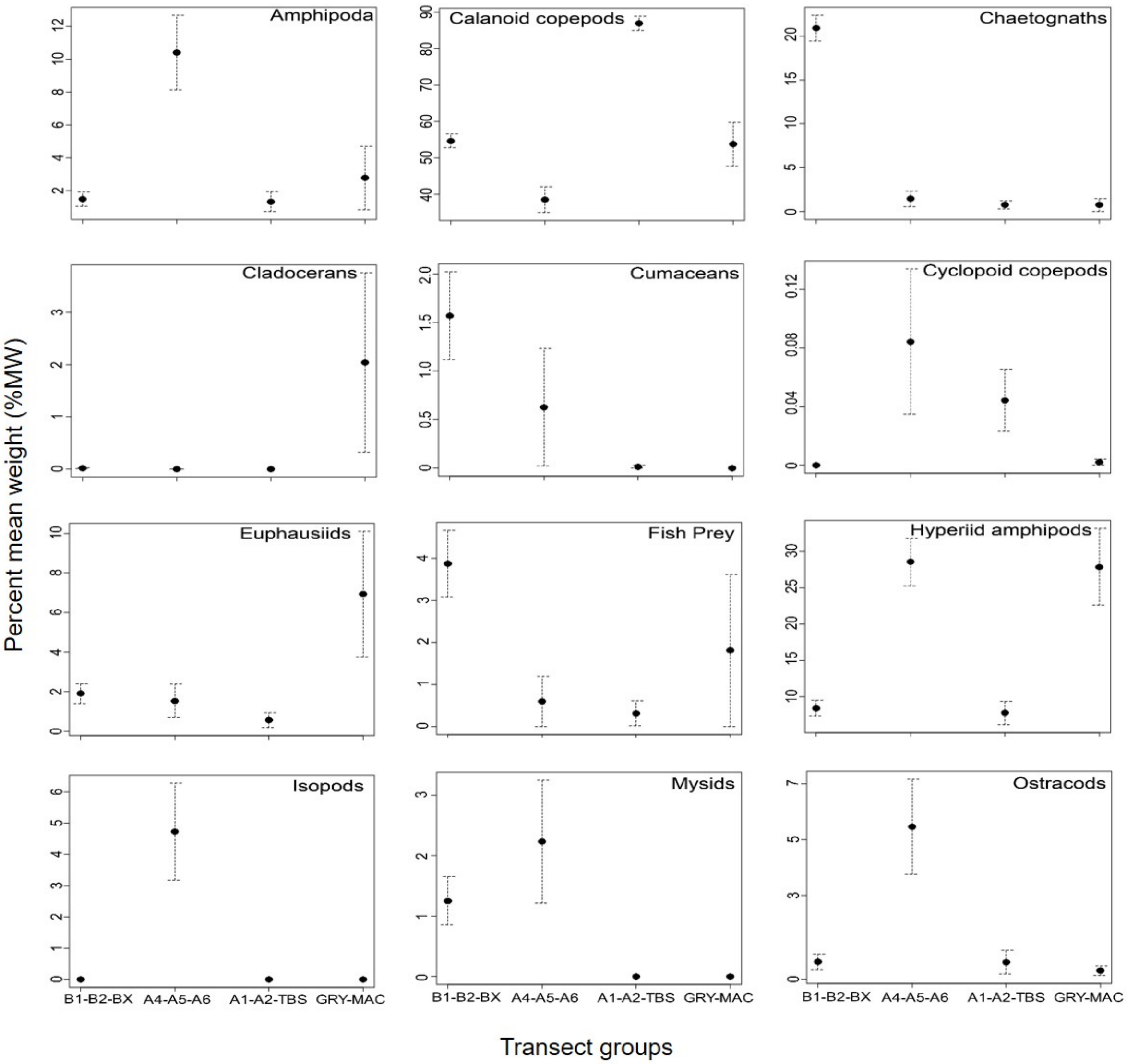
Whitehouse, G.A., K. Aydin, T. Essington, G. Hunt Jr. 2014. A trophic mass balance model of the eastern Chukchi Sea with comparisons to other high-latitude systems. Polar Biology 37(7):911–939.



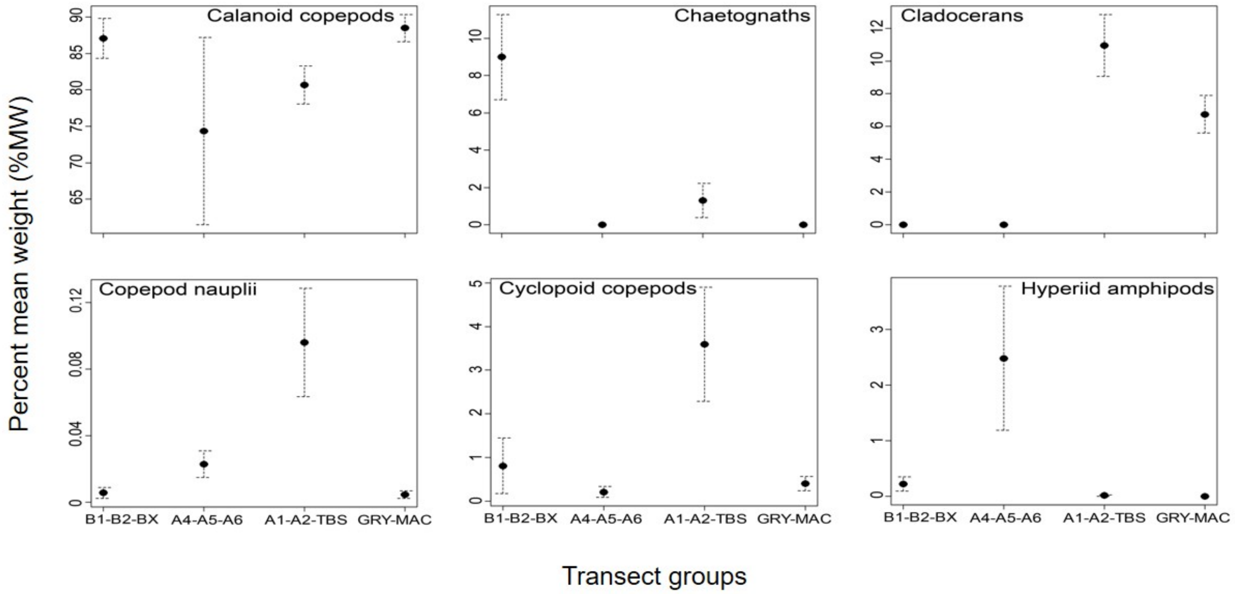
Appendix F Figure 1. Cumulative prey curves of demersal Arctic Cod diet composition summarized by four transect groups: (B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC). Appendix F Figure 1A represents the accumulation of all identifiable prey taxa as stomachs were added, while Figure 1B represents the accumulation of the 14 taxonomically-coarse prey groups as stomachs were added.



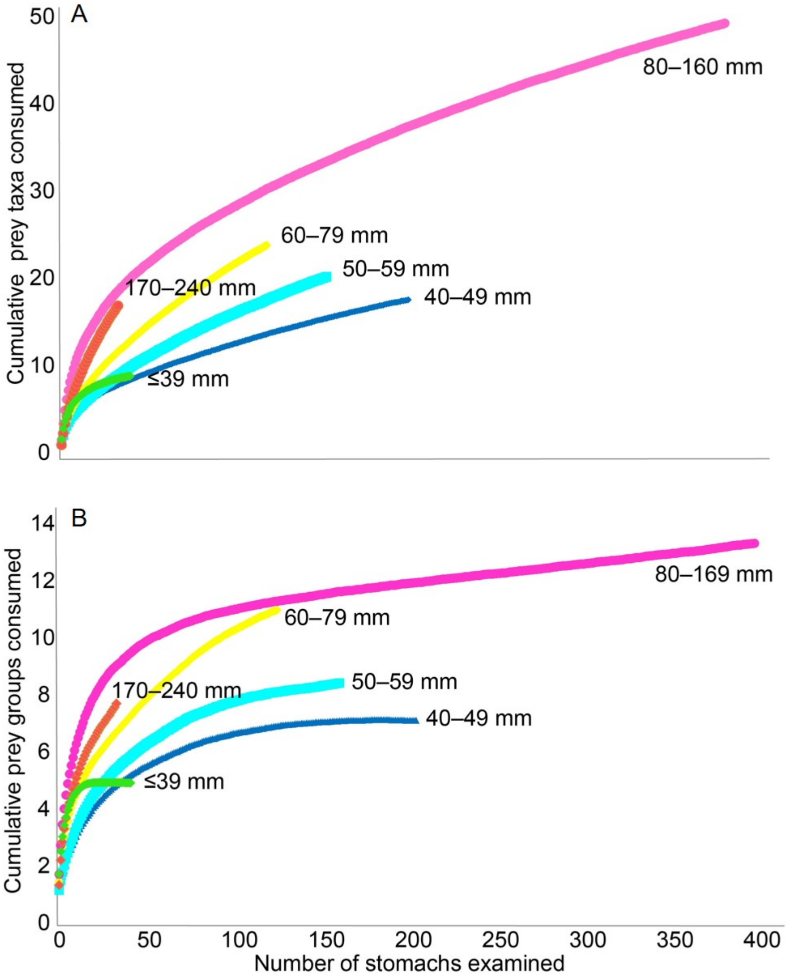
Appendix F Figure 2. Cumulative prey curves of pelagic Arctic Cod diet composition summarized by four transect groups: (B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC). Appendix F Figure 2A represents the accumulation of all identifiable prey taxa as stomachs were added, while Figure 2B represents the accumulation of the 14 taxonomically-coarse prey groups as stomachs were added.



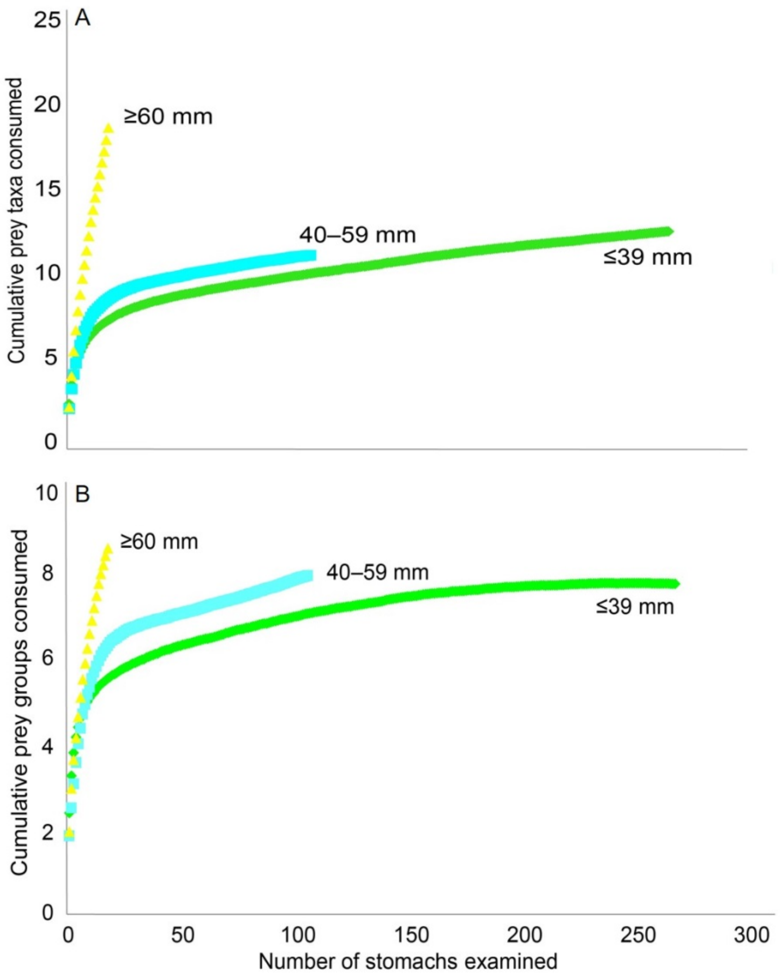
Appendix F Figure 3. Mean values of %MW of the major prey groups consumed by demersal Arctic Cod in the four transect groups (B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC). The “other prey” group is not reported here because it represents the combination of multiple prey taxa. Error bars signify the standard error of the mean %MW values of prey items in demersal Arctic Cod diet within a transect group. Note: y-axes vary in scale so that differences in prey use are more detectable.



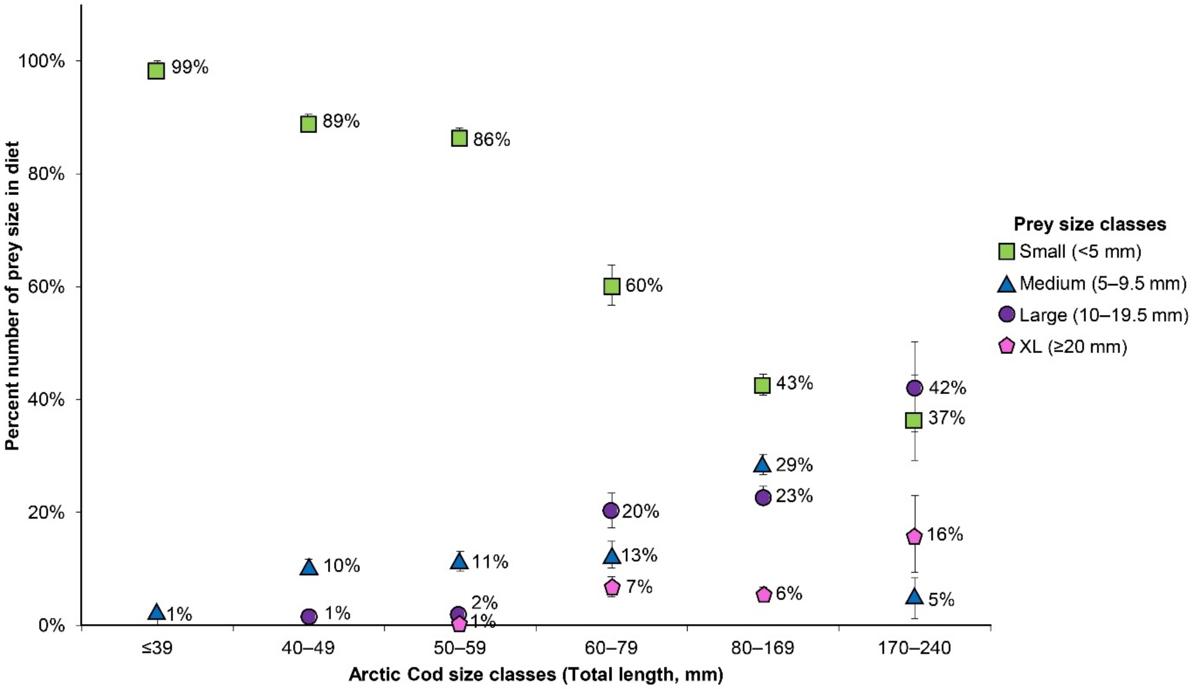
Appendix F Figure 4. Mean values of %MW of the major prey groups consumed by pelagic Arctic Cod in the four transect groups (B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC). The “other prey” group is not reported here because it represents the combination of multiple prey taxa. Error bars signify the standard error of the mean %MW values of prey items in pelagic Arctic Cod diet within a transect group. Note: y-axes vary in scale so that differences in prey use are more detectable.



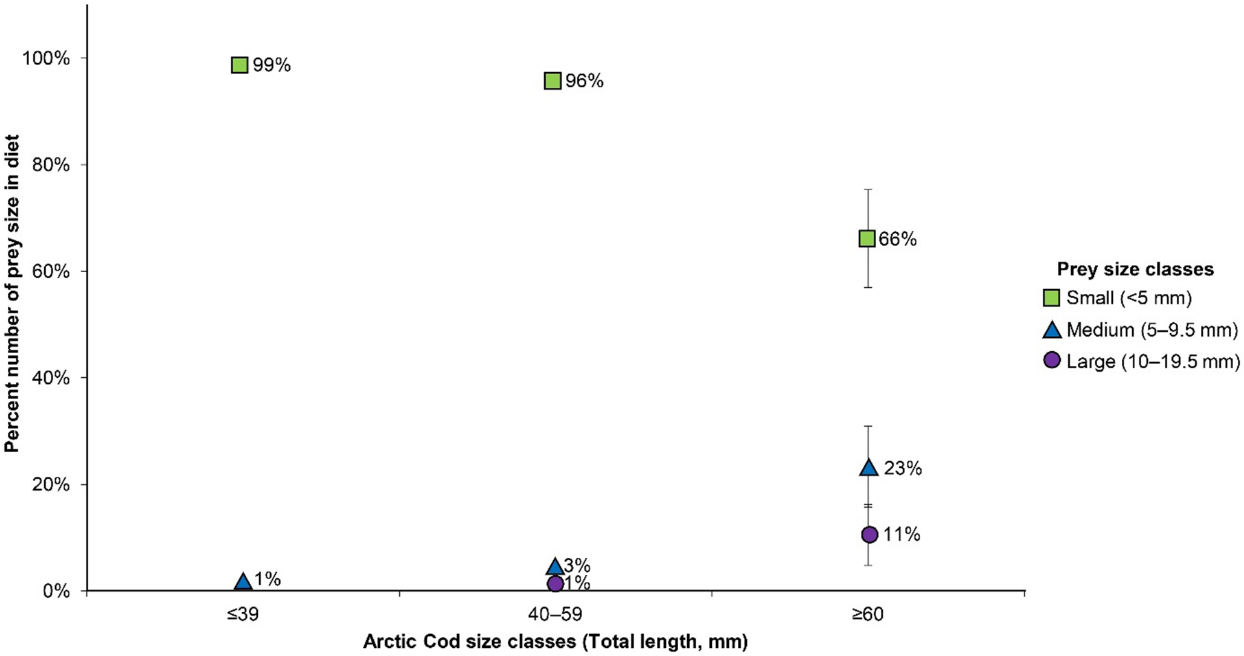
Appendix F Figure 5. Cumulative prey curves of demersal Arctic Cod diet composition summarized by six size classes: (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Appendix F Figure 5A represents the accumulation of all identifiable prey taxa as stomachs were added, Figure 5B represents the accumulation of the 14 taxonomically-coarse prey groups as stomachs were added.



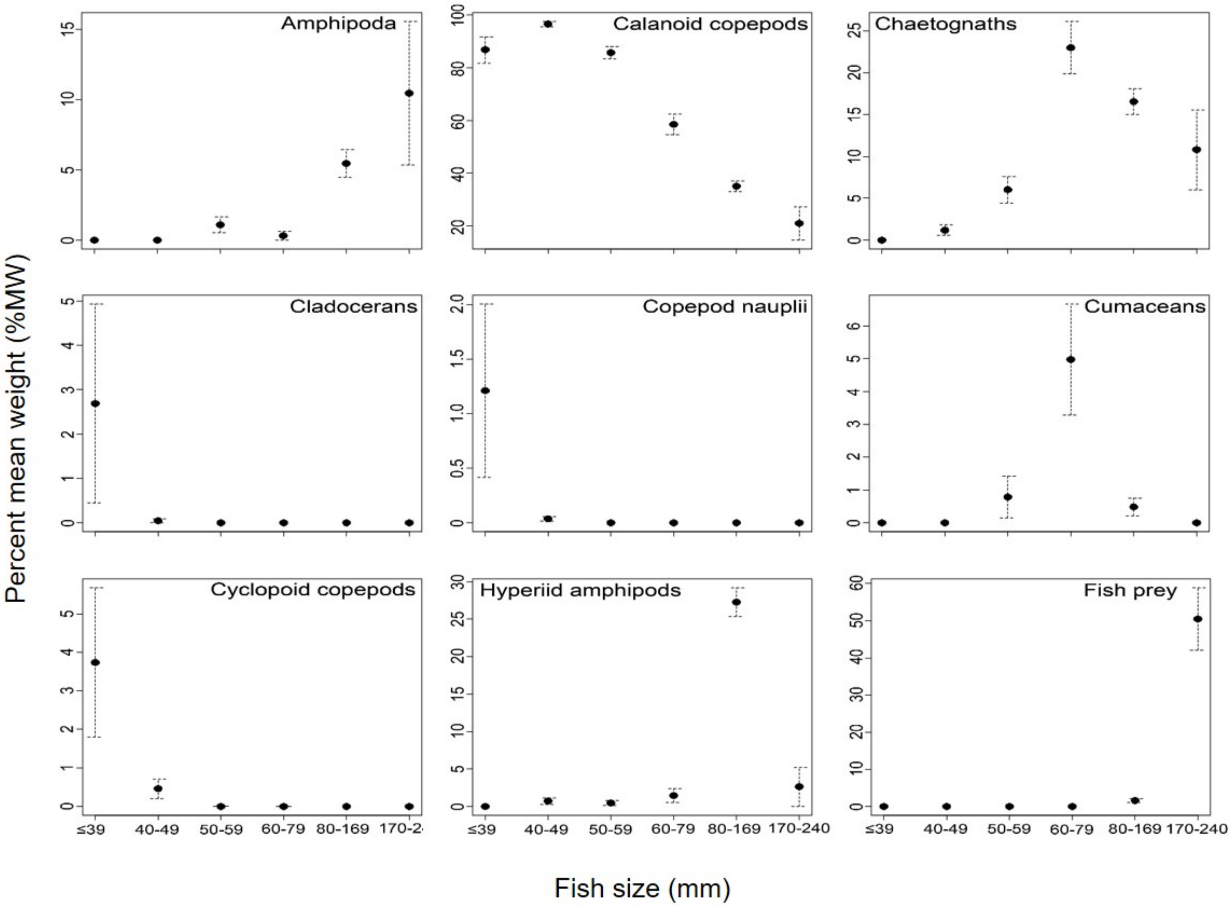
Appendix F Figure 6. Cumulative prey curves of pelagic Arctic Cod diet composition summarized by three size classes: (≤39 mm, 40–59 mm, and ≥60 mm). Appendix F Figure 6A represents the accumulation of all identifiable prey taxa as stomachs were added, Figure 6B represents the accumulation of the 14 taxonomically-coarse prey groups as stomachs were added.



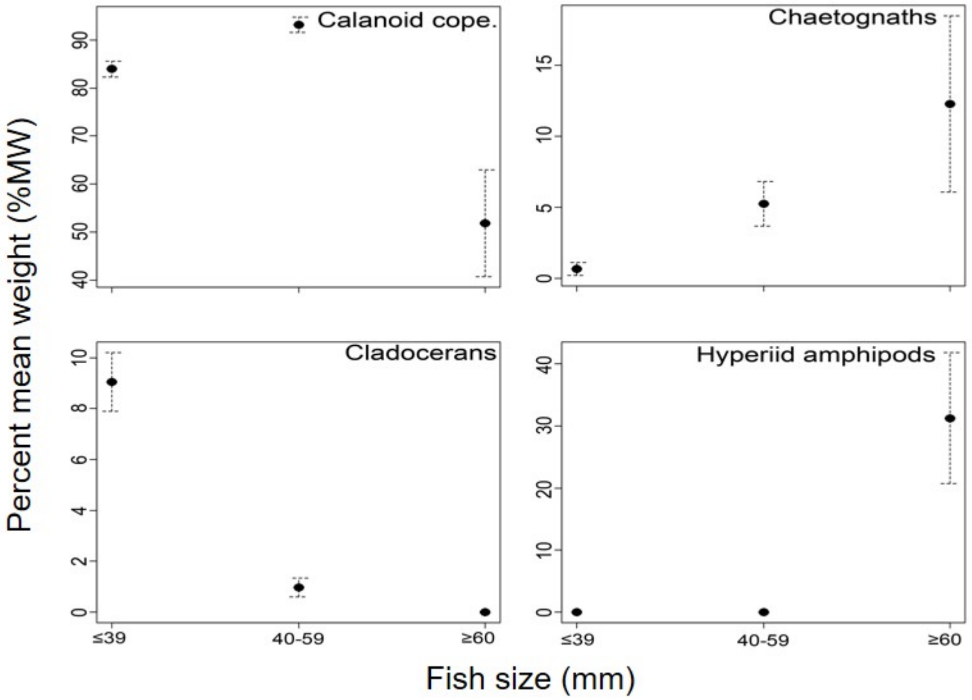
Appendix F Figure 7. The percent contribution by number of small (<5 mm), medium (5–9.5 mm), large (10–19.5 mm) and extra-large (≥20 mm) prey eaten by demersal Arctic Cod summarized by six size classes of fish: (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Error bars signify the standard error of the mean percent number of prey sizes in demersal Arctic Cod diet.



Appendix F Figure 8. The percent contribution by number of small (<5 mm), medium (5–9.5), and large (10–19.5) prey summarized by three size classes of pelagic Arctic Cod: (≤39 mm, 40–59 mm, ≥60 mm). Error bars signify the standard error of the mean percent number of prey sizes in pelagic Arctic Cod diet.



Appendix F Figure 9. Mean values of %MW of the major prey groups consumed by demersal Arctic Cod summarized by six size classes: (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). The “other prey” group is not reported here because it represents the combination of multiple prey taxa. Error bars signify the standard error of the mean %MW values of prey items in demersal Arctic Cod diet within their respective size classes. Note: y-axes vary in scale so that differences in prey use are more detectable.



Appendix F Figure 10. Mean values of %MW of the major prey groups consumed by pelagic Arctic Cod summarized by three size classes: (≤39 mm, 40–59 mm, and ≥60 mm). The “other prey” group is not reported here because it represents the combination of multiple prey taxa. Error bars signify the standard error of the mean %MW values of prey items in pelagic Arctic Cod diet within their respective size classes. Note: y-axes vary in scale so that differences in prey use are more detectable.

Appendix F Table 1. Average weight per individual prey item determined using prey count, size, and weight data from Arctic Cod stomach contents. Sample sizes indicate the amount of individual prey items per taxon used in the average weight per individual calculations. If it was not possible to estimate a prey weight, one was assigned using peer-reviewed literature.

Estimated average wt./individual			
Prey	Size (mm)	Avg. wt./individual (mg)	Sample size (n)
Amphipoda			
Aceroides spp.	5.0–6.0	2.583	n=17
	7.0–9.0	3.555	n=24
	10.0–15.0	29.88	n=7
	16.0–22.0	43.44	n=4
Ampeliscidae	10.0–15.0	21.10	n=9
Apherusa spp.	7.0–10.0	4.896	n=39
Lysianassidae	5.0–7.0	5.558	n=12
Melita spp.	21.0–25.0	72.27	n=12
Monoculodes spp.	5.0–9.0	3.778	n=9
Oediceros spp.	6.0–8.0	2.250	n=4
Orchomene spp.	6.0–11.0	6.600	n=4
Rhachotropsis spp.	7.0–16.0	20.64	n=7
Anonyx spp.	10.0–12.0	15.40	n=4
Unid. Amphipoda	5.0–8.0	3.878	n=65
	10.0	20.45	n=158
Calanoid copepods			
Aetidiedae	3.0–4.0	0.689	n=9
	>4.0–5.0	1.120	n=17
Calanus glacialis	3.0–3.5	0.215	n=299
	4.0–4.5	0.271	n=4,773
Calanus hyperboreus	5.0–5.5	0.972	n=26
	6.0–6.5	1.278	n=80
	7.0–7.5	2.137	n=592
	8.0–9.0	2.525	n=515
Calanus spp.	3.0–4.5	0.319	n=88
	5.0–5.5	0.731	n=184
	6.0–8.5	1.459	n=44
Euchaeta spp.	4.0	0.300	n=5
	5.0–6.0	0.600	n=9
	7.0–9.0	3.750	n=2
Eurytemora spp.	<1.5	0.013	n=2,067
Limnocalanus spp.	1.0–1.2	0.018	n=18
Metridia longa	3.0–4.0	0.402	n=32
	5.0–6.0	0.682	n=76
Paraeuchaeta norvegica	6.0–8.0	4.290	n=15
	9.0–13.0	5.472	n=62
Unid. Calanoid copepods	0.5	0.020	n=27
	1.0–2.0	0.043	n=4,468
	>2.0–3.0	0.315	n=118
	>3.0–4.0	0.629	n=159
	>4.0–5.0	0.739	n=111
	>5.0–6.0	0.842	n=106
	7.0–8.0	3.150	n=4
	9.0–13.0	4.417	n=11
Chaetognaths	>10.0	2.404	n=237
Cladocerans	0.5–1.0	0.005	n=135
Copepod nauplii	0.5–1.0	0.000	Castellani et al. 2008
Cumaceans			
Diastylis spp.	6.0–7.0	1.823	n=11
	12.0–15.0	10.65	n=8
Eudorella spp.	≤5.0	1.211	n=12
	10.0–12.0	4.375	n=15

Appendix F Table 1 continued. Average weight per individual

Estimated average wt/individual			
Prey	Size (mm)	Avg. wt/individual (mg)	Sample size (n)
Cumaceans			
Leptostylis spp.	15.0	16.70	n=1
Unid. Cumaceans	≤4.5	0.741	n=118
	5.0–9.5	1.078	n=34
	10.0–12.0	7.866	n=23
	≥20.0	37.55	n=2
Cyclopoid copepods	0.5–1.0	0.001	Castellani et al. 2008
Euphausiids			
Thysanoessa spp.	15.0–20.0	19.70	n=47
	≥21.0	28.88	n=52
Fish prey			
Boreogadus saida	60.0	1208.0	n=135
	70.0	2030.0	n=64
	73.0	2368.0	n=32
	105.0	7699.	n=53
	120.0	11074.0	n=40
Cottidae	30.0	233.0	n=19
Hyperiid amphipods			
Themisto abysorrum	3.5–4.5	0.662	n=189
	5.0–7.0	4.420	n=30
	8.0–9.0	6.880	n=23
Themisto libellula	7.0	4.420	n=30
	10.0–15.0	32.92	n=38
	16.0–20.0	45.06	n=18
	21.0–26.0	123.3	n=6
	34.0	383.0	n=1
Themisto spp.	3.5–4.5	0.662	n=189
	5.0–7.0	4.420	n=30
	10.0–15.0	32.92	n=38
	3.0–4.5	1.617	n=41
Unid. Hyperiidae			
	5.0–7.0	4.420	n=30
	8.0–9.0	6.880	n=23
Isopods	3.0–4.0	1.125	n=12
	5.0–7.0	6.638	n=16
	10.0	17.64	n=9
Mysids			
Mysis spp.	10.0–19.0	12.30	n=2
	23.0–26.0	63.20	n=3
Unid. Mysids	8.0–15.0	12.30	n=2
	30.0–35.0	119.3	n=2
Ostracods	≤1.0	0.010	n=4
	2.0–3.0	0.761	n=76
	3.5–4.0	0.831	n=18
Other prey			
Bivalve veliger	0.2–1.0	0.004	n=27
Bivalve juvenile	3.0–4.0	6.013	n=9
Harpacticoid copepod	0.5–1.0	0.075	n=1,774
Gastropoda	0.5–1.0	0.004	n=27
Paguridae zoea	5.0–7.0	2.886	n=34
Pteropoda	Na	20.50	n=3

Appendix F Table 2. Overall model results of nonparametric multivariate analysis of variance (NP MANOVA) for demersal Arctic Cod diet compositions.

Demersal Arctic Cod NP MANOVA			
Factors	*Df*	*F*	*p*
Cruise (Year)	2	49.070	<0.001
Transect	2	26.430	<0.001
Depth	1	38.230	<0.001
Size class	5	33.960	<0.001
Transect*Depth*Size class	28	2.7230	<0.001
Cruise*Transect*Depth*Size class	9	2.6080	<0.001

Appendix F Table 3. Overall model results of nonparametric multivariate analysis of variance (NP MANOVA) for pelagic Arctic Cod diet compositions.

Pelagic Arctic Cod NP MANOVA			
Factors	*Df*	*F*	*p*
Cruise (Year)	2	17.095	<0.001
Transect	2	5.2739	<0.001
Depth	1	0.0046	0.989
Size class	2	16.335	<0.001
Transect*Depth*Size class	10	2.7534	0.01
Cruise*Transects*Depth*Size class	4	3.5373	0.018

Appendix F Table 4. Demersal Arctic Cod diet summarized by %MW, %MN, and %O in four transect groups (B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC). Major prey categories used in the analysis are in boldface; prey items contributing to the major categories are listed underneath. Summary information including total prey, total prey weight (g), total stomachs, and body size is listed at the end of the table. A dash (–) indicates a prey item was not consumed by Arctic Cod in a respective transect group.

	Transect groups											
Demersal Arctic Cod	B1-B2-BX			A4-A5-A6			A1-A2-TBS			GRY-MAC		
Prey	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O
Amphipoda	**1.4**	**0.9**	**3.1**	**10.4**	**10.0**	**15.1**	**1.5**	**0.9**	**3.5**	**2.8**	**1.9**	**5.5**
Apherusa spp.	0.1	0.1	0.6	0.5	0.1	0.6	–	–	–	–	–	–
Lysianassidae	0.2	<0.1	0.2	2.9	2.6	3.0	0.4	0.4	0.6	1.6	0.9	1.8
Oedicerotidae	0.2	0.2	0.2	1.1	1.3	3.0	<0.1	<0.1	0.3	–	–	–
Other Amphipoda	0.9	0.6	2.1	5.9	5.8	10.2	1.1	0.5	2.5	1.2	0.9	3.6
Calanoid copepods	**54.6**	**68.5**	**79.6**	**38.5**	**39.8**	**54.8**	**80.4**	**81.6**	**92.4**	**53.7**	**66.7**	**87.3**
Aetidiedae	0.4	0.5	1.9	0.6	0.7	2.4	0.1	0.3	1.3	–	–	–
Calanus glacialis	44.3	56.1	69.9	1.7	1.8	6.6	17.1	10.6	39.8	4.4	1.2	5.5
Calanus hyperboreus	0.8	0.4	3.1	8.5	6.4	16.9	18.4	9.5	34.7	20.6	22.4	30.9
*Calanu*s spp.	0.7	0.8	1.4	2.5	3.3	6.6	7.5	4.2	18.3	5.6	8.3	16.4
Euchaeta spp.	0.3	0.3	1.0	1.3	1.4	2.4	0.2	0.1	1.0	–	–	–
Eurytemora spp.	–	–	–	–	–	–	0.1	0.2	1.6	0.8	1.8	7.3
Metridia longa	1.3	2.0	8.5	1.7	2.3	7.8	1.5	1.3	4.7	<0.1	0.1	1.8
Paraeuchaeta norvegica	1.5	0.8	3.7	2.0	2.0	6.0	1.1	0.6	5.1	3.1	3.2	12.7
Other Calanoid copepods	5.3	7.8	17.5	20.3	21.9	38.6	34.3	55.0	77.3	19.2	29.8	67.3
Chaetognaths	**23.7**	**15.4**	**39.6**	**1.5**	**1.3**	**2.4**	**0.7**	**0.5**	**3.5**	**0.7**	**0.9**	**1.8**
Cladocerans	**–**	**–**	**–**	**<0.1**	**<0.1**	**0.6**	<0.1	**0.2**	**0.6**	**2.0**	**3.5**	**10.9**
Copepod nauplii	**–**	**–**	**–**	**0.2**	**2.6**	**9.0**	**0.1**	**0.9**	**4.1**	**–**	**–**	**–**
Cumaceans	**1.8**	**1.4**	**4.5**	**0.6**	**0.6**	**1.2**	<0.1	<0.1	**0.3**	**–**	**–**	**–**
Diastylidae	0.8	0.6	1.7	<0.1	<0.1	0.6	–	–	–	–	–	–
Leuconidae	0.1	<0.1	0.4	–	–	–	–	–	–	–	–	–
Other Cumaceans	0.9	0.7	2.7	0.6	0.6	0.6	<0.1	<0.1	0.3	–	–	–
Cyclopoid copepods	**–**	**–**	**–**	**0.8**	**3.1**	**10.8**	**0.4**	**2.7**	**8.8**	**<0.1**	**1.0**	**3.6**
Euphausiids	**1.0**	**0.4**	**1.2**	**1.5**	**1.2**	**2.4**	**2.3**	**1.4**	**5.4**	**6.9**	**4.0**	**9.1**
Fish prey	**4.2**	**3.2**	**5.2**	**0.6**	**0.2**	**0.6**	**0.6**	**0.6**	**1.3**	**1.8**	**0.6**	**1.8**
Boreogadus saida	2.4	1.9	2.5	0.6	0.2	0.6	–	–	–	–	–	–
Cottidae	0.2	0.2	0.2	–	–	–	–	–	–	–	–	–
Other fish prey	1.5	1.1	2.5	–	–	–	0.6	0.6	1.3	1.8	0.6	1.8
Hyperiid amphipods	**6.0**	**3.4**	**9.7**	**28.6**	**24.7**	**36.8**	**11.6**	**9.2**	**18.3**	**27.9**	**14.0**	**41.8**
Themisto abyssorum	1.1	0.7	2.5	2.4	2.1	6.0	0.1	0.5	2.2	–	–	–
Themisto libellula	1.4	0.7	1.9	11.4	8.8	12.1	3.9	2.6	5.4	12.0	3.6	16.4
Themisto spp.	0.1	0.1	0.2	<0.1	0.2	0.6	1.1	0.7	2.2	0.1	<0.1	1.8
Other Hyperiid amph.	3.3	1.9	6.2	14.8	13.7	23.5	6.4	5.4	12.6	15.8	10.4	30.9
Isopods	**–**	**–**	**–**	**4.7**	**5.2**	**7.2**	**–**	**–**	**–**	**–**	**–**	**–**
Mysids	**1.4**	**0.6**	**2.3**	**2.2**	**1.4**	**3.6**	**0.1**	**<0.1**	**0.3**	**–**	**–**	**–**
Mysis spp.	0.9	0.4	1.4	1.3	0.8	1.8	–	–	–	–	–	–
Neomysis spp.	0.2	<0.1	0.2	0.3	0.2	1.2	–	–	–	–	–	–
Other Mysids	0.3	0.1	0.6	0.7	0.4	1.8	0.1	<0.1	0.3	–	–	–
Ostracods	**0.6**	**0.5**	**1.4**	**5.5**	**6.2**	**12.1**	**0.7**	**1.2**	**3.5**	**0.3**	**2.6**	**14.6**
Other prey	**5.5**	**5.7**	**9.7**	**4.8**	**3.8**	**7.2**	**1.8**	**1.0**	**4.7**	**3.8**	**4.8**	**12.7**
Bivalve veligers	–	–	–	<0.1	<0.1	0.6	0.2	0.1	1.0	<0.1	0.1	1.8
Bivalve juveniles	<0.1	<0.1	0.2	0.6	0.5	1.2	–	–	–	–	–	–
Decapods	0.6	0.6	1.7	–	–	–	0.2	0.2	0.3	–	–	–
Gastropods	–	–	–	<0.1	<0.1	1.2	0.2	0.1	1.0	<0.1	0.4	3.6
Paguridae zoea	0.4	0.3	1.0	–	–	–	–	–	–	–	–	–
Polychaetes	0.2	0.1	0.2	3.6	2.7	4.2	0.8	0.5	1.3	1.8	1.8	1.8
Pteropods	–	–	–	–	–	–	0.3	0.2	0.6	–	–	–
Shrimps	–	–	–	0.6	0.6	0.6	–	–	–	1.8	1.8	1.8
All other prey	4.3	4.7	6.8	<0.1	<0.1	<0.1	<0.1	<0.1	1.0	0.1	0.6	3.6
Total number prey	8,155			3,377				9,634		1,254		
Total prey weight (g)	37.2			11.9			14.2			4.4		
Total stomachs	485			166			317			55		
Size range (mm)	35–240			30–191			27–230			30–156		
Avg. size (mm)	89			104			67			96		

Appendix F Table 5. Pelagic Arctic Cod diet summarized by %MW, %MN, and %O in four transect groups (B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC). Major prey categories used in the analysis are in boldface; prey items contributing to the major categories are listed underneath. Summary information including total prey, total prey weight (g), total stomachs, and body size is listed at the end of the table. A dash (–) indicates a prey item that was not consumed by Arctic Cod in a respective transect group.

	Transect groups											
Pelagic Arctic Cod	B1-B2-BX			A4-A5-A6			A1-A2-TBS			GRY-MAC		
Prey	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O
Calanoid copepods	**87.1**	**92.9**	**98.8**	**74.3**	**63.6**	**83.3**	**80.9**	**55.6**	**94.2**	**88.2**	**67.7**	**94.7**
Aetideidae	–	–	–	0.1	1.4	8.3	–	–	–	–	–	–
Calanus glacialis	48.7	44.1	70.2	0.5	0.1	8.3	4.2	1.5	13.1	4.4	1.0	10.5
Calanus hyperboreus	0.8	0.4	2.4	5.4	1.1	8.3	3.6	1.3	5.1	1.2	0.1	1.8
Calanus spp.	–	–	–	3.3	2.7	16.7	2.3	1.1	3.7	1.6	0.7	3.5
Euchaeta spp.	–	–	–	–	–	–	0.2	<0.1	1.5	0.2	<0.1	0.6
Eurytemora spp.	–	–	–	0.1	0.2	8.3	3.7	4.6	24.8	11.4	15.2	52.6
Metridia longa	0.3	0.7	2.4	0.2	0.2	8.3	0.1	0.2	1.5	–	–	–
Paraeuchaeta norvegica	0.5	0.2	1.2	–	–	–	–	–	–	–	–	–
Other Calanoid copepods	36.9	47.6	78.6	64.8	57.9	83.3	66.9	46.9	87.6	69.4	50.6	87.7
Chaetognaths	**9.0**	**1.4**	**19.1**	**–**	**–**	**–**	**1.2**	**0.1**	**1.5**	**–**	**–**	**–**
Cladocerans	**–**	**–**	**–**	**–**	**–**	**–**	**11.1**	**25.0**	**50.4**	**6.8**	**17.6**	**69.6**
Copepod nauplii	**<0.1**	**0.6**	**6.0**	**<0.1**	**5.0**	**58.3**	**0.1**	**3.5**	**13.9**	**<0.1**	**0.8**	**2.9**
Cyclopoid copepods	**0.81**	**2.5**	**4.8**	**0.2**	**10.6**	**58.3**	**3.4**	**9.8**	**27.7**	**0.4**	**6.0**	**36.3**
Hyperiid amphipods	**2.2**	**1.7**	**4.8**	**24.9**	**19.4**	**25.0**	**0.1**	**0.2**	**0.7**	**–**	**–**	**–**
Themisto abyssorum	0.4	0.2	1.2	–	–	–	–	–	–	–	–	–
Themisto libellula	–	–	–	24.7	16.7	25.0	–	–	–	–	–	–
Other Hyperiid amph.	1.8	1.5	3.6	0.2	2.8	8.3	0.1	0.2	0.7	–	–	–
Ostracods	**0.3**	**<0.1**	**1.2**	**0.3**	**0.2**	**8.3**	**0.2**	**0.3**	**2.2**	**–**	**–**	**–**
Other prey	**0.6**	**0.9**	**7.1**	**0.3**	**1.3**	**8.3**	**3.0**	**5.6**	**16.1**	**4.6**	**8.0**	**32.2**
Bivalve veliger	0.5	0.8	6.0	0.3	1.3	8.3	0.8	0.8	5.1	1.4	3.1	25.2
Gastropoda	–	–	–	–	–	–	<0.1	<0.1	0.7	–	–	–
Pteropods	–	–	–	–	–	–	0.5	0.2	0.7	–	–	–
All other prey	0.2	0.1	1.2	–	–	–	1.7	4.6	11.0	3.2	4.9	8.2
Total number prey	2,155			807			10,285			9,953		
Total prey weight (g)	0.3			0.2			0.5			0.3		
Total stomachs	88			12			141			175		
Size range (mm)	29–102			20–132			19–98			22–83		
Avg. size (mm)	49.0			59.0			34.0			33.0		

Appendix F Table 6. Differences in demersal Arctic Cod diet compositions between transect groups as determined by one-way ANOVA and Tukey's method of multiple comparisons. Comparisons were made between the B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC transect groups. Prey items found significantly different in Arctic Cod diet compositions between transect groups are in boldface. The transect group in which %MW of a certain prey item was greatest is in parenthesis below its corresponding t-statistic and p-value. Collection years, depth categories, and size classes were pooled for these comparisons.

Demersal Arctic Cod			Transect group comparisons					
Prey groups	F	p	B1-B2-BX vs A4-A5-A6	B1-B2-BX vs A1-A2-TBS	B1-B2-BX vs GRY-MAC	A4-A5-A6 vs A1-A2-TBS	A4-A5-A6 vs GRY-MAC	A1-A2-TBS vs GRY-MAC
Amphipoda	**16.13**	**0.001***	**t=-6.615,** **p <0.001** **(A4-A5-A6)**	t=-0.063, p=0.999	t=0.634, p=0.917	**t=6.162,** **p <0.001** **(A4-A5-A6)**	**t=-3.244,** **p=0.006** **(A4-A5-A6)**	t=0.586, p=0.932
Calanoid copepods	**42.21**	**0.001***	**t=4.245,** **p<0.001** **(B1-B2-BX)**	**t=-8.477,** **p<0.001** **(A1-A2-TBS)**	t=-0.142, p=0.999	**t=-10.375,** **p<0.001** **(A1-A2-TBS)**	t=2.324, p=0.087	**t=-4.330,** **p<0.001** **(A1-A2-TBS)**
Chaetognaths	**67.56**	**0.001***	**t=9.686,** **p<0.001** **(B1-B2-BX)**	**t=12.467,** **p<0.001** **(B1-B2-BX)**	**t=-6.317,** **p<0.001** **(B1-B2-BX)**	t=0.307, p=0.989	t=-0.179, p=0.998	t=0.011 p=1.000
Cladocerans	**8.245**	**0.001***	t=-0.005, p=1.000	t=-0.138, p= 0.999	**t=4.867,** **p<0.001** **(GRY-MAC)**	t=-0.099, p=1.000	**t=4.448,** **p=0.001** **(GRY-MAC)**	**t=4.672,** **p=0.001** **(GRY-MAC)**
Copepod nauplii	2.219	0.084	—	—	—	—	—	—
Cumaceans	3.227	0.219	t=1.531, p=0.403	**t=2.921,** **p=0.017** **(B1-B2-BX)**	t=-1.492, p=0.427	t=0.765, p=0.863	t=-0.479, p=0.962	t=-0.009, p=1.000
Cyclopoid copepods	**3.360**	**0.018***	**t=-3.058,** **p=0.011** **(A4-A5-A6)**	t=-1.583, p=0.373	t=0.051, p=1.000	t=1.677, p= 0.322	t=-1.721, p=0.299	t=-0.733, p=0.877
Euphausiids	**4.714**	**0.003***	t=-0.564, p=0.939	t=-1.632, p=0.346	**t=3.633,** **p=0.001** **(GRY-MAC)**	t=-0.700, p=0.891	**t=2.996,** **p=0.013** **(GRY-MAC)**	**t=2.732,** **p=0.030** **(GRY-MAC)**
Fish prey	**4.895**	**0.002***	**t=2.736,** **p=0.030** **(B1-B2-BX)**	**t=3.398,** **p=0.003** **(B1-B2-BX)**	t=-1.141, p=0.651	t=-0.006, p=1.00	t=0.538, p=0.947	t=0.569, p=0.938
Hyperiid amphipods	**29.86**	**0.001***	**t=-8.583,** **p<0.001** **(A4-A5-A6)**	t=-2.658, p=0.036	**t=5.258,** **p<0.001** **(GRY-MAC)**	**t=6.052,** **p<0.001** **(A4-A5-A6)**	t=-0.152, p=0.999	**t=3.808,** **p<0.001** **(GRY-MAC)**
Isopods	**16.14**	**0.001***	**t=-6.562,** **p<0.001** **(A4-A5-A6)**	t=0.000, p=1.000	t=0.000, p=1.000	**t=6.159** **p<0.001** **(A4-A5-A6)**	**t=-3.792,** **p<0.001** **(A4-A5-A6)**	t=0.000, p=1.000
Mysids	**2.818**	**0.038***	t=-1.109, p=0.671	t=2.046, p=0.161	t=-1.107, p=0.672	**t=2.583,** **p=0.045** **(A4-A5-A6)**	t=-1.653, p=0.334,	t=-0.067, p=0.999
Ostracods	**9.750**	**0.001***	**t=5.100,** **p<0.001** **(A4-A5-A6)**	t=-0.080, p=0.999	t=-0.191, p=0.997	**t=4.727,** **p<0.001** **(A4-A5-A6)**	**t=-3.122,** **p=0.009** **(A4-A5-A6)**	t=-0.226, p=0.996
Other prey	**2.791**	**0.039***	t=0.438, p=0.970	**t=2.847,** **p=0.021** **(B1-B2-BX)**	t=-0.671, p=0.9027	t=1.735, p=0.291	t=-0.361, p=0.983	t=0.754, p=0.868

Appendix F Table 7. Differences in pelagic Arctic Cod diet compositions between transect groups as determined by one-way ANOVA and Tukey's method of multiple comparisons. Comparisons were made between the B1-B2-BX, A4-A5-A6, A1-A2-TBS, and GRY-MAC transect groups. Prey items found significantly different in Arctic Cod diet compositions between transect groups are in boldface. The transect group in which %MW of a certain prey item was greatest is in parenthesis below its corresponding t-statistic and p-value. Collection years, depth categories, and size classes were pooled for these comparisons.

Pelagic Arctic Cod			Transect group comparisons					
Prey groups	F	p	B1-B2-BX vs A4-A5-A6	B1-B2-BX vs A1-A2-TBS	B1-B2-BX vs GRY-MAC	A4-A5-A6 vs A1-A2-TBS	A4-A5-A6 vs GRY-MAC	A1-A2-TBS vs GRY-MAC
Calanoid copepods	**2.799**	**0.040***	t=1.526, p=0.401	t=1.693, p= 0.308	t=0.385, p=0.979	t=-0.775, p=0.856	t=1.747, p=0.281	*t=2.459, p=0.061* *(GRY-MAC)*
Chaetognaths	**12.32**	**0.001***	**t=2.552, p=0.048** **(B1-B2-BX)**	**t=4.810, p<0.001** **(B1-B2-BX)**	**t=-5.869, p<0.001** **(B1-B2-BX)**	t=-0.378, p=0.980	t=0.000, p=1.000	t=-0.972, p=0.751
Cladocerans	**8.946**	**0.001***	t=0.000, p=1.000	**t=-4.973, p< 0.001** **(A1-A2-TBS)**	**t=3.197, p=0.007** **(GRY-MAC)**	t=-2.307, p=0.089	t=1.435, p=0.456	t=-2.275, p=0.095
Copepod nauplii	**5.031**	**0.002***	t=-0.257, p=0.994	**t=-2.979, p=0.014** **(A1-A2-TBS)**	t=-0.034, p=0.999	t=-1.119, p=0.659	t=-0.280, p=0.992	**t=-3.590, p=0.002** **(A1-A2-TBS)**
Cyclopoid copepods	**3.302**	**0.020***	t=0.212, p=0.996	t=-2.176, p= 0.120	t=-0.334, p= 0.986	t=-1.227, p=0.590	t=0.069, p=1.000	**t=-2.976, p=0.014** **(A1-A2-TBS)**
Hyperiid amphipods	**26.72**	**0.001***	**t=-7.750, p<0.001** **(A4-A5-A6)**	t=1.576, p=0.372	t=-1.741, p=0.284	**t=8.659, p<0.001** **(A4-A5-A6)**	**t=-8.779, p<0.001** **(A4-A5-A6)**	t=-0.111, p=0.999
Ostracods	0.736	0.531	—	—	—	—	—	—
Other prey	1.470	0.222	—	—	—	—	—	—

Appendix F Table 8. Differences in demersal Arctic Cod diet compositions between size classes as determined by one-way ANOVA and Tukey's method of multiple comparisons. Comparisons were made between six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items found significantly different in Arctic Cod diet compositions between size classes are in boldface. The size class in which %MW of a certain prey item was greatest is in parenthesis below its corresponding t-statistic and p-value. Collection years, transect groups, and depth categories were pooled for this analysis.

Demersal Arctic Cod			Comparisons between size classes (mm)				
Prey type	F	P	≤39 vs. 40–49	40–49 vs. 50–59	50–59 vs. 60–79	60–79 vs. 80–169	80–169 vs. 170–240
Amphipoda	**7.212**	**0.001***	t=0.000, p=1.000	t=0.674, p=0.983	t=-0.426, p=0.998	**t=3.355, p=0.009 (80–169)**	t=-1.849, p=0.408
Calanoid copepods	**118.9**	**0.001***	t=1.630 p=0.553	**t=2.923, p=0.037 (40–59)**	**t=-6.448, p<0.001 (50–59)**	**t=-6.583, p <0.001 (60–79)**	t=2.232, p=0.204
Chaetognaths	**16.73**	**0.001***	t=0.265, p=0.999	t=1.701, p=0.505	**t=5.322, p< 0.001 (60–79)**	t=-2.383, p=0.148	t=1.204, p=0.819
Cladocerans	**6.717**	**0.001***	**t=-5.323, p< 0.001 (≤39)**	t=-0.138, p=0.999	t=0.000, p=1.000	t=0.000, p=1.000	t=0.000, p=1.000
Copepod nauplii	**10.81**	**0.001***	**t=-6.680, p<0.001 (≤39)**	t=-0.308, p=1.000	t=-0.001, p=1.000	t=0.000, p=1.000	t=0.000, p=1.000
Cumaceans	**6.947**	**0.001***	t=0.000, p=1.000	t=0.892, p=0.942	**t=4.251, p<0.001 (60–79)**	**t=-5.365, p<0.001 (60–79)**	t=0.328, p=0.999
Cyclopoid copepods	**12.69**	**0.001***	**t=-6.473, p<0.001 (≤39)**	t=-1.447, p=0.676	t=-0.008, p=1.000	t=-0.004, p=1.000	t=0.000, p=1.000
Euphausiids	**4.535**	**0.004***	t=0.000, p=1.000	t=0.000, p=1.000	t=1.023, p=0.900	t=1.939, p=0.354	t=1.782, p=0.451
Fish prey	**122.4**	**0.001***	t=0.000, p=1.000	t=0.000, p=1.000	t=0.000, p=1.000	t=1.321, p=0.754	**t=-23.78, p<0.001 (170–240)**
Hyperiid amphipods	**46.40**	**0.001***	t=0.149, p=1.000	t=-0.086, p=1.000	t=0.309, p=1.000	**t=9.296, p<0.001 (80–169)**	**t=5.032, p<0.001 (80–169)**
Isopods	**2.274**	**0.045***	t=0.000, p=1.000	t=0.000, p=1.000	t=0.000, p=1.000	t=2.107, p=0.262	t=1.194, p=0.825
Mysids	**2.243**	**0.048***	t=0.000, p=1.000	t=0.000, p=1.000	t=1.864, p<0.399	t=-0.131, p=1.000	t=1.171, p=0.836
Ostracods	**3.711**	**0.002***	t=0.000, p=1.000	t=0.000, p=1.000	t=0.238, p=0.999	t=2.497, p=0.113	t=1.231, p=0.805
Other prey	**2.969**	**0.011***	t=-1.497, p=0.642	t=2.634, p=0.080	t=0.994, p=0.911	t=-2.508, p=0.110	t=-0.201, p=0.999

Appendix F Table 9. Differences in pelagic Arctic Cod diet compositions between size classes as determined by one-way ANOVA and Tukey's method of multiple comparisons. Comparisons were made between three size classes (≤39 mm, 40–59 mm, and ≥60 mm). Prey items found significantly different in Arctic Cod diet compositions between size classes are in boldface. The size class in which %MW of a certain prey item was greatest is in parenthesis below its corresponding t-statistic and p-value. Collection years, transect groups, and depth categories were pooled for this analysis.

Pelagic Arctic Cod			Comparisons between size classes (mm)	
Prey group	F	p	≤39 vs. 40–59	40–59 vs ≥60
Calanoid copepods	**18.35**	**0.001***	**t=30.910, p=0.005 (40–59)**	**t=5.906, p<0.001 40–59)**
Chaetognaths	**11.98**	**0.001***	**t=3.433, p<0.001 (40–59)**	**t=-2.270, p=0.056 (≥60)**
Cladocerans	**11.36**	**0.001***	**t=-4.462, p<0.001 (≤39)**	t=0.230, p=.967
Copepod nauplii	0.511	0.600	—	—
Cyclopoid copepods	1.681	0.187	—	—
Hyperiid amphipods	**108.2**	**0.001***	t=0.000, p=1.000	**t=-14.000, p<0.001 (≥60)**
Ostracods	0.266	0.766	—	—
Other prey	**2.905**	**0.050***	**t=-2.374, p=0.043 (≤39)**	t=-1.125, p=0.482

Appendix F Table 10. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod in the B1-B2-BX transect group at depths ≤100 m by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Cladocerans, copepod nauplii, cyclopoid copepods, and isopods were not present in the diet of demersal Arctic Cod at ≤100 m depths within the B1-B2-BX transect group.

Demersal Arctic Cod								
B1-B2-BX ≤100 m (Df=5)			%O of prey groups in Arctic Cod size classes (mm)					
Prey	H	p-value	≤39 (4)	40–49 (40)	50–59 (69)	60–79 (96)	80–169 (59)	170–240 (9)
Amphipoda	**14.28**	**0.014***	**0**	**0**	**0**	**1**	**8**	**0**
Calanoid copepods	**70.43**	**0.001***	**75**	**95**	**88**	**70**	**70**	**44**
Chaetognaths	**60.71**	**0.001***	**0**	**0**	**19**	**54**	**64**	**22**
Cumaceans	**14.51**	**0.013***	**0**	**0**	**3**	**14**	**3**	**0**
Euphausiids	5.771	0.329	—	—	—	—	—	—
Fish prey	**100.5**	**0.001***	**0**	**0**	**0**	**0**	**10**	**67**
Hyperiid amphipods	**50.18**	**0.001***	**0**	**0**	**0**	**0**	**22**	**0**
Mysids	10.05	0.074	—	—	—	—	—	—
Ostracods	**15.70**	**0.008***	**0**	**0**	**0**	**0**	**2**	**11**
Other prey	10.09	0.073	—	—	—	—	—	—

Appendix F Table 11. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod in the B1-B2-BX transect group at depths >100 m by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Cladocerans, copepod nauplii, cyclopoid copepods, and isopods were not present in the diet of demersal Arctic Cod at >100 m depths within the B1-B2-BX transect group.

Demersal Arctic Cod								
B1-B2-BX >100 m (Df=5)			%O of prey groups in Arctic Cod size classes (mm)					
Prey	H	p	≤39 (2)	40–49 (17)	50–59 (25)	60–79 (11)	80–169 (132)	170–240 (21)
Amphipoda	4.329	0.516	—	—	—	—	—	—
Calanoid copepods	**48.49**	**0.001***	**100**	**100**	**88**	**91**	**83**	**52**
Chaetognaths	**30.81**	**0.001***	**0**	**12**	**16**	**18**	**57**	**19**
Cumaceans	3.999	0.550	—	—	—	—	—	—
Euphausiids	0.576	0.989	—	—	—	—	—	—
Fish prey	**86.31**	**0.001***	**0**	**0**	**0**	**0**	**2**	**52**
Hyperiid amphipods	**19.52**	**0.002***	**0**	**0**	**0**	**0**	**25**	**5**
Mysids	1.744	0.883	—	—	—	—	—	—
Ostracods	2.935	0.710	—	—	—	—	—	—
Other prey	4.076	0.538	—	—	—	—	—	—

Appendix F Table 12. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod in the B1-B2-BX transect group between ≤100 and >100 m depths by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between depths and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Cladocerans, copepod nauplii, cyclopoid copepods, and isopods were not present in the diet of demersal Arctic Cod at ≤100 m or >100 m depths within the B1-B2-BX transect group.

Demersal Arctic Cod			%O of prey groups in Arctic Cod diet by size class (mm) and depth (m)											
B1-B2-BX (Df=11)			≤39		40–49		50–59		60–79		80–169		170–240	
			(2,4)		(40,17)		(62,25)		(96,11)		(59,132)		(9,21)	
Prey	H	P	≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100	
Amphipoda	17.80	0.086	—	—	—	—	—	—	—	—	—	—	—	—
Calanoid copepods	**121.0**	**0.001***	**75**	**100**	**95**	**100**	**88**	**88**	**70**	**91**	**70**	**83**	**44**	**52**
Chaetognaths	**92.53**	**0.001***	**0**	**0**	**0**	**12**	**19**	**16**	**54**	**18**	**64**	**57**	**22**	**19**
Cumaceans	**25.56**	**0.008***	**0**	**0**	**0**	**0**	**3**	**0**	**14**	**9**	**3**	**3**	**0**	**0**
Euphausiids	10.31	0.503	—	—	—	—	—	—	—	—	—	—	—	—
Fish prey	**190.0**	**0.001***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**	**2**	**67**	**52**
Hyperiid amphipods	**74.77**	**0.001***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**22**	**25**	**0**	**5**
Mysids	15.010	0.182	—	—	—	—	—	—	—	—	—	—	—	—
Ostracods	15.140	0.176	—	—	—	—	—	—	—	—	—	—	—	—
Other	18.910	0.063	—	—	—	—	—	—	—	—	—	—	—	—

Appendix F Table 13. Kruskal-Wallis one-way ANOVA comparing the diet compositions of pelagic Arctic Cod in the B1-B2-BX transect at depths >100 m by three size classes (≤39 mm, 40–59 mm, and ≥60 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Amphipoda, cladocerans, cumaceans, euphausiids, fish prey, isopods, and mysids were not present in the diet of pelagic Arctic Cod at >100 m depths within the B1-B2-BX transect group.

Pelagic Arctic Cod					
B1-B2-BX >100 m (Df=2)			%O of prey groups in Arctic Cod size classes (mm)		
Prey	H	p	≤39 (9)	40–59 (65)	≥60 (10)
Calanoid copepods	**13.10**	**0.001***	**100**	**100**	**90**
Chaetognaths	3.280	0.194	—	—	—
Copepod nauplii	**13.22**	**0.001***	**33**	**3**	**0**
Cyclopoid copepods	**18.46**	**0.001***	**33**	**2**	**0**
Hyperiid amphipods	**30.69**	**0.001***	**0**	**0**	**40**
Ostracods	**8.333**	**0.016***	**11**	**0**	**0**
Other prey	**20.98**	**0.001***	**44**	**3**	**0**

Appendix F Table 14. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal and pelagic Arctic Cod in the B1-B2-BX transect group at depths >100 m by standardized size classes (≤40 mm, 41–50 mm, 51–60 mm, and 61–132 mm). Prey items that created significant differences in diet compositions between demersal and pelagic Arctic Cod size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes and either the demersal (D) or pelagic (P) region of the water column in which Arctic Cod were collected.

Demersal vs. Pelagic			%O of prey groups in Arctic Cod size classes (mm)							
B1-B2-BX >100 m (Df=7)			≤40		41–50		51–60		61–132	
Prey	H	P	D (2)	P (11)	D (23)	P (47)	D (20)	P (16)	D (111)	P (10)
Amphipoda	5.909	0.550	—	—	—	—	—	—	—	—
Calanoid copepods	**79.27**	**0.001***	**100**	**100**	**96**	**100**	**90**	**100**	**80**	**90**
Chaetognaths	**42.56**	**0.001***	**0**	**18**	**9**	**19**	**20**	**6**	**53**	**40**
Copepod nauplii	**66.95**	**0.001***	**0**	**36**	**0**	**2**	**0**	**0**	**0**	**0**
Cumaceans	3.516	0.834	—	—	—	—	—	—	—	—
Cyclopoid copepods	**47.34**	**0.001***	**0**	**27**	**0**	**2**	**0**	**0**	**0**	**0**
Euphausiids	1.162	0.992	—	—	—	—	—	—	—	—
Fish prey	1.162	0.992	—	—	—	—	—	—	—	—
Hyperiid amphipods	**33.76**	**0.001***	**0**	**0**	**0**	**0**	**0**	**0**	**22**	**40**
Mysids	1.162	0.992	—	—	—	—	—	—	—	—
Ostracods	6.303	0.505	—	—	—	—	—	—	—	—
Other prey	**17.25**	**0.016***	**0**	**36**	**4**	**2**	**5**	**6**	**7**	**0**

Appendix F Table 15. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected at the A4-A5-A6 transect group during 2014 at depths >100 m by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Chaetognaths and cumaceans were not present in demersal Arctic Cod at >100 m depths within the A4-A5-A6 transect group during 2014.

Demersal Arctic Cod								
A4-A5-A6 >100 m (Df=5)			%O of prey groups in Arctic Cod size classes (mm)					
Prey	H	P	≤39 (8)	40–49 (9)	50–59 (4)	60–79 (5)	80–169 (62)	170–240 (1)
Amphipoda	5.106	0.403	—	—	—	—	—	—
Calanoid copepods	**35.26**	**0.001***	**88**	**100**	**100**	**0**	**29**	**0**
Cladocerans	8.444	0.133	—	—	—	—	—	—
Copepod nauplii	**59.01**	**0.001***	**88**	**56**	**0**	**0**	**0**	**0**
Cyclopoids	**62.88**	**0.001***	**100**	**56**	**0**	**0**	**2**	**0**
Euphausiids	0.371	0.996	—	—	—	—	—	—
Fish prey	0.371	0.996	—	—	—	—	—	—
Hyperiid amphipods	**11.34**	**0.045***	**0**	**22**	**50**	**100**	**45**	**0**
Isopods	3.228	0.665	—	—	—	—	—	—
Mysids	1.538	0.909	—	—	—	—	—	—
Ostracods	4.135	0.530	—	—	—	—	—	—
Other	**12.24**	**0.032***	**13**	**0**	**0**	**0**	**10**	**100**

Appendix F Table 16. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected during 2014 in the A4-A5-A6 transect group between ≤100 and >100 m depths by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between depths and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes. Chaetognaths were not present in the diet of demersal Arctic Cod at <100 m or >100 m depths within the A4-A5-A6 transect group during 2014.

Demersal Arctic Cod			%O of prey groups in Arctic Cod diet by size class (mm) and depth (m)											
A4-A5-A6 (Df=10)			≤39 (4,8)		40–49 (6,9)		50–59 (1,4)		60–79 (5,1)		80–169 (6,62)		170–240 (0,1)	
Prey	H	p	≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100	
Amphipoda	13.12	0.217	—	—	—	—	—	—	—	—	—	—	NA	—
Calanoid copepods	**62.51**	**0.001***	**100**	**88**	**100**	**100**	**100**	**100**	**100**	**0**	**100**	**29**	**NA**	**0**
Cladocerans	10.89	0.366	—	—	—	—	—	—	—	—	—	—	NA	—
Copepod nauplii	**65.84**	**0.001***	**25**	**88**	**33**	**56**	**0**	**0**	**0**	**0**	**0**	**0**	**NA**	**0**
Cumaceans	16.83	0.078	—	—	—	—	—	—	—	—	—	—	NA	—
Cyclopoids	**69.08**	**0.001***	**50**	**100**	**33**	**56**	**0**	**0**	**0**	**0**	**0**	**2**	**NA**	**0**
Euphausiids	0.726	1.000	—	—	—	—	—	—	—	—	—	—	NA	—
Fish prey	0.726	1.000	—	—	—	—	—	—	—	—	—	—	NA	—
Hyperiid amphipods	**21.48**	**0.018***	**0**	**0**	**0**	**22**	**100**	**50**	**0**	**100**	**33**	**45**	**NA**	**0**
Isopods	6.205	0.798	—	—	—	—	—	—	—	—	—	—	NA	—
Mysids	4.082	0.944	—	—	—	—	—	—	—	—	—	—	NA	—
Ostracods	7.908	0.638	—	—	—	—	—	—	—	—	—	—	NA	—
Other prey	17.03	0.074	—	—	—	—	—	—	—	—	—	—	NA	—

Appendix F Table 17. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected between 2013 and 2014 sampling years in the A4-A5-A6 transect group at >100 m depths by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between year and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class and year. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a year. Sample sizes are listed underneath the size classes.

Demersal Arctic Cod			%O of prey groups in Arctic Cod diet by size class (mm) and year											
A4-A5-A6 >100 m (Df=8)			≤39 (0,8)		40–49 (0,9)		50–59 (0,4)		60–79 (1, 1)		80–169 (56,62)		170–240 (1,1)	
Prey	H	p	'13	'14	'13	'14	'13	'14	'13	'14	'13	'14	'13	'14
Amphipoda	11.36	0.182	NA	—	NA	—	NA	—	—	—	—	—	—	—
Calanoid copepods	**36.51**	**0.001***	**NA**	**88**	**NA**	**100**	**NA**	**100**	**100**	**0**	**52**	**29**	**0**	**0**
Chaetognaths	6.347	0.608	NA	—	NA	—	NA	—	—	—	—	—	—	—
Cladocerans	14.89	0.061	NA	—	NA	—	NA	—	—	—	—	—	—	—
Copepod nauplii	**102.4**	**0.001***	**NA**	**88**	**NA**	**56**	**NA**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Cumaceans	1.554	0.992	NA	—	NA	—	NA	—	—	—	—	—	—	—
Cyclopoid copepods	**108.0**	**0.001***	**NA**	**100**	**NA**	**56**	**NA**	**0**	**0**	**0**	**0**	**2**	**0**	**0**
Euphausiids	1.190	0.997	NA	—	NA	—	NA	—	—	—	—	—	—	—
Fish prey	1.306	0.995	NA	—	NA	—	NA	—	—	—	—	—	—	—
Hyperiid amphipods	13.14	0.107	NA	—	NA	—	NA	—	—	—	—	—	—	—
Isopods	3.916	0.865	NA	—	NA	—	NA	—	—	—	—	—	—	—
Mysids	3.052	0.931	NA	—	NA	—	NA	—	—	—	—	—	—	—
Ostracods	9.885	0.273	NA	—	NA	—	NA	—	—	—	—	—	—	—
Other prey	14.03	0.081	NA	—	NA	—	NA	—	—	—	—	—	—	—

.

Appendix F Table 18. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected in 2013 in the A1-A2-TBS transect group at depths >100 m by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes. Cladocerans, copepod nauplii, cyclopoid copepods, cumaceans, isopods, and mysids were not present in the diet of demersal Arctic Cod at >100 m depths within the A1-A2-TBS transect group during 2013.

Demersal Arctic Cod								
A1-A2-TBS >100 m (Df=2)			%O of prey groups in Arctic Cod size classes (mm)					
Prey	H	P	≤39 (0)	40–49 (0)	50–59 (0)	60–79 (4)	80–169 (43)	170–240 (1)
Amphipoda	0.364	0.834	NA	NA	NA	—	—	—
Calanoid copepods	**6.396**	**0.041***	**NA**	**NA**	**NA**	**100**	**86**	**0**
Chaetognaths	0.364	0.834	NA	NA	NA	—	—	—
Euphausiids	0.926	0.630	NA	NA	NA	—	—	—
Fish prey	**24.05**	**0.001***	**NA**	**NA**	**NA**	**0**	**2**	**100**
Hyperiid amphipods	2.930	0.231	NA	NA	NA	—	—	—
Ostracods	0.238	0.888	NA	NA	NA	—	—	—
Other prey	0.469	0.780	NA	NA	NA	—	—	—

Appendix F Table 19. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected in 2013 in the A1-A2-TBS transect group at ≤100 m and >100 m depths by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the depths and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An “NA” signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes. Cladocerans, copepod nauplii, cumaceans, and isopods were not present in the diet of demersal Arctic Cod at ≤100 m and >100 m depths within the A1-A2-TBS transect group during 2013.

Demersal Arctic Cod			%O of prey groups in Arctic Cod diet by size class (mm) and depth (m)											
A1-A2-TBS (Df=5)			≤39 (2,0)		40–49 (0,0)		50–59 (0,0)		60–79 (3,4)		80–169 (13,43)		170–240 (0,1)	
Prey	H	p	≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100	
Amphipoda	1.655	0.895	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—
Calanoid copepods	**11.69**	**0.039***	**100**	**NA**	**NA**	**NA**	**NA**	**NA**	**100**	**100**	**100**	**86**	**NA**	**0**
Chaetognaths	4.408	0.492	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—
Cladocerans	**64.99**	**0.001***	**100**	**NA**	**NA**	**NA**	**NA**	**NA**	**0**	**0**	**0**	**0**	**NA**	**0**
Cyclopoid copepods	**32.00**	**0.001***	**50**	**NA**	**NA**	**NA**	**NA**	**NA**	**0**	**0**	**0**	**0**	**NA**	**0**
Euphausiids	7.410	0.192	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—
Fish prey	**33.26**	**0.001***	**0**	**NA**	**NA**	**NA**	**NA**	**NA**	**0**	**0**	**0**	**2**	**NA**	**100**
Hyperiid amphipods	7.507	0.186	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—
Mysids	4.077	0.538	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—
Ostracods	1.086	0.955	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—
Other prey	2.240	0.815	0	NA	NA	NA	NA	NA	—	—	—	—	NA	—

Appendix F Table 20. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected in 2014 in the A1-A2-TBS transect group at depths ≤100 m by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes. Cladocerans, copepod nauplii, isopods, mysids, and ostracods were not present in the diet of demersal Arctic Cod at ≤100 m depths within the A1-A2-TBS transect group during 2014.

Demersal Arctic Cod								
A1-A2-TBS ≤100 m (Df=4)			%O of prey groups in Arctic Cod size classes (mm)					
Prey	H	P	≤39 (12)	40–49 (111)	50–59 (61)	60–79 (2)	80–169 (10)	170–240 (0)
Amphipoda	8.334	0.080	—	—	—	—	—	NA
Calanoid copepods	**21.01**	**0.001***	**100**	**100**	**100**	**100**	**80**	**NA**
Chaetognaths	6.059	0.195	—	—	—	—	—	NA
Cumaceans	2.213	0.697	—	—	—	—	—	NA
Cyclopoids	9.915	0.056	—	—	—	—	—	NA
Euphausiids	**18.60**	**0.001***	**0**	**0**	**0**	**0**	**10**	**NA**
Fish prey	**18.60**	**0.001***	**0**	**0**	**0**	**0**	**10**	**NA**
Hyperiid amphipods	**23.71**	**0.001***	**0**	**1**	**0**	**0**	**20**	**NA**
Other prey	9.451	0.051	—	—	—	—	—	NA

Appendix F Table 21. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected in 2014 in the A1-A2-TBS transect group at depths >100 m by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Cladocerans, cumaceans, isopods, and mysids were not present in the diet of demersal Arctic Cod at >100 m depths within the A1-A2-TBS transect group during 2014.

Demersal Arctic Cod								
A1-A2-TBS >100 m (Df=5)			%O of prey groups in Arctic Cod size classes (mm)					
Prey	H	p	≤39 (4)	40–49 (21)	50–59 (2)	60–79 (3)	80–169 (24)	170–240 (1)
Amphipoda	**17.19**	**0.004***	**0**	**0**	**0**	**0**	**13**	**100**
Calanoid copepods	**35.98**	**0.001***	**50**	**100**	**100**	**100**	**50**	**0**
Chaetognaths	0.471	0.993	—	—	—	—	—	—
Copepod nauplii	**20.48**	**0.001***	**75**	**43**	**50**	**0**	**0**	**0**
Cyclopoid copepods	**28.38**	**0.001***	**100**	**48**	**50**	**0**	**0**	**0**
Euphausiids	4.020	0.546	—	—	—	—	—	—
Fish prey	1.292	0.936	—	—	—	—	—	—
Hyperiid amphipods	**38.96**	**0.001***	**0**	**0**	**0**	**33**	**88**	**0**
Ostracods	10.87	0.054	—	—	—	—	—	—
Other prey	9.809	0.081	—	—	—	—	—	—

Appendix F Table 22. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected in 2014 in the A1-A2-TBS transect group at ≤100 m and >100 m depths by six size classes (≤39 mm, 40–49 mm, 50–59 mm, 60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between the depths and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, percent occurrence (%O) values were listed underneath the corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes. Cladocerans, cumaceans, and isopods were not present in the diet of demersal Arctic Cod at ≤100 m and >100 m depths within the A1-A2-TBS transect group during 2014.

Demersal Arctic Cod			%O of prey groups in Arctic Cod diet by size class (mm) and depth (m)											
A1-A2-TBS (Df=10)			≤39 (12,4)		40–49 (111,21)		50–59 (61,2)		60–79 (2,3)		80–169 (10,24)		170–240 (0,1)	
Prey	H	p	100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100		≤100,>100	
Amphipoda	**45.64**	**0.001***	**0**	**0**	**0**	**0**	**5**	**0**	**0**	**0**	**10**	**13**	**NA**	**100**
Calanoid copepods	**138.3**	**0.001***	**100**	**50**	**100**	**100**	**100**	**100**	**100**	**100**	**80**	**50**	**NA**	**0**
Chaetognaths	6.534	0.769	—	—	—	—	—	—	—	—	—	—	NA	—
Copepod nauplii	**121.5**	**0.001***	**0**	**75**	**0**	**43**	**0**	**50**	**0**	**0**	**0**	**0**	**NA**	**0**
Cumaceans	3.115	0.979	—	—	—	—	—	—	—	—	—	—	NA	—
Cyclopoid copepods	**87.99**	**0.001***	**0**	**100**	**7**	**48**	**5**	**50**	**50**	**0**	**0**	**0**	**NA**	**0**
Euphausiids	**26.11**	**0.004***	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10**	**13**	**NA**	**0**
Fish prey	15.90	0.102	—	—	—	—	—	—	—	—	—	—	NA	—
Hyperiid amphipods	**188.6**	**0.001***	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**33**	**20**	**88**	**NA**	**0**
Ostracods	**77.11**	**0.001***	**0**	**0**	**0**	**0**	**7**	**0**	**0**	**33**	**10**	**33**	**NA**	**0**
Other prey	**35.73**	**0.001***	**0**	**50**	**0**	**10**	**5**	**0**	**0**	**33**	**10**	**4**	**NA**	**100**

Appendix F Table 23. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected between 2013 and 2014 sampling years in the A1-A2-TBS transect group at ≤100 m depths by three size classes (≤39 mm, 60–79 mm, and 80–169 mm). Prey items that created significant differences in diet compositions between year and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class and year. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Within these specific size classes, copepod nauplii, cumaceans, isopods, and ostracods were not present in the diet of demersal Arctic Cod at ≤100 m depths within the A1-A2-TBS transect group during 2013 and 2014.

Demersal Arctic Cod			%O of prey groups in Arctic Cod size classes (mm) by year					
A1-A2-TBS ≤100 m (Df=5)			≤39 (2,12)		60–79 (3,2)		80–169 (13,10)	
Prey	H	p	‘13	‘14	‘13	‘14	‘13	‘14
Amphipoda	3.200	0.669	—	—	—	—	—	—
Calanoid copepods	**15.81**	**0.007***	**100**	**100**	**100**	**100**	**100**	**80**
Chaetognaths	4.445	0.487	—	—	—	—	—	—
Cladocerans	**40.98**	**0.001***	**100**	**0**	**0**	**0**	**0**	**0**
Cyclopoid copepods	**19.48**	**0.002***	**50**	**0**	**0**	**50**	**0**	**0**
Euphausiids	**11.84**	**0.037***	**0**	**0**	**0**	**0**	**46**	**10**
Fish prey	3.200	0.669	—	—	—	—	—	—
Hyperiid amphipods	**13.72**	**0.017***	**0**	**0**	**0**	**0**	**54**	**20**
Mysids	2.231	0.816	—	—	—	—	—	—
Other prey	3.200	0.669	—	—	—	—	—	—

Appendix F Table 24. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal Arctic Cod collected between 2013 and 2014 sampling years in the A1-A2-TBS transect group at >100 m depths by three size classes (60–79 mm, 80–169 mm, and 170–240 mm). Prey items that created significant differences in diet compositions between year and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class and year. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Within these specific size classes, cladocerans, copepod nauplii, cyclopoid copepods, cumaceans, isopods, and mysids were not present in the diet of demersal Arctic Cod at >100 m depths within the A1-A2-TBS transect group during 2013 and 2014.

Demersal Arctic Cod			%O of prey groups in Arctic Cod size classes (mm) by year					
A1-A2-TBS >100 m (Df=6)			60–79 (4,3)		80–169 (43,24)		170–240 (1,1)	
Prey	H	p	‘13	‘14	‘13	‘14	‘13	‘14
Amphipoda	**12.69**	**0.026***	**0**	**0**	**7**	**13**	**0**	**100**
Calanoid copepods	**27.77**	**0.001***	**100**	**100**	**86**	**50**	**0**	**0**
Chaetognaths	0.846	0.974	—	—	—	—	—	—
Euphausiids	1.750	0.883	—	—	—	—	—	—
Fish prey	**22.95**	**0.001***	**0**	**0**	**2**	**4**	**100**	**0**
Hyperiid amphipods	**23.60**	**0.001***	**25**	**33**	**58**	**88**	**0**	**0**
Ostracods	**12.01**	**0.035***	**0**	**33**	**5**	**33**	**0**	**0**
Other prey	3.435	0.633	—	—	—	—	—	—

Appendix F Table 25. Kruskal-Wallis one-way ANOVA comparing the diet compositions of pelagic Arctic Cod collected between 2013 and 2014 sampling years in the A1-A2-TBS transect group at >100 m depths by two size classes (≤39 mm and 40–59 mm). Prey items that created significant differences in diet compositions between year and size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class and year. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. Sample sizes are listed underneath the size classes. Within these specific size classes, Amphipoda, cumaceans, euphausiids, hyperiid amphipods, fish prey, isopods, and mysids were not present in the diet of pelagic Arctic Cod at >100 m depths within the A1-A2-TBS transect group during 2013 and 2014.

Pelagic Arctic Cod			%O of prey groups in Arctic Cod size classes (mm) by year			
A1-A2-TBS >100 m (Df=3)			≤39 (51,10)		40–59 (8,6)	
Prey	H	p	‘13	‘14	‘13	‘14
Calanoid copepods	**11.21**	**0.011***	**95**	**91**	**89**	**100**
Chaetognaths	**8.177**	**0.042***	**0**	**10**	**0**	**17**
Cladocerans	**16.60**	**0.001***	**56**	**0**	**67**	**0**
Copepod nauplii	**49.06**	**0.001***	**0**	**82**	**33**	**50**
Cyclopoid copepods	**47.07**	**0.001***	**16**	**91**	**22**	**100**
Ostracods	0.471	0.925	—	—	—	—
Other prey	0.233	0.972	—	—	—	—

Appendix F Table 26. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal and pelagic Arctic Cod during 2013 in the A1-A2-TBS transect group at depths >100 m by standardized size classes (≤40 mm, 41–50 mm, 51–60 mm, and 61–132 mm). Prey items that created significant differences in diet compositions between demersal and pelagic Arctic Cod size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes and either the demersal (D) or pelagic (P) region of the water column in which Arctic Cod were collected. Cumaceans, isopods, and mysids were not present in the diet of demersal or pelagic Arctic Cod during 2013 in the A1-A2-TBS transect group at >100 m depths.

Demersal vs. pelagic			%O of prey groups in Arctic Cod size classes (mm)							
A1-A2-TBS >100 m (Df=3)			≤40		41–50		51–60		61–132	
Prey	H	P	D (0)	P (52)	D (0)	P (7)	D (0)	P (0)	D (38)	P (1)
Amphipoda	3.190	0.363	NA	—	NA	—	NA	NA	—	—
Calanoid copepods	5.092	0.165	NA	—	NA	—	NA	NA	—	—
Chaetognaths	3.190	0.363	NA	—	NA	—	NA	NA	—	—
Cladocerans	**35.18**	**0.001***	**NA**	**62**	**NA**	**47**	**NA**	**NA**	**0**	**0**
Copepod nauplii	**39.81**	**0.001***	**NA**	**0**	**NA**	**43**	**NA**	**NA**	**0**	**0**
Cyclopoid copepods	**8.335**	**0.040***	**NA**	**19**	**NA**	**14**	**NA**	**NA**	**0**	**0**
Euphausiids	**8.227**	**0.042***	**NA**	**0**	**NA**	**0**	**NA**	**NA**	**13**	**0**
Fish prey	1.579	0.664	NA	—	NA	—	NA	NA	—	—
Hyperiid amphipods	**40.97**	**0.001***	**NA**	**0**	**NA**	**0**	**NA**	**NA**	**55**	**0**
Ostracods	0.227	0.973	NA	—	NA	—	NA	NA	—	—
Other prey	1.718	0.633	NA	—	NA	—	NA	NA	—	—

Appendix F Table 27. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal and pelagic Arctic Cod during 2014 in the A1-A2-TBS transect group at depths >100 m by standardized size classes (≤40 mm, 41–50 mm, 51–60 mm, and 61–132 mm). Prey items that created significant differences in diet compositions between demersal and pelagic Arctic Cod size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An "NA" signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes and either the demersal (D) or pelagic (P) region of the water column in which Arctic Cod were collected. Cladocerans, cumaceans, fish prey, isopods, and mysids were not present in the diet of demersal or pelagic Arctic Cod during 2014 in the A1-A2-TBS transect group at >100 m depths.

Demersal vs. Pelagic			%O of prey groups in Arctic Cod size classes (mm)							
A1-A2-TBS >100 m (Df=6)			≤40		41–50		51–60		61–132	
Prey	H	p	D (6)	P (12)	D (20)	P (4)	D (1)	P (0)	D (22)	P (1)
Amphipoda	6.187	0.403	–	–	–	–	–	NA	–	–
Calanoid copepods	**33.71**	**0.001***	**67**	**92**	**100**	**100**	**100**	**NA**	**50**	**100**
Chaetognaths	5.883	0.436	–	–	–	–	–	NA	–	–
Copepod nauplii	**27.24**	**0.001***	**67**	**75**	**45**	**75**	**0**	**NA**	**0**	**0**
Cyclopoid copepods	**43.86**	**0.001***	**83**	**100**	**50**	**100**	**0**	**NA**	**0**	**0**
Euphausiids	4.062	0.668	–	–	–	–	–	NA	–	–
Hyperiid amphipods	**44.20**	**0.001***	**0**	**0**	**0**	**0**	**0**	**NA**	**77**	**100**
Ostracods	**19.59**	**0.003***	**0**	**0**	**0**	**0**	**0**	**NA**	**27**	**0**
Other prey	**17.14**	**0.009***	**50**	**17**	**5**	**0**	**0**	**NA**	**9**	**100**

Appendix F Table 28. Kruskal-Wallis one-way ANOVA comparing the diet compositions of demersal and pelagic Arctic Cod during 2013 in the GRY-MAC transect group at depths >100 m by standardized size classes (≤40 mm, 41–50 mm, 51–60 mm, and 61–132 mm). Prey items that created significant differences in diet compositions between demersal and pelagic Arctic Cod size classes are in boldface. To approximate the size class or classes that consumed the highest amount of a significantly different prey item, %O values were listed underneath their corresponding Arctic Cod size class. A dash (–) in the %O column indicates a prey type was not significantly different by Kruskal-Wallis analysis. An “NA” signifies that no fish were available for comparisons for a size class within a depth category. Sample sizes are listed underneath the size classes and either the demersal (D) or pelagic (P) region of the water column in which Arctic Cod were collected. Cumaceans, isopods, or mysids were not present in the diet of demersal or pelagic Arctic Cod during 2013 in the GRY-MAC transect group at >100 m depths.

Demersal vs. Pelagic			%O of prey groups in Arctic Cod size classes (mm)							
GRY-MAC >100 m (Df=5)			≤40		41–50		51–60		61–132	
Prey	H	p	D (6)	P (89)	D (2)	P (12)	D (0)	P (0)	D (39)	P (1)
Amphipoda	8.576	0.172	–	–	–	–	NA	NA	–	–
Calanoid copepods	9.984	0.076	–	–	–	–	NA	NA	–	–
Chaetognaths	2.821	0.728	–	–	–	–	NA	NA	–	–
Cladocerans	**64.08**	**0.001***	**67**	**82**	**50**	**67**	**NA**	**NA**	**0**	**0**
Copepod nauplii	0.674	0.984	–	–	–	–	NA	NA	–	–
Cyclopoid copepods	**19.96**	**0.001***	**33**	**36**	**0**	**25**	**NA**	**NA**	**0**	**0**
Euphausiids	5.679	0.339	–	–	–	–	NA	NA	–	–
Fish prey	2.821	0.728	–	–	–	–	NA	NA	–	–
Hyperiid amphipods	**53.50**	**0.001***	**0**	**0**	**0**	**0**	**NA**	**NA**	**43**	**0**
Ostracods	**14.49**	**0.013***	**0**	**0**	**0**	**0**	**NA**	**NA**	**13**	**0**
Other prey	6.435	0.266	–	–	–	–	NA	NA	–	–

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

Appendix G

Diets of Three Families of Demersal Fishes in the Beaufort Sea: Agonidae, Cottidae and Stichaeidae

Author
Ben Gray

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Table of Contents

Diets of Three Families of Demersal Fishes in the Beaufort Sea: Agonidae, Cottidae and Stichaeidae

Introduction

Fishes are important links between lower and upper trophic levels in Arctic marine food webs (Lowry et al. 1980; Coyle et al. 1997), yet little published information exists on the diets of species other than Arctic Cod (*Boreogadus saida*). This research focuses on the diets of seven, primarily demersal fishes distributed throughout the Transboundary study area. These seven species represent three families commonly encountered by bottom-trawling surveys in the western Arctic: Agonidae (Poachers), Cottidae (Sculpins), and Stichaidae (Pricklebacks; Barber et al. 1997; Norcross et al. 2013). In this study, family Agonidae is represented by the Arctic Alligatorfish (*Aspidophoroides olrikii*), family Cottidae by Hamecon (*Artediellus scaber*), Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*), Spatulate Sculpin (*Icelus spatula*), and Ribbed Sculpin (*Triglops pingelii*), and family Stichaeidae by the Stout Eelblenny (*Anisarchus medius*) and Slender Eelblenny (*Lumpenus fabricii*).

Because fishes were collected using bottom trawls, their diets are generally expected to be composed of mostly benthic and epibenthic macroinvertebrates. This is supported by various published accounts of their diets in the northern Bering Sea (*A. olrikii* and *G. tricuspis*; Cui et al. 2012), the northeastern Chukchi Sea (*G. tricuspis*; Coyle et al. 1997; Gray 2015), the U.S. Beaufort Sea (*G. tricuspis*; Gray 2015), the Canadian Beaufort Sea (*A. olrikii*, *G. tricuspis*, *T. pingelii*, and *L. fabricii*; Atkinson and Percy 1992), and near Baffin Island, Canada (*A. olrikii*, *G. tricuspis*, *I. spatula*, and *T. pingelii*; Atkinson and Percy 1992). Within these respective regions, benthic amphipods were eaten by all species, bivalve siphons by *A. olrikii* and *G. tricuspis*, mysids by *I. spatula* and *T. pingelii*, and polychaetes by *G. tricuspis* and *L. fabricii* (Atkinson and Percy 1992; Coyle et al. 1997; Cui et al. 2012; Gray 2015). Unlike the other species, *T. pingelii* also consumes pelagic zooplankton such as calanoid copepods and hyperiid amphipods (Atkinson and Percy 1992). To the best of our knowledge, no published diet data exists for *A. scaber* and *A. medius*.

The goals of this research are to examine both inter- and intraspecific diet variation among these seven fish species within the Transboundary study area and to recommend size classes for each species based on ontogenetic shifts in their diet. This is accomplished through 1) a complete description of each species' diet, 2) an interspecific diet comparison using nonmetric multidimensional scaling (nMDS), 3) an intraspecific diet comparison using canonical correspondence analysis (CCA), and 4) species-specific size class analyses using Bray-Curtis distance measures (i.e., nMDS or cluster analysis). High interspecific diet variability is likely given differences in habitat and fish body morphologies; however, groups of fish species can consume very similar diets and thereby be classified into feeding guilds (Root 1967; Garrison and Link 2000). Intraspecific diet variability could arise in a multitude of ways, here we consider biological, spatial, and temporal (i.e., cruise year) factors. Changes in fish length is a biological example. As fishes grow larger, their diets typically change (Werner and Gilliam 1984; Labropoulou and Eleftheriou 1997). Latitude, longitude, and depth are examples of spatial factors that influence the distribution of fish communities (Norcross et al. 2013), and their prey, i.e., benthic macroinvertebrates (Iken et al. 2010; Blanchard et al. 2013) and pelagic zooplankton (Ashijian et al. 2005; Hopcroft et al. 2010) in the western Arctic. Depending on sampling year, prey availability could differ due to variability in sea ice retreat, water mass formation, and terrestrial hydrographic conditions (Walkusz et al. 2013). Examining both inter- and intraspecific sources of diet variability offers a comprehensive account of these fishes' food habits and advances our knowledge of lesser-known fishes in Arctic food webs.

Methods

Laboratory methods

Initial fish length and weight measurements, along with all processes associated with stomach contents analysis, took place at the University of Alaska Fairbanks (UAF) fisheries oceanography laboratory. Fishes were thawed, individually blotted with tissue paper, weighed to the nearest 0.01 g, and measured for total length in millimeters. Whole stomachs (defined as esophagus to pyloric valve) were removed, placed in petri dishes, and frozen in fresh water until examined. Stomachs were opened and prey was identified using a dissecting microscope. At 6x to 100x magnification, all recognizable prey were identified to the lowest taxonomic level using keys (Barnard 1969; Gardner and Szabo 1982; Vassilenko and Petryashov 2009) or through consultation with invertebrate specialists. Once identified, the wet weight of each prey item was recorded to the nearest 0.0001 g.

Due to the diversity of prey consumed by fish in the transboundary study area, all identifiable prey were aggregated into broader taxonomic groups at the level of order or sub-order for descriptive and statistical comparisons. Overall, 11 prey groups were chosen to concisely summarize and compare the fishes' diets: unidentified amphipods [(hereafter, amphipods (unid.)], benthic amphipods, calanoid copepods, other copepods, cumaceans, fish prey, hyperiid amphipods, isopods, ostracods, polychaetes, and "other prey." Benthic prey included benthic amphipods, cumaceans, isopods, ostracods, polychaetes, and other copepods, while pelagic prey included calanoid copepods and hyperiid amphipods. Fish prey and "other prey" were either benthic or pelagic depending on the type consumed. "Other prey" were generally rare and included various species of ascidians, bivalves, chaetognaths, crabs, cyprids, decapods, euphausiids, gastropods, marine worms, mysids, nematodes, shrimps, and tanaids. Unidentifiable animal tissues and crustacean fragments were excluded from statistical analyses due to their lack of ecological interpretability, but kept in the descriptive analyses because of their high occurrence in each of the fishes' diets.

Prey items were in various stages of digestion, which was a potential source of error in determining the importance, by weight, of those prey items to fish diets. To address this potential error, we determined average weight-at-length values of all prey taxa consumed by fish throughout the Transboundary study area (Appendix G Table 1). This was accomplished using prey count, length, and weight data from all available UAF fisheries oceanography laboratory studies that focused on fish diets. The taxa-specific averages were then multiplied by prey counts to assign prey weights to all fish stomachs used in this diet study.

Some prey items were very small, i.e., <0.5 mm, and thus did not register a weight value on a 0.0001 g mass balance. This scenario was particularly noticeable in the diets of smaller fishes. If an individual fish ate enough of the same, small prey taxa, it was possible to develop an average weight value per individual from their combined weight in a stomach. When this was not possible, we assigned a weight to a prey item using values from peer-reviewed literature (Appendix G Table 1). These methods allowed for a more accurate representation of the importance of small prey by weight.

Three diet indices were used to characterize fish diets: percent mean weight (%MW), percent mean number (%MN), and percent occurrence (%O). Percent mean weight was calculated as: $\%MW_i=1/P\times(\sum[W_{ij}/\sum W_{ij}])\times 100$, where ($\%MW_i$) is the percent mean weight of prey i consumed by a predator, W_{ij} is the weight of prey i in a single predator j, and ΣW_{ij} is the sum of all prey weights in the stomach of a single predator j. The sums of this calculation for each prey item over the entire sample were divided by the number of fish with food in their stomachs (P). Percent mean number (%MN) was calculated similarly. Percent occurrence (%O) was calculated as: $\%O=[O_i/P] \text{ x } 100$, where %O is defined as the occurrence of a prey group i divided by the sum of non-empty stomachs (P). Each diet index offers unique information about fish diet composition within a category of interest. Percent mean weight values can be used as an indicator of the energetic importance of prey types to a fish population (Hyslop 1980; Chipps and Garvey 2007). Alternatively, %MN gives information about the numerical importance of prey in the diets, and %O indicates the percentage of individuals in the sampled population that ate a specific prey type (Hyslop 1980; Chipps and Garvey 2007, Baker et al. 2014). We ultimately chose %MW for statistical analyses because it represented prey energetic importance and was the most comparable method.

Cumulative prey curves were generated at both fine and broad taxonomic levels to determine how adequately diets were described by our sample sizes and to visualize overall differences in diet diversity. This method plots the occurrence of novel prey taxa or prey groups against a running total of examined stomachs (Chipps and Garvey 2007). Fish diet diversity is said to be adequately described when the curve is close to an asymptote. Cumulative prey curves were constructed using the species-accumulation plot function in PRIMER v7 multivariate statistics package. Following the methods outlined in Hallett and Daley (2011), we randomized fish stomach contents data across 999 permutations using a bootstrap method that removed biases associated with plotting the accumulation of prey types by sample order and allowed for a visualization of any major trends in prey use.

Statistical analyses

The interspecific, guild analysis was conducted by pooling %MW diet data by fish species into the 11 coarse prey categories and using nonmetric multidimensional scaling (nMDS). This Bray-Curtis distance based ordination method was used to show relationships between fish diets in multidimensional space, with fish species closer together having more similar diets than those further apart (Quinn and Keough 2002). Vectors were overlain to show the specific prey groups that drove differences between fish species. The degree to which the nMDS ordination fit relationships between fish diet compositions was evaluated by a stress statistic, with a value less than 0.10 considered a good fit (Clarke 1993). All statistical tests associated with nMDS were conducted in PRIMER v7.

Intraspecific diet variability was examined using canonical correspondence analysis (CCA). This method treated each fish stomach as an individual sampling unit, with the 11 coarse prey groups representing multivariate response variables. Biological data (i.e., fish length), along with environmental data (i.e., latitude, longitude, depth, and cruise year) were assigned to each fish stomach, where available, and included as continuous predictor variables. An initial permutation test at a 5% significance level was conducted to determine if a significant relationship existed between the multivariate diet data and the selected predictor variables. If the test was significant, a full CCA analysis took place. As outlined in Jaworski and Ragnarsson (2006) and Gray et al. (2015), we used CCA to generate ordination plots for fishes in the Transboundary study area by regressing the selected predictor variables against axes from a correspondence analysis on the multivariate diet data. The resulting ordinations show prey groups consumed by fishes as weighted averages with vectors indicating the correlation between our biological and environmental predictor variables and each axis (Quinn and Keough 2002). The significance of the predictor variables was determined using an additional permutation test at a 5% significance level. All statistical tests associated with CCA were conducted in the vegan library of R. As a graphic aid, fish stomachs used in CCA were plotted categorically by fish length, depth, latitude, longitude, and cruise year to visualize sample distributions (Figures 1–5).

Size class analysis

To recommend size classes for future diet studies, we used two Bray-Curtis-distance-based methods, i.e., nMDS or cluster analysis, to find groupings in size intervals. These intervals (e.g., 21–30 or 91–150 mm) were grouped in a way that included at least a sample size of four individuals per interval. We used nMDS for comparisons if there were more than four size intervals (groups) with which to calculate differences between. Cluster analysis was used for fish species where only three size intervals were available with which to calculate differences between. Therefore, nMDS was used to determine the size classes of *A. olrikii*, *G. tricuspis*, and *I. spatula*, and cluster analysis for *A. medius*, *T. pingelii*, and *L. fabricii*. Size classes were determined when size intervals grouped at similarity percentages >55 %. It was not possible to assign size classes for *A. scaber* due to small sample sizes.

Results

A total of 928 fish stomachs containing both identifiable and unidentifiable prey were included in the initial descriptive %MW, %MN, and %O-based analyses. Of these 928 stomachs, 757 contained identifiable prey (*A. olrikii*=135, *A. scaber*=8, *G. tricuspis*=382, *I. spatula*=134, *T. pingelii*=34, *A. medius*=27, *L. fabricii*=37) and were included in statistical, %MW-based analyses. A total of 198 fish stomachs were empty (*A. olrikii*=110, *G. tricuspis*=45, *I. spatula*=10, *T. pingelii*=4, *A. medius*=5, *L. fabricii*=24) thus not included in this research. In general, the initial descriptive analyses determined that amphipods (unid.) were consumed in highest amounts by *A. olrikii* (Appendix G Table 2; Figure 6). Benthic macroinvertebrates, including benthic crustaceans (i.e., benthic amphipods, cumaceans, isopods, ostracods, and other copepods) and polychaetes were consumed in greatest amounts by *A. scaber*, *G. tricuspis*, *I. spatula*, *A. medius*, and *L. fabricii* (Appendix G Tables 3, 4; Figure 6). *T. pingelii* consumed the greatest amount of pelagic prey (i.e., calanoid copepods and hyperiid amphipods), fish prey, and other prey, which included two other pelagic prey groups, chaetognaths and euphausiids (Appendix GTable 3; Figure 6). Unidentifiable prey composed a large proportion of each species' diet (Appendix G Tables 2–4; Figure 6). The overall amount of identifiable prey and prey biomass in each species' diet generally increased with increasing stomach sample sizes, although *L. fabricii* consumed a large amount of identifiable prey relative to the small amount of stomachs available for this species (Appendix G Tables 2–4).

Each species consumed a diverse array of prey taxa and consequently, when prey were analyzed to the lowest possible taxon, cumulative prey curves did not attain an asymptote (i.e., more stomachs were needed to describe each species' diet; Figure 7A). At our level of prey identification, the lowest taxonomic prey curves indicated that *G. tricuspis* consumed the most diverse diet with over 100 unique prey taxa consumed, followed in decreasing order of diet diversity by *I. spatula*, *T. pingelii*, *L. fabricii*, *A. olrikii*, *A. medius*, and *A. scaber* (Figure 7A). Fish diets were generally better described when prey taxa were aggregated into the 11 taxonomic groups based on order and suborder (Figure 7B). At this level of identification, cumulative prey curves for *G. tricuspis*, *I. spatula*, and *L. fabricii* appeared to attain asymptotes at about 50 stomachs, while curves for *A. olrikii*, *A. scaber*, *A. medius*, and *T. pingelii* did not (Figure 7B). Although the *A. olrikii* cumulative prey curve did not reach an asymptote, we considered its diet as sufficiently described given most prey groups were accounted for in the 170 stomachs containing identifiable prey. *A. scaber*, *A. medius*, and *T. pingelii* diets were not as well described, but kept in the guild, CCA, and size class analyses, where appropriate, because little information exists regarding their food habits.

Statistical analyses

Analysis by nMDS at the 60% similarity level found evidence of two guilds: benthic crustacean consumers (*A. medius* and *L. fabricii*) and benthic crustacean/macroinvertebrate consumers (*A. scaber*, *I. spatula*, and *G. tricuspis*; Appendix G Figure 8). Cumaceans, ostracods, and other copepods composed the benthic crustaceans group and benthic amphipods, isopods and polychaetes composed the benthic crustaceans/macroinvertebrate group (Appendix G Figure 8). The findings for *A. olrikii* (mostly amphipod consumers) and *T. pingelii* (mostly pelagic zooplankton and fish consumers) were similar to those highlighted by the descriptive analyses (Tables 2–4; Appendix G Figure 6).

The initial permutation test at a 5% significance level found significant relationships between the predictor variables used in the CCA analyses (i.e., fish length, depth, latitude, longitude, and year) and the multivariate diet data for *A. olrikii*, *G. tricuspis*, and *I. spatula* (p=0.001–0.031; Appendix G Table 5). A similar, significant relationship was found for *L. fabricii* (p=0.031; Appendix G Table 5), however, all specimens were collected during 2012 at fairly similar latitudes and longitudes making fish length and depth the most appropriate variables for the analysis. The relationship between the predictor variables and the multivariate diet data was not significant for *A. scaber*, *T. pingelii*, and *A. medius* (p=0.182–0.519; Appendix G Table 5). In light of these findings, only the diet compositions of *A. olrikii*, *G. tricuspis*, *I. spatula*, and *L. fabricii* are considered in the full CCA analyses.

Aspidophoroides olrikii

The continuous predictors of fish length, depth, latitude, longitude, and year accounted for 10% of the total variance explained in *A. olrikii* diet composition (Appendix G Table 6). The first two canonical axes (i.e., CCA1 and CCA2, respectively) accounted for 94.7% (CCA1=58.7%; CCA2=36.0%) of the total variance in *A. olrikii* diet (i.e., 10%). At the 5% significance level, year and longitude were found as significant predictors of *A. olrikii* diet composition (p=0.001 and 0.007, respectively; Appendix G Table 6). Fish length, depth, and latitude were not significant as continuous predictors of *A. olrikii* diet composition (p=0.171–0.529; Appendix G Table 6) thus are not included in figures.

Year was moderately correlated with CCA1 and longitude with CCA2 (Appendix G Table 6; Figure 9). CCA1 mostly highlighted a negative correlation in polychaete consumption with greatest proportions consumed by *A. olrikii* during the 2012 cruise year (Figures 9, 10A). CCA2 highlighted an increase in polychaete consumption with increasing longitude and a decrease in calanoid copepod, cumacean, isopod, and other copepod proportions with increasing longitude; however, each of these latter four prey types, were consumed very rarely thus not reported in the %MW longitude figure (Appendix G Figure 10B). The greatest contributors to *A. olrikii* diet, i.e., amphipods (unid.) and benthic amphipods, were consumed in high proportions with little apparent influence by all factors (Figures 9, 10A and 10B).

Gymnocanthus tricuspis and Icelus spatula

The continuous predictors of fish length, depth, latitude, longitude, and year accounted for 8–10% of the total variance explained in *G. tricuspis* and *I. spatula* diets (Appendix G Table 6). The first two canonical axes (i.e., CCA1 and CCA2, respectively) accounted for 81.7% (CCA1=55.2%; CCA2=26.5%) of the total variance in *G. tricuspis* diet (i.e., 8%) and 79.8% (CCA1=53.7%; CCA2=26.1%) of the total variance in *I. spatula* diet (i.e., 10%). At the 5%

significance level, all variables considered were significant predictors of *G. tricuspis* diet (p=0.001–0.005; Appendix G Table 6). Fish length, latitude, and year were the only significant predictors of *I. spatula* diet (p=0.001–0.012; Appendix G Table 6).

For *G. tricuspis*, fish length was highest correlated with CCA1, while year, latitude, longitude, and depth showed moderate-to-low correlations with both CCA1 and CCA2 (Appendix G Table 6; Figure 11). With an increase in fish length, CCA1 primarily highlighted an increase in the proportions of benthic amphipods, fish prey, and polychaetes in *G. tricuspis* diet (Figures 11, 12A). Proportions of hyperiid amphipods, isopods, ostracods, other copepods, and other prey were slightly-negatively correlated with fish length (Figure 11), with individuals ≤80 mm consuming the majority of these prey types (Figure 12A). Additionally, other copepod and polychaete proportions showed a negative correlation with increasing depth (Figures 11 and 12B). CCA2 most notably highlighted that ostracods and other prey were consumed in greatest proportions by *G. tricupsis* during 2012 at higher latitudes and further-western longitudes, while the greatest proportions of amphipods (unid.) and cumaceans were consumed during 2013 and 2014 at lower latitudes and further-eastern longitudes (Appendix G Figures 11, 12C–E).

Of the significant *I. spatula* diet predictors (i.e., fish length, latitude, and year), latitude was highest correlated with CCA1, followed by fish length, while year was highest correlated with CCA2 (Appendix G Table 6; Figure 13). CCA1 highlighted an increase in the proportions of benthic amphipods and ostracods in *I. spatula* diet with an increase in latitude (Figures 13, 14A), and an increase in proportions of hyperiid amphipods, other copepods, and polychaetes with an increase in fish length (Appendix G Figure 13), however, hyperiid amphipods and other copepods were consumed very rarely, thus not reported in the %MW fish length figure (Appendix G Figure 14B). Calanoid copepods were slightly positively correlated with fish length (Appendix G Figure 13), although only 41–60 mm *I. spatula* consumed these prey (Appendix G Figure 14B). CCA2 revealed that ostracods were consumed in highest proportions in 2012 and that cumaceans, isopods, and other prey were consumed mostly in 2013 and 2014 (Appendix G Figures 13 and 14C).

Lumpenus fabricii

Overall, fish length and depth accounted for 14% of the total variance explained in *L. fabricii* diet (Appendix G Table 6). The two canonical axes accounted for 100% (CCA1=73.8%; CCA2=26.2%) of the total variance in *L. fabricii* diet composition (i.e., 14%). At the 5% significance level, only fish length was a significant predictor of *L. fabricii* diet (p=0.005; Appendix G Table 6), making CCA1 the only significant axis. CCA1 highlighted a positive correlation between fish length and proportions of amphipods (unid.), benthic amphipods, cumaceans, and polychaetes. Additionally, CCA1 showed a negative correlation between fish length and calanoid copepod consumption (Appendix G Figure 15), with 41–60 mm individuals consuming the greatest proportions of this prey (Appendix G Figure 16). Ostracods and other copepod proportions appeared less influenced by fish length (Appendix G Figures 15, 16).

Size class analysis

At 55–80% similarity, there was evidence of size interval groupings (i.e., size classes) for *A. olrikii*, *G. tricuspis*, *I. spatula*, *T. pingelii*, *A. medius*, and *L. fabricii*. At an 80% similarity level, we determined two size classes for *A. olrikii* (≤60 mm and 61–80 mm) (Appendix G Figure 17). At a 60% similarity level, there were three *G. tricuspis* size classes (≤70 mm, 71–90 mm, and 91–150 mm) (Appendix G Figure 18). Two size classes grouped for *I. spatula* at a 70% similarity level (≤50 mm and 51–80 mm) (Appendix G Figure 19). At a 60% similarity level, we determined two size classes for *T. pingelii* (≤50 mm and 51–114 mm) (Appendix G Figure 20). Two size classes grouped at the 55% similarity level for *A. medius* (≤70 mm and 71–140 mm) (Appendix G Figure 21). Lastly, at the 55% similarity level, there were two size classes for *L. fabricii* (≤60 mm and 61–103 mm) (Appendix G Figure 22). All size class recommendations are recorded in Appendix G Table 7.

Discussion

Overall, each of these fish species exhibited generalist feeding strategies by consuming diverse diets throughout the Transboundary study area. It was possible to examine the prey use patterns of most of these fishes by pooling taxonomically-alike prey into groups and using multivariate methods. The patterns examined here include both differences and similarities in inter- and intraspecific prey use.

The purpose of the interspecific, guild analysis was to determine if the seven fishes exploited similar prey groups. The guild concept is useful in that it can concisely summarize the feeding habits of multiple species into broader resource user groups (Root 1967; Garrison and Link 2000), making it possible to examine the broad-scale effects of groups of fishes in food webs (Whitehouse et al. 2014). The major pattern that emerged from this analysis was that fish diets were generally more similar within families than between them, with three of the four cottids constituting one guild and the two stichaeids the other. The separation seen between both guilds, *A. olrikii*, and *T. pingelii* highlights the degree of resource partitioning between demersal fish species within the Transboundary study area. Resource partitioning is greatly influenced by predator/prey habitat characteristics and predator morphological constraints (Garrison and Link 2000). Given that these fishes were collected in similar places and that those in guilds shared similar morphological characteristics (personal observation; UAF Fisheries Oceanography Laboratory) the similarities and differences noticed here are understandable.

The goal of the intraspecific diet analysis was to examine the influence of the factors fish length, depth, latitude, longitude, and year on each species' diet using canonical correspondence analysis (CCA). However, the relationship between these factors and the diet data was only significant for *A. olrikii*, *G. tricuspis*, *I. spatula*, and *L. fabricii* making these the only appropriate species for the analysis. These four species' diet compositions were significantly influenced by one or more of these factors, with fish length, latitude, and longitude generally being highest correlated with CCA1 (i.e., the axis which accounts for the majority of the explainable variance). Currently, there are no other published studies that have used CCA to examine these species' diets. Other demersal fishes such as the Atlantic Wolffish (*Anarhichas lupus*) and the Long Rough Dab (*Hippoglossoides platessoides*) have been analyzed using this method and, similar to our results, Jaworski and Ragnarsson (2006) found that CCA could explain about 8–14% of the total variance in these fishes' diets, and of that total variance, fish body size and spatial factors accounted for the majority. While the amount of variance explained by CCA may seem low, one must realize that the objective of CCA is not to explain 100% of the variance (Ter Braak 1986). A portion of the total variance is due to noise in the data (Ter Braak 1986) which is caused, in part, by the large amount of zero values characteristic of ecological data sets (Bennion 1994; Reeves et al. 2007). The patterns highlighted by CCA in this study contribute to a weight of evidence in association with descriptive methods presented here supporting the influence of fish length, depth, latitude, longitude, and year on demersal fish diets throughout the Transboundary study area.

Of the four species analyzed using CCA, fish length was a significant predictor of *G. tricuspis*, *I. spatula*, and *L. fabricii* diet compositions. With an increase in fish length, these species generally consumed fewer prey groups. This decrease in diet diversity likely occurs because as fishes grow larger, changes in body morphology allow them to consume larger, more energy-dense prey (Werner and Hall 1974; Werner and Gilliam 1984; Scharf et al. 2000). In this study, these larger prey included amphipods, cumaceans, polychaetes, and fish, which were consumed by the largest representatives of these three species. *A. olrikii* consumed primarily amphipods regardless of body size and did not exhibit any noticeable ontogenetic shift in its diet. While not as common, a lack of changes in a fishes' diet throughout ontogeny is not uncommon (Garrison and Link 2000). In the case of *A. olrikii*, however, the majority of individuals collected were 51–70 mm in length meaning their diets could just be fairly similar at similar body sizes.

Spatial and interannual effects accounted for variability in the diets of *A. olrikii*, *G. tricuspis*, and *I spatula*, however, isolating the effect of any one variable was difficult at times. In some cases, one prey type might be correlated with multiple predictor variables. This generally happened when that one prey type occurred in only a few stomachs collected at similar latitudes, longitudes, depths, and years. Examples of this included polychaete consumption for *A. olrikii* and ostracod consumption for *I. spatula*; both prey types exhibited negative correlations with year and positive correlations with latitude or longitude. These prey were rarely consumed by either species but accounted for a relatively large proportion of the diet of fish collected during 2012 because of small available stomach sample sizes. Regardless of these variables, the common prey types consumed by *A. olrikii* (i.e., amphipods) and *G. tricuspis* and *I. spatula* (i.e., amphipods, benthic amphipods, and polychaetes), only varied slightly in proportion throughout the Transboundary study area. The consistency of these prey groups in each species' diet is understandable given that deposit feeders, such as amphipods and polychaetes, are highly abundant throughout the U.S. and Canadian Beaufort Sea shelf (Carey and Ruff 1977;Craig et al. 1982; Carey 1991).

While this study is informative, stronger conclusions could be made about some of these species' food habits were more stomachs available. Of all species' diets, those of *G. tricuspis* and *I. spatula* were best documented due to a fairly well-distributed and large sample size of stomachs available throughout the Transboundary study area. It is obvious that more stomachs are needed to fully analyze *A. scaber*, *T. pingelii*, and *A. medius* diets. It is also obvious that a better distribution of *A. olrikii* and *L. fabricii* stomachs across fish lengths and depths could have increased the effectiveness of the intraspecific analysis for these species. These species stomachs were primarily available from either similar-sized fish (*A. olrikii*) or similar depths (*L. fabricii*) which meant there was little differentiation among samples. Because this occurred, CCA was not very effective in finding significant gradients among the predictor variables. As a result, fish length did not explain significant variation in *A. olrikii* diet likely because most individuals captured were 51–70 mm in length. Similarly, depth did not explain significant variation in *L. fabricii* diet likely because individuals were primarily collected at 10–20 m depths. If stomachs were available from a wider size and depth range for these species, our results may have been different.

The methods we used to recommend size classes were categorical, exploratory, and non-hypothesis testing, in contrast to CCA where length was included as a continuous predictor variable in a hypothesis-testing analysis. This was done because determining ontogenetic shifts in diet using length as a continuous variable became quite muddled and eventually lead to visual speculations in where the shifts occurred (i.e., picking size classes from a large diet plot). Therefore, we opted for the less-speculative, Bray-Curtis-distance-based techniques described here and used similarity percentages at a level >55% to recommend size classes. Doing so, we determined diet-based size classes for all fish species examined, except for *A. scaber* due to very small sample sizes. We recommend these size classes be viewed as a starting point for future diet studies. That said, we advise future researchers to periodically compare their results against ours, as differences in fish body sizes and spatial and temporal distributions, amongst other factors, will likely cause shifts from our recommended size classes.

This study was successful in increasing what is known about these species' diets and in highlighting a need for further research. One issue that deserves consideration is that of unidentifiable prey and its importance to the diets of these fish species. Unidentifiable prey occurred in 42–74% of these species' stomachs. Were this prey identifiable, it most certainly would have contributed to some of the other prey groups, thereby affecting our original analyses. Perhaps through fatty acid and stable isotope analysis of the fishes and their prey it might be possible to apportion some of the unidentifiable prey to prey groups. Were such an analysis feasible, it could greatly enhance current diet analysis methods allowing for a more accurate understanding of these and other fishes' roles in food webs.

References

Ashjian CJ, Gallager SM, Plourde S (2005) Transport of plankton and particles between the Chukchi and Beaufort Seas during summer 2002, described using a video plankton recorder. Deep-Sea Res II 52:3259–3280

Atkinson EG, Percy JA (1992) Diet comparison among demersal marine fish from the Canadian Arctic. Polar Biol 11:567–573

Baker R, Buckland A, Sheaves M (2014) Fish gut content analysis: robust measures of diet composition. Fish Fish 15:170–177

Barber WE, Smith RL, Vallarino M, Meyer RM (1997) Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fish B-NOAA 95:195–209

Barnard JL (1969) The families and genera of marine gammaridean Amphipoda. Smithsonian Institution Press, Washington

Bennion H (1994) A diatom-phosphorous transfer function for shallow, eutrophic ponds in southeast England. Hydrobiologia 275/276:391–410

Blanchard AL, Parris CL, Knowlton AL, Wade NR (2013) Benthic ecology of the northeastern Chukchi Sea. Part I. Environmental characteristics and macrofaunal community structure, 2008–2010. Cont Shelf Res 67:52–66

Carey AG Jr. (1991) Ecology of North American Arctic continental shelf benthos: a review. Cont Shelf Res 11:865–883

Carey AG Jr., Ruff RE (1977) Ecological studies of the benthos in the western Beaufort Sea with special reference to bivalve mollusks. In: Dunbar, M. L. (ed) Polar Oceans. Calgary: Arctic Institute of North American, pp 505–530

Castellani C, Irigoien X, Mayor DJ, Harris RP, Wilson D (2008) Feeding of *Calanus finmarchicus* and *Oithona similis* on the microplankton assemblage in the Irminger Sea, North Atlantic. J Plankton Res 30:1095–1116

Clarke KR (1993) Non-parametric multivariate analyses of changes in community structure. Aust J Ecol 18:117–143

Chipps SR, Garvey JE (2007) Assessment of diets and feeding patterns. In: Guy CS, Brown ML (eds) Analysis and Interpretation of Freshwater Fisheries Data, American Fisheries Society, Bethesda, Maryland, pp 473–514

Coyle KO, Gillespie JA, Smith RL, Barber WE (1997) Food habits of four demersal Chukchi Sea fishes. Am Fish Soc Symp 19:310–318

Craig PC, Griffiths WB, Haldorson L, McElderry H (1982) Ecological studies of Arctic cod (*Boreogadus saida*) in the Beaufort Sea coastal waters, Alaska. Can J Fish Aquat Sci 39:395−406

Cui X, Grebmeier JM, Cooper LW (2012) Feeding ecology of dominant groundfish in the northern Bering Sea. Polar Biol 35:1407−1419

Gardner GA, Szabo I (1982) British Columbia pelagic marine Copepoda: an identification manual and annotated bibliography. Vol. 62. Department of Fisheries and Oceans

Garrison LP, Link JS (2000) Dietary guild structure of the fish community in the Northeast United States continental shelf ecosystem. Mar Ecol Prog Ser 202:231–240

Gray BP (2015) Comparisons of Arctic Cod (*Boreogadus saida*), Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*), and Shorthorn Sculpin (*Myoxocephalus scorpius*) diets across the northeastern Chukchi and western Beaufort Seas. MS Thesis, School of Fisheries and Ocean Sciences

Gray BP, Norcross BL, Blanchard AL, Beaudreau AH, Seitz AC (2015) Variability in the summer diets of juvenile polar cod (Boreogadus saida) in the northeastern Chukchi and western Beaufort Seas. Polar Biol. doi:10.1007/s00300-015-1796-7

Hyslop EJ (1980) Stomach contents analysis – a review of methods and their application. J Fish Biol 17:411–429

Iken K, Bluhm B, Dunton K (2010) Benthic food-web structure under differing water mass properties in the southern Chukchi Sea. Deep-Sea Res II 57:71–85

Jaworski A, Ragnarsson SA (2006) Feeding habits of demersal fish in Icelandic waters: a multivariate approach ICES J Mar Sci 63:1682–1694

Hallett CS, Daley RK (2011) Feeding ecology of the southern lanternshark (*Etmopterus baxteri*) and the brown lanternshark (*E. unicolor*) off southeastern Australia. ICES J Mar Sci 68:157–165

Hopcroft RR, Kosobokova KN, Pinchuk AI (2010) Zooplankton community patterns in the Chukchi Sea during summer 2004. Deep-Sea Res II 57:27–39

Labropoulou M, Eleftheriou A (1997) The foraging ecology of two pairs of congeneric demersal fish species: importance of morphological characteristic in prey selection. J Fish Biol 50:324−340

Lowry LF, Frost KJ, Burns JJ (1980) Variability in the diet of ringed seals, *Phoca hispida*, in Alaska. Can. J of Fish Aquat Sci 37: 2254–2261

Norcross BL, Raborn SW, Holladay BA, Gallaway BJ, Crawford ST, Priest JT, Edenfield LE, Meyer R (2013) Northeastern Chukchi Sea demersal fishes and associated environmental characteristics, 2009–2010. Cont Shelf Res 67:77−95

Quinn GP, Keough MJ (2002) Experimental design and data analysis for biologists. Cambridge University Press, Cambridge, pp 467–469

Reeves JM, Deckker PD, Haise SA (2007) Groundwater Ostracods from the arid Pilbara region of northwestern Australia: distribution and water chemistry. Hydrobiologia 585:99–118

Root RB (1967) The niche exploitation pattern of the blue-gray gnatchatcher. Ecol Monogr 37:317–350

Scharf FS, Juanes F, Rountree AR (2000) Predator size-prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic niche breadth. Mar Ecol-Prog Ser 208:229–248

Ter Braak CJF (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67:1167–1179

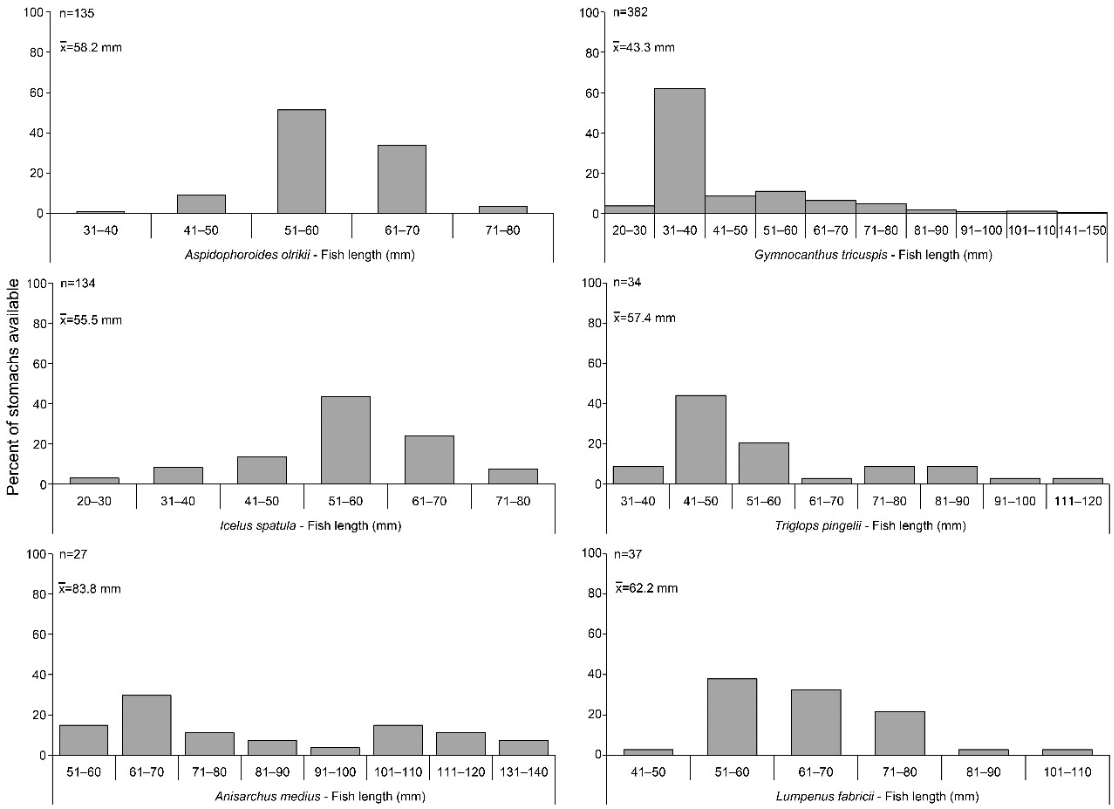
Vassilenko SV, Petryashov VV (2009) Illustrated keys to free-living invertebrates of Eurasian Arctic seas and adjacent deep waters. Vol. 1. Alaska Sea Grant. Fairbanks: University of Alaska Fairbanks

Walkusz W, Majewski A, Reist JD (2013) Distribution and diet of the bottom dwelling Arctic cod in the Canadian Beaufort Sea. J Mar Syst 127:65–75

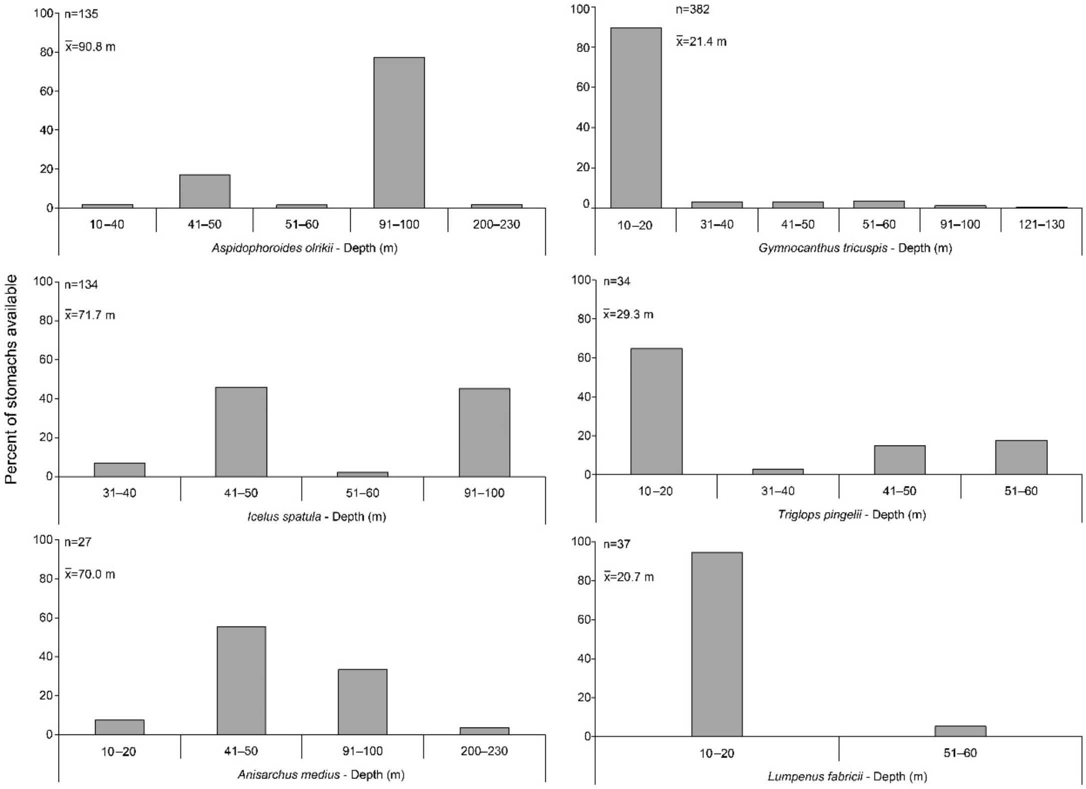
Werner EE, Gilliam JF (1984) The ontogenetic niche and species interaction in size-structured populations. Annu Rev Ecol Syst 15:393–425

Werner EE, Hall DJ (1974) Optimal foraging and the size selection of prey by the Bluegill sunfish (*Lepomis macrochirus*). Ecology 55:1042−1052

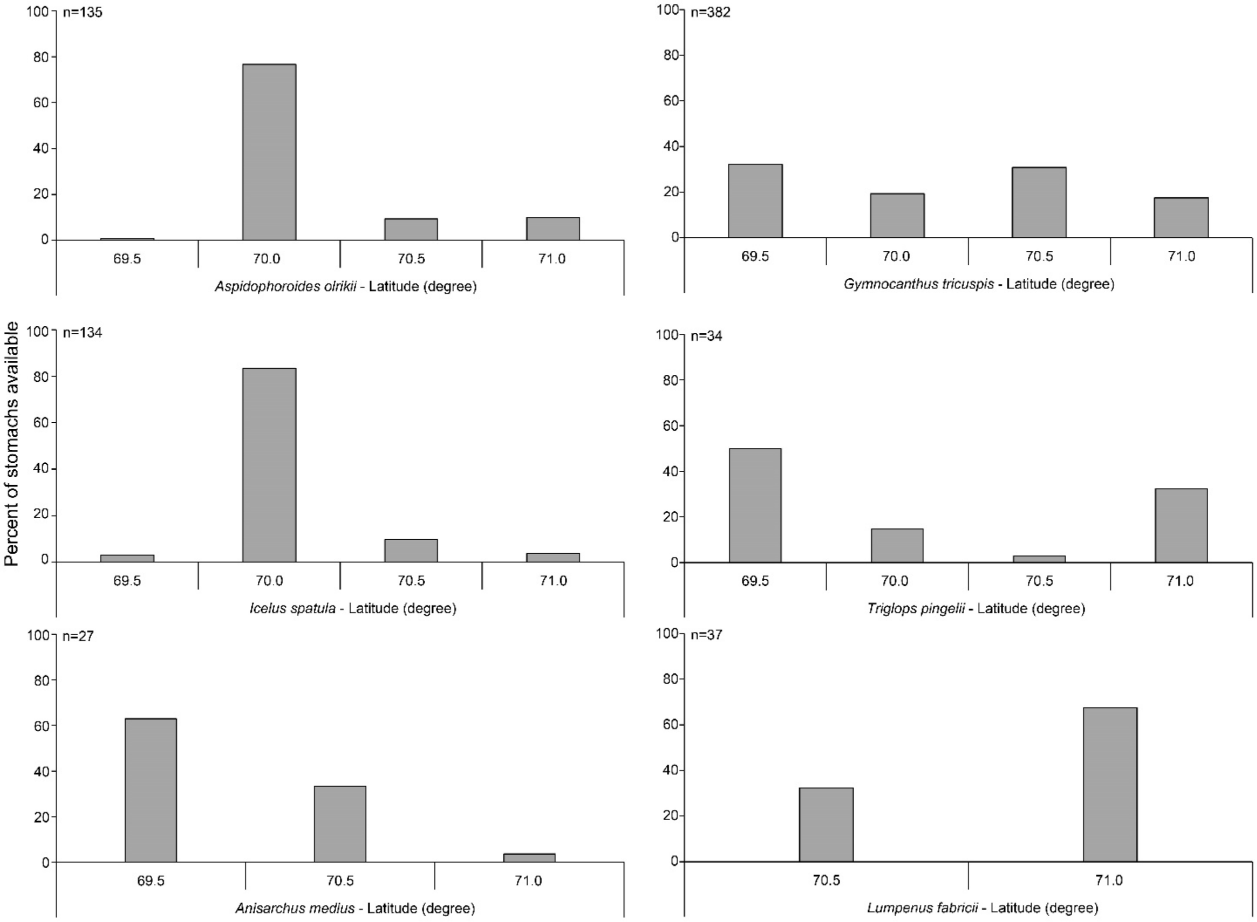
Whitehouse GA, Aydin K, Essington T, Hunt G, Jr. (2014) A trophic mass balance model of the eastern Chukchi Sea with comparisons to other high-latitude systems. Polar Biol 37:911–939



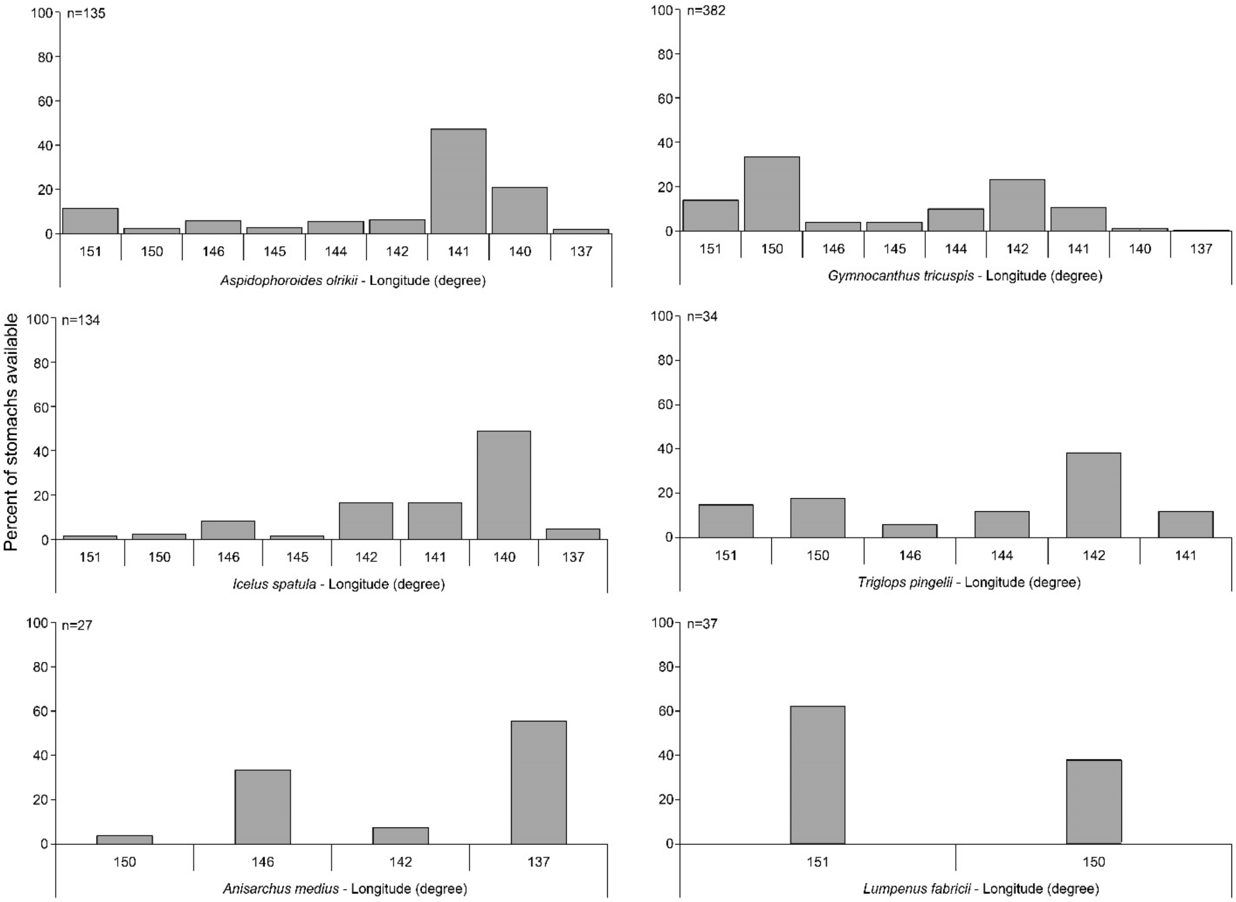
Appendix G Figure 1. Distribution of available fish stomachs within 10 mm fish length bins. Only stomachs containing identifiable prey are shown in the distributions. The *A. scaber* distribution is not included here due to very low sample sizes.



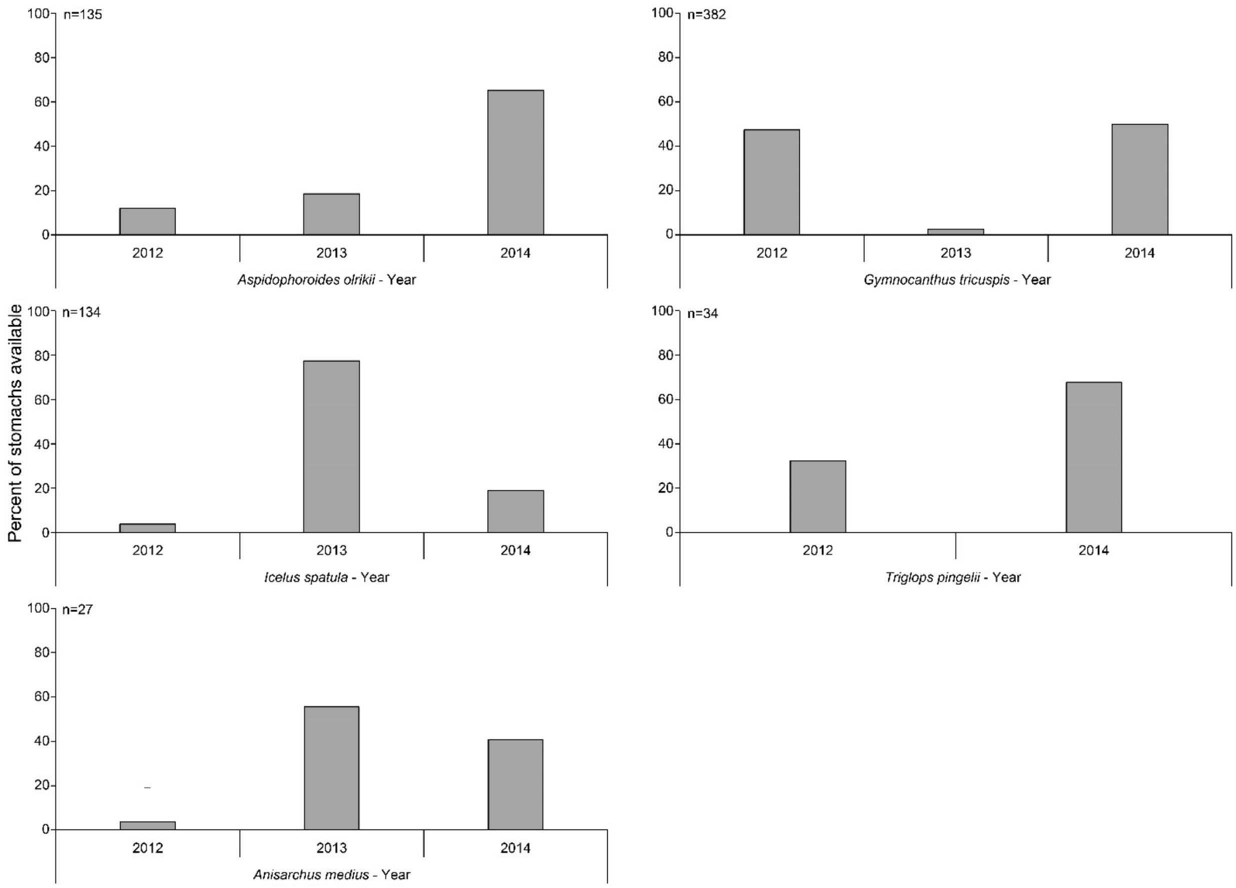
Appendix G Figure 2. Distribution of available fish stomachs within 10–30 m depth bins. Only stomachs containing identifiable prey are shown in the distributions. The *A. scaber* distribution is not included here due to very low sample sizes.



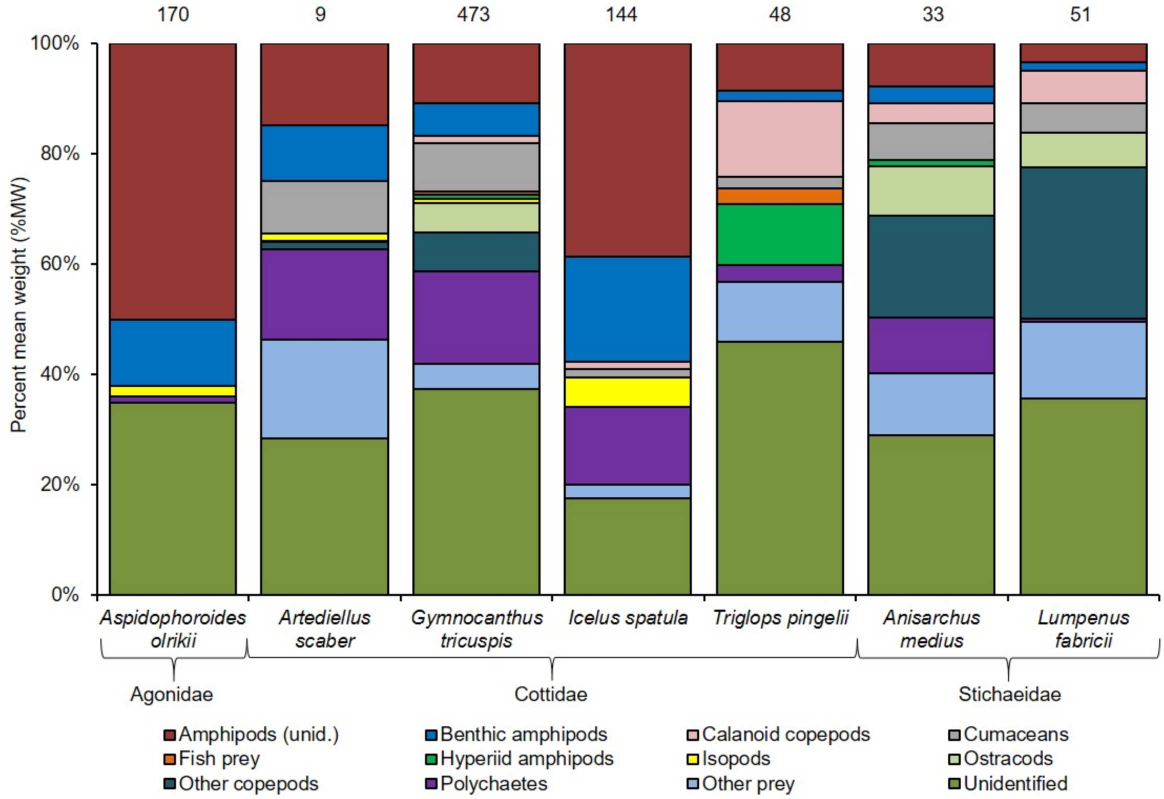
Appendix G Figure 3. Distribution of available fish stomachs within 0.5° latitude bins. Only stomachs containing identifiable prey are shown in the distributions. The *A. scaber* distribution is not included here due to very low sample sizes.



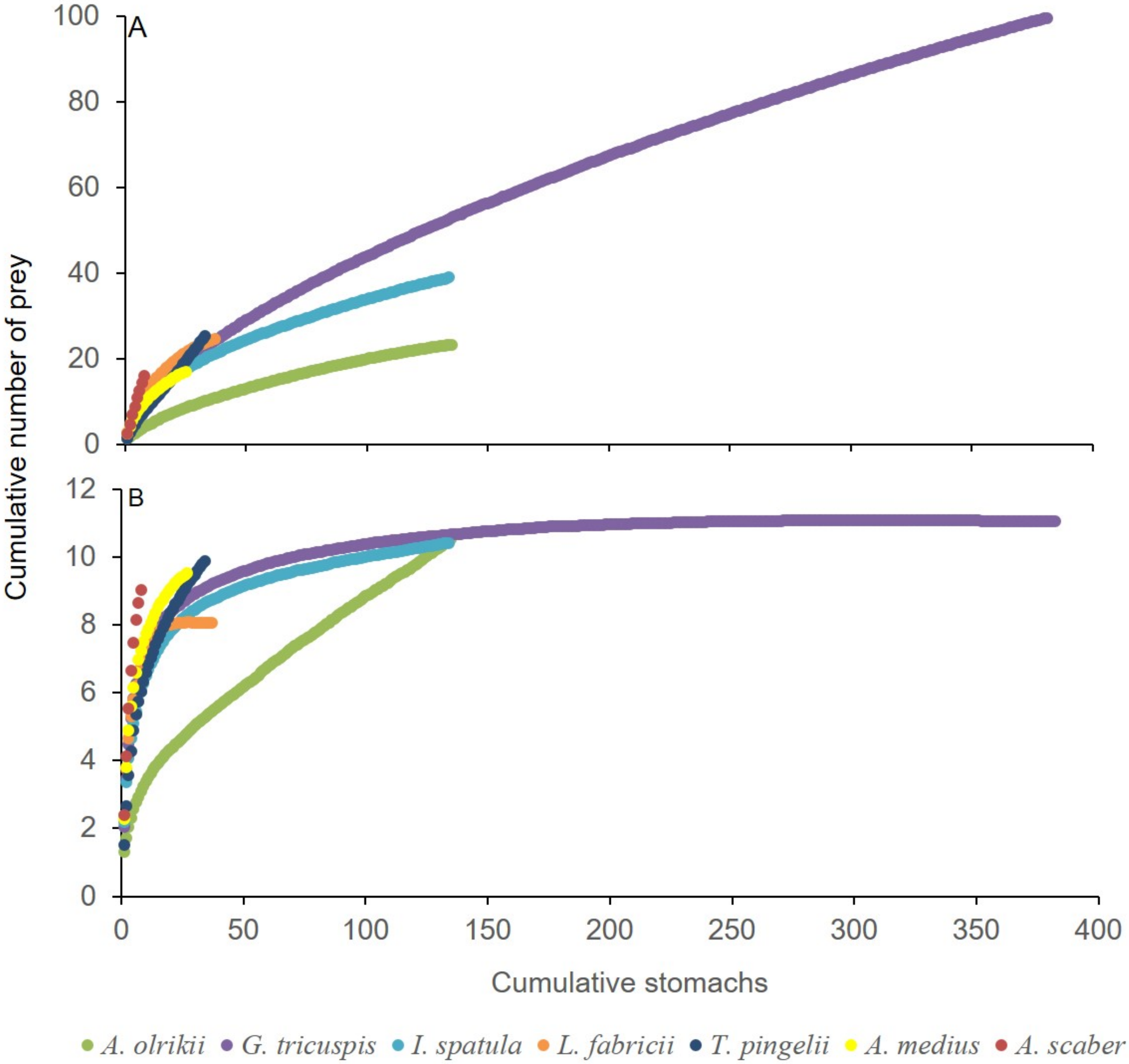
Appendix G Figure 4. Distribution of available fish stomachs within 1.0° longitude bins. Only stomachs containing identifiable prey are shown in the distributions. The *A. scaber* distribution is not included here due to very low sample sizes.



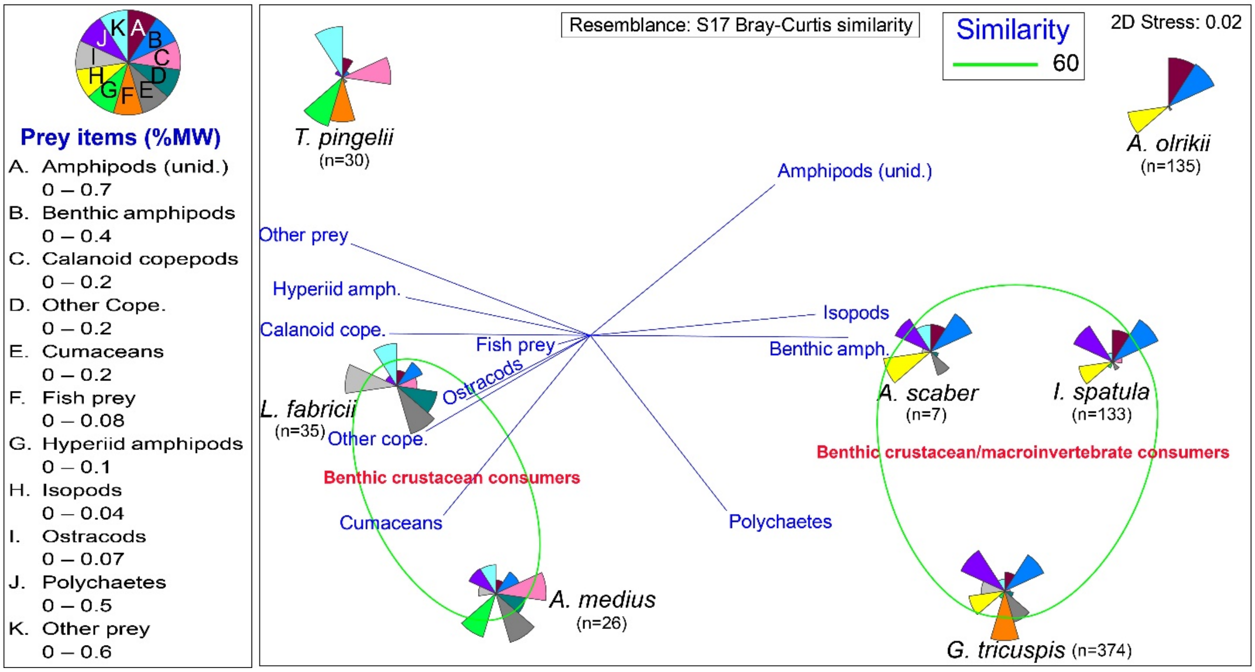
Appendix G Figure 5. Distribution of available fish stomachs within cruise year bins. Only stomachs containing identifiable prey are shown in the distributions. The *A. scaber* distribution is not included here due to very low sample sizes. The *L. fabricii* distribution is not included because all stomachs were collected in 2012.



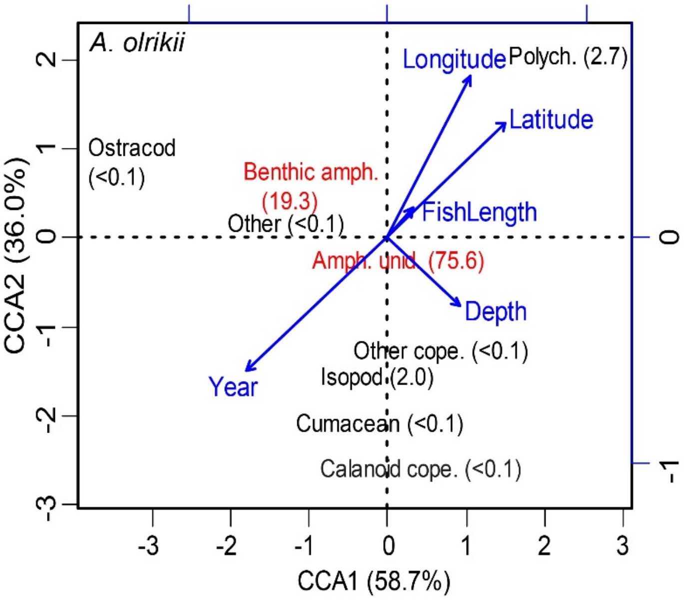
Appendix G Figure 6. Pooled diet compositions of all *A. olrikii*, *A. scaber*, *G. tricuspis*, *I. spatula*, *T. pingelii*, *A. medius*, and *L. fabricii*, including stomachs with unidentifiable prey. Stomach sample sizes are listed above each species column.



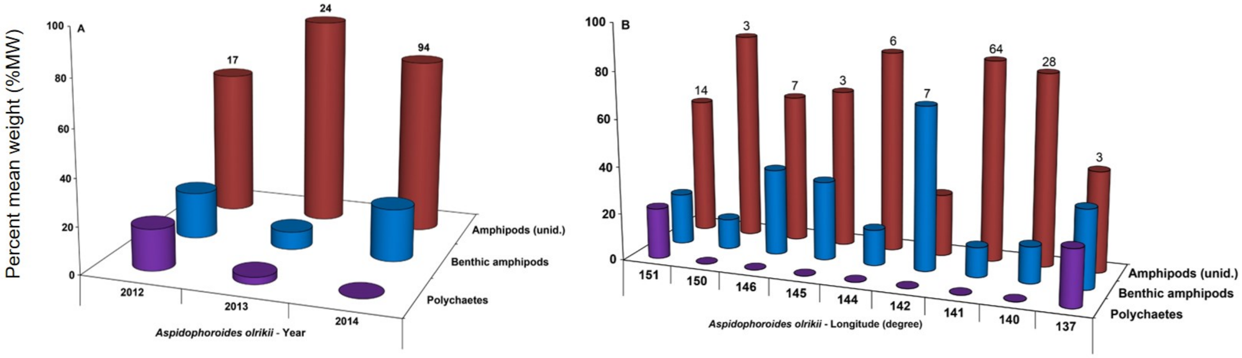
Appendix G Figure 7. Cumulative prey curves of *A. olrikii*, *A. scaber*, *G. tricuspis*, *I. spatula*, *T. pingelii*, *A. medius*, and *L. fabricii* showing the accumulation of prey taxa or groups relative to the running total of stomachs processed. Curves were generated at both A) low taxonomic clarity (all prey) and B) coarse taxonomic groups (prey groups) to show the effectiveness of aggregating prey groups and to visualize differences in diet diversity.



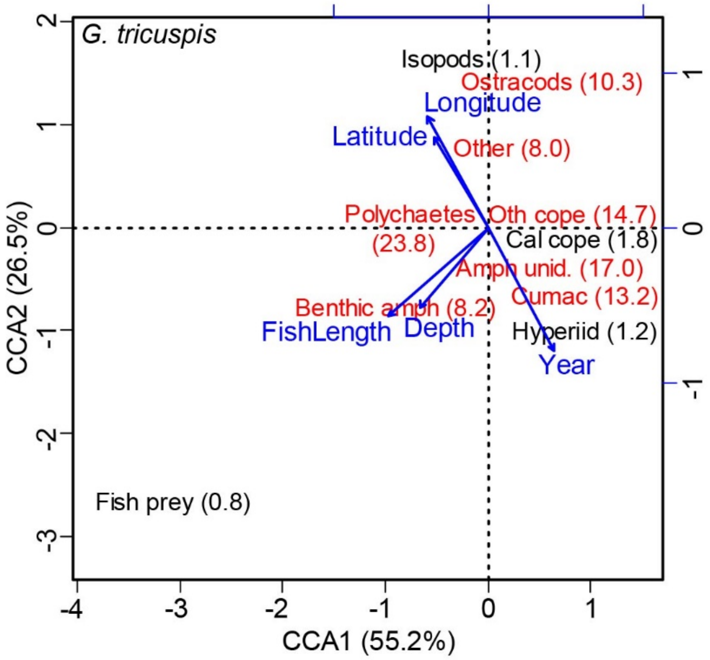
Appendix G Figure 8. Results of nMDS (3D Stress: <0.01), using a Bray-Curtis distance matrix, to determine feeding guilds among the seven fish species. Guilds, defined here as species that exhibited 60% similarity in prey use, are circled in green, with the respective guild names listed in red lettering. *A. scaber*, *I. spatula*, and *G. tricuspis* were primarily benthic crustacean/macroinvertebrate consumers and *L. fabricii* and *A. medius* were primarily benthic crustacean consumers. *A. olrikii* and *T. pingelii* were not included in either guild.



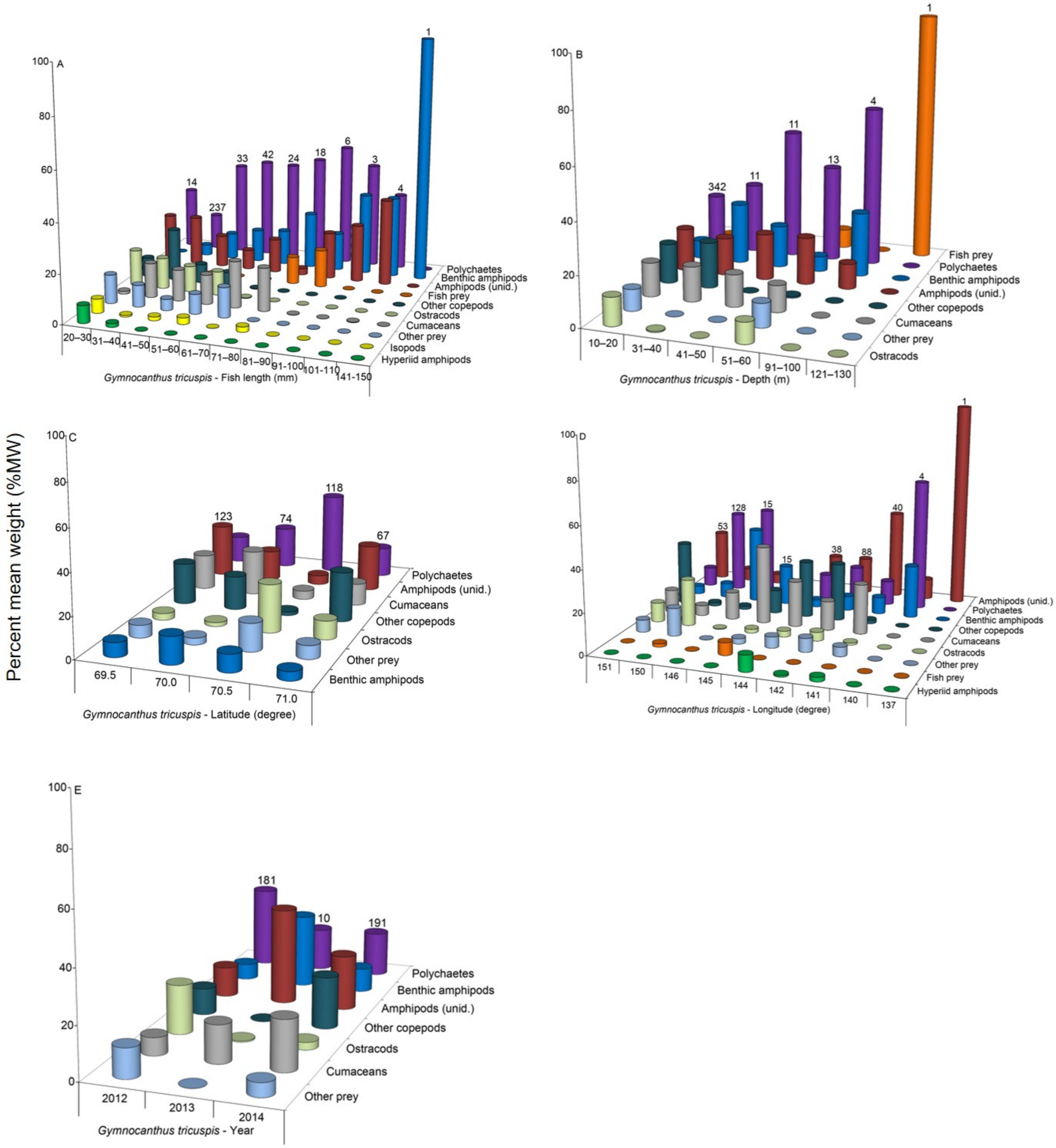
Appendix G Figure 9. Canonical correspondence analysis (CCA) ordination relating biological (i.e., fish length) and environmental (i.e., depth, latitude, longitude, and year) factors as continuous variables affecting *A. olrikii* diets in the Transboundary study area. The percent of the total variance explained by CCA1 and CCA2 is listed within parentheses along the x and y-axes. Numbers in parentheses next to prey categories signify their contribution to pooled *A. olrikii* diet by %MW. Prey categories that contributed ≥5% by %MW are in red text.



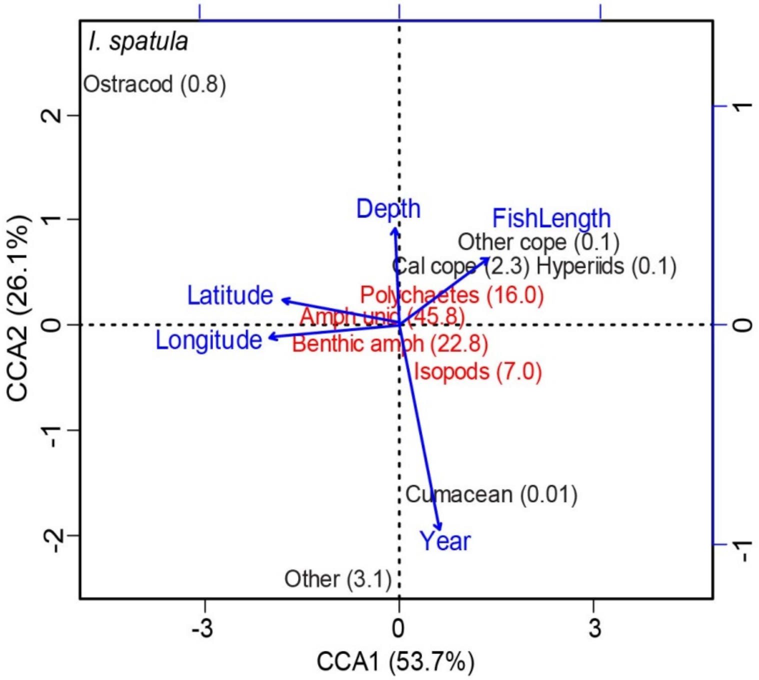
Appendix G Figure 10. Major prey groups (defined as prey ≥5% by %MW in a respective category) consumed by *A. olrikii* in the Transboundary study area. Plots are in order from highest to lowest variable correlations with CCA1, i.e., A) year and B) longitude. Fish length, depth, and latitude were not significant predictors of *A. olrikii* diet composition, therefore they are not reported here. Prey groups along the z-axis were listed in an order that maximizes visibility. Only prey items accounting for ≥5% by %MW within at least one bin in a respective figure are listed along the z-axis. Sample sizes are listed above the rear column in each figure. For visual purposes, longitude was pooled to the nearest whole degree.



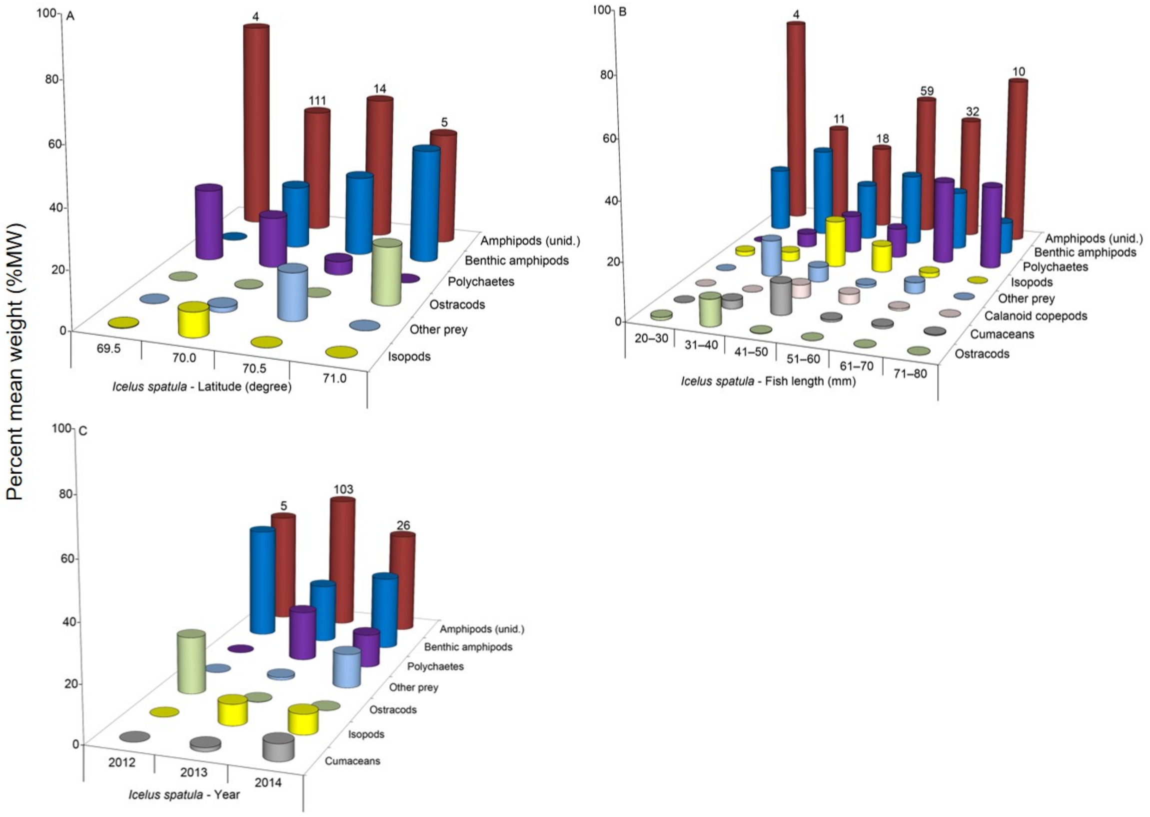
Appendix G Figure 11. Canonical correspondence analysis (CCA) ordination relating biological (i.e., fish length) and environmental (i.e., depth, latitude, longitude, and year) factors as continuous variables affecting *G. tricuspis* diets in the Transboundary study area. The percent of the total variance explained by CCA1 and CCA2 is listed within parentheses along the x and y-axes. Numbers in parentheses next to prey categories signify their contribution to pooled *G. tricuspis* diet by %MW. Prey categories that contributed ≥5% by %MW are in red text.



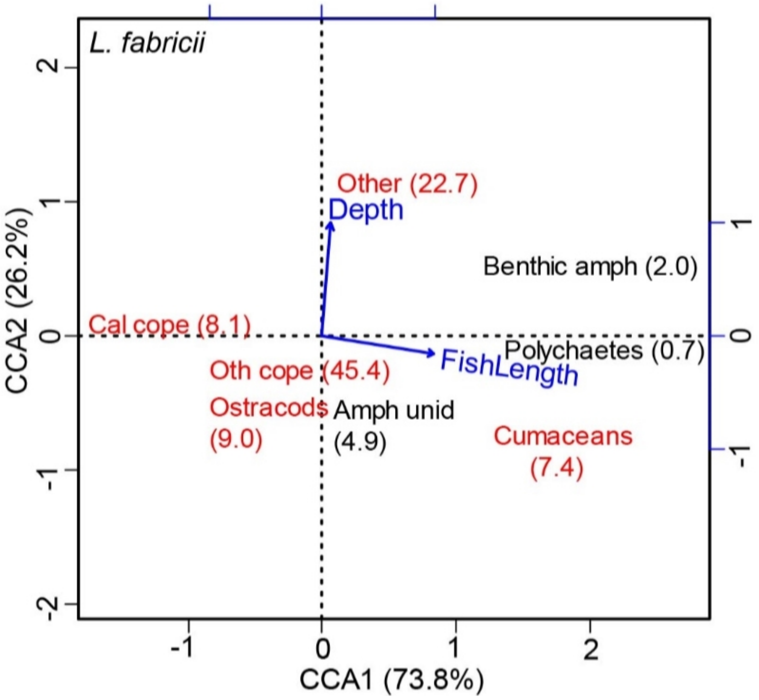
Appendix G Figure 12. Major prey groups (defined as prey ≥5% by %MW in a respective category) consumed by *G. tricuspis* in the Transboundary study area. Plots are in order from highest to lowest variable correlations with CCA1, i.e., A) fish length, B) depth, C) latitude, D) longitude, and E) year. Prey groups along the z-axis were listed in an order that maximizes visibility. Only prey items accounting for ≥5% by %MW within at least one bin in a respective figure are listed along the z-axis. Sample sizes are listed above the rear column in each figure. For visual purposes, x-axis units were pooled: fish length by 10 mm, depth into 10 m bins, latitude to nearest 0.5 degrees, and longitude to the nearest whole degree.



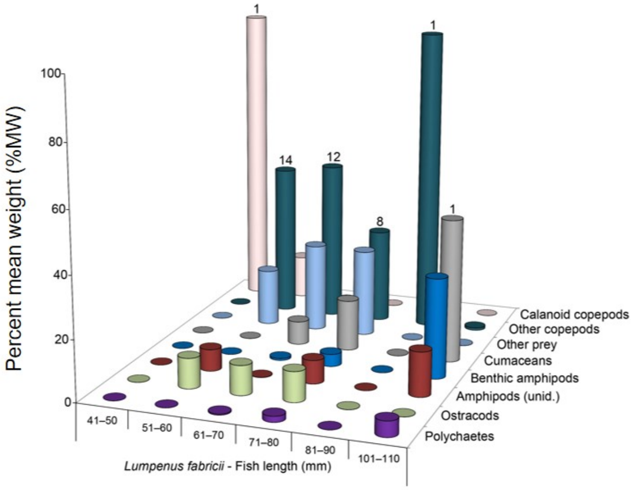
Appendix G Figure 13. Canonical correspondence analysis (CCA) ordination relating biological (i.e., fish length) and environmental (i.e., depth, latitude, longitude, and year) factors as continuous variables affecting *I. spatula* diets in the Transboundary study area. The percent of the total variance explained by CCA1 and CCA2 is listed within parentheses along the x and y-axes. Numbers in parentheses next to prey categories signify their contribution to pooled *I. spatula* diet by %MW. Prey categories that contributed ≥5% by %MW are in red text.



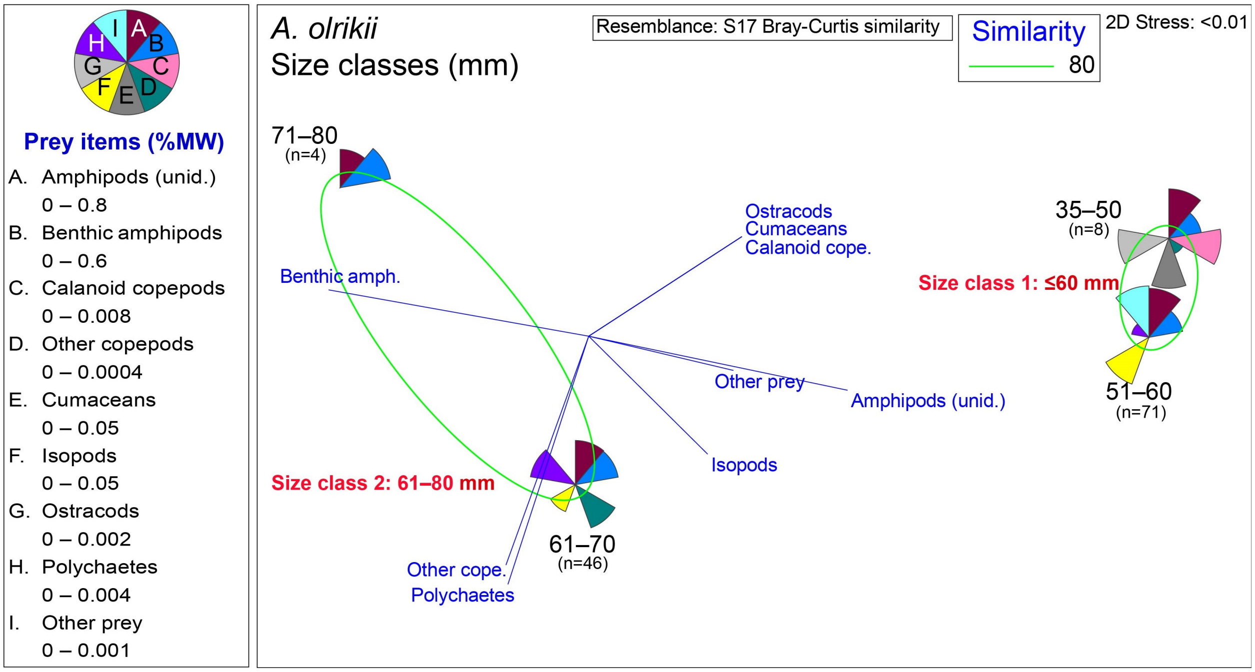
Appendix G Figure 14. Major prey groups (defined as prey ≥5% by %MW in a respective category) consumed by *I. spatula* in the Transboundary study area. Plots are in order from highest to lowest variable correlations with CCA1, i.e., A) latitude, B) fish length, and C) year. Depth and longitude were not reported because they were not significant predictors of *I. spatula* diet composition. Prey groups along the z-axis were listed in an order that maximizes visibility. Only prey items accounting for ≥5% by %MW within at least one bin in a respective figure are listed along the z-axis. Sample sizes are listed above the rear column in each figure. For visual purposes, x-axis units were pooled: latitude to nearest 0.5 degrees and fish length by 10 mm.



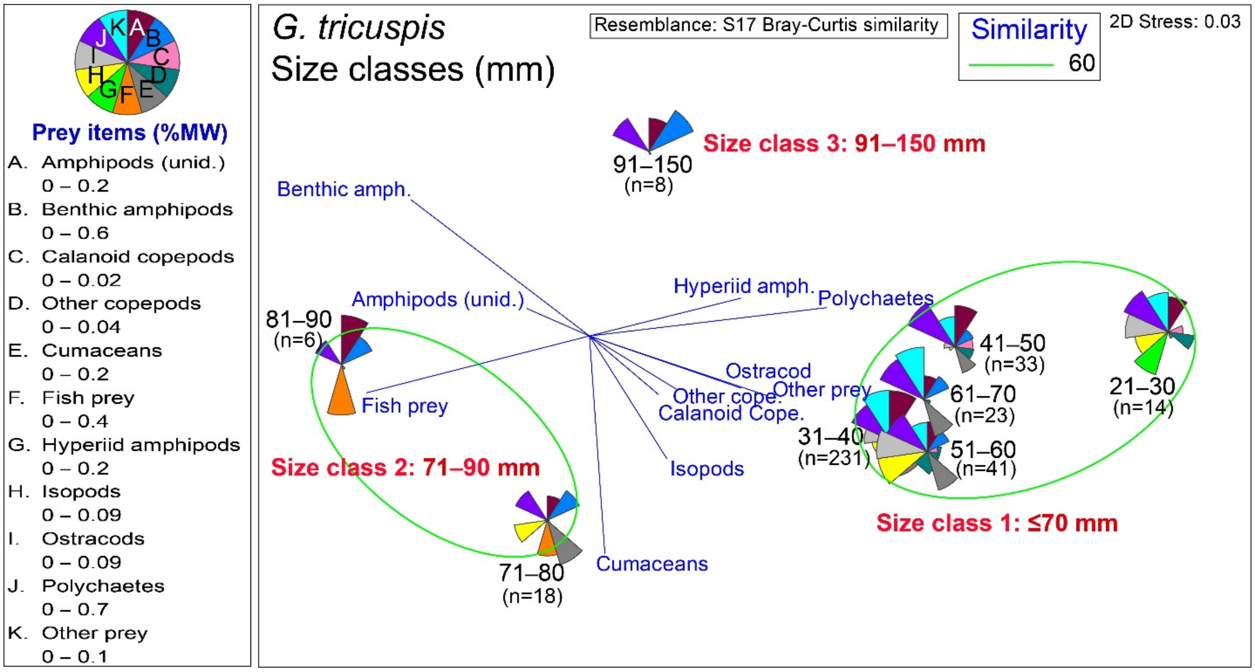
Appendix G Figure 15. Canonical correspondence analysis (CCA) ordination relating biological (i.e., fish length) and environmental (i.e., depth) factors as continuous variables affecting *L. fabricii* diets in the Transboundary study area. The percent of the total variance explained by CCA1 and CCA2 is listed within parentheses along the x and y-axes. Numbers in parentheses next to prey categories signify their contribution to pooled *L. fabricii* diet by %MW. Prey categories that contributed ≥5% by %MW are in red text.



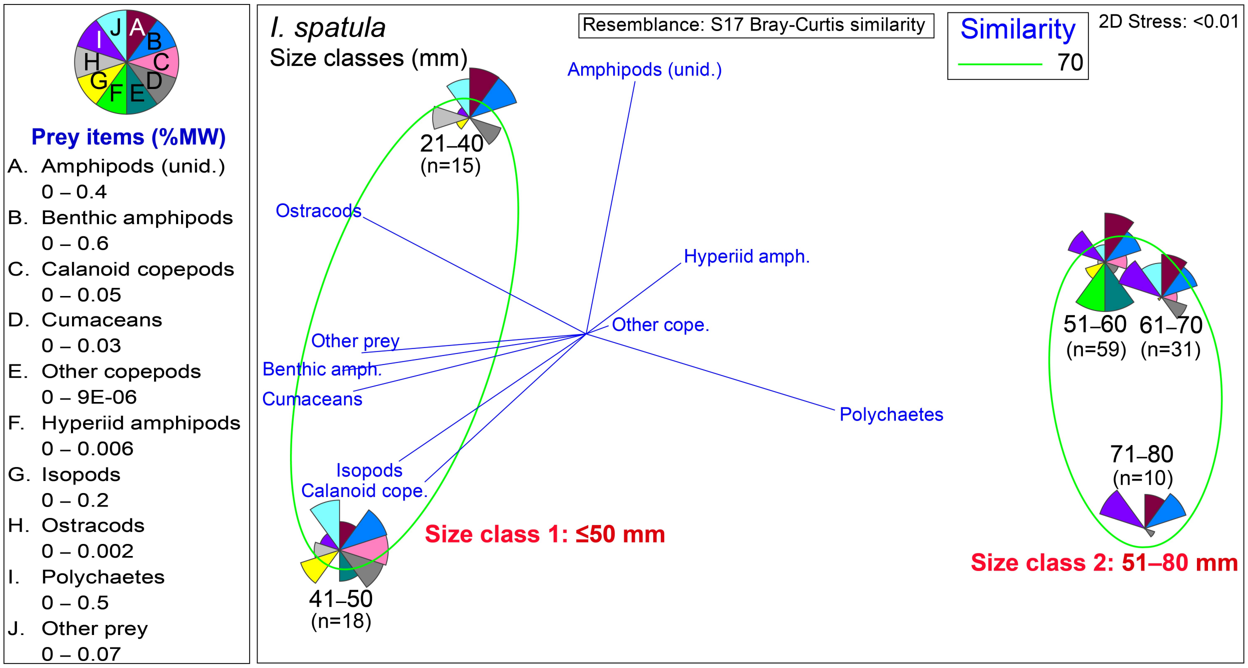
Appendix G Figure 16. Major prey groups (defined as prey ≥5% by %MW in a respective category) consumed by *L fabricii* in the Transboundary study area. Out of the available predictor variables, fish length and depth, fish length was the only significant predictor of *L. fabricii* diet composition. Prey groups along the z-axis were listed in an order that maximizes visibility. Only prey items accounting for ≥5% by %MW within at least one bin are listed along the z-axis. Sample sizes are listed above the rear column in each figure. For visual purposes, fish length along the x-axis was pooled by 10 mm.



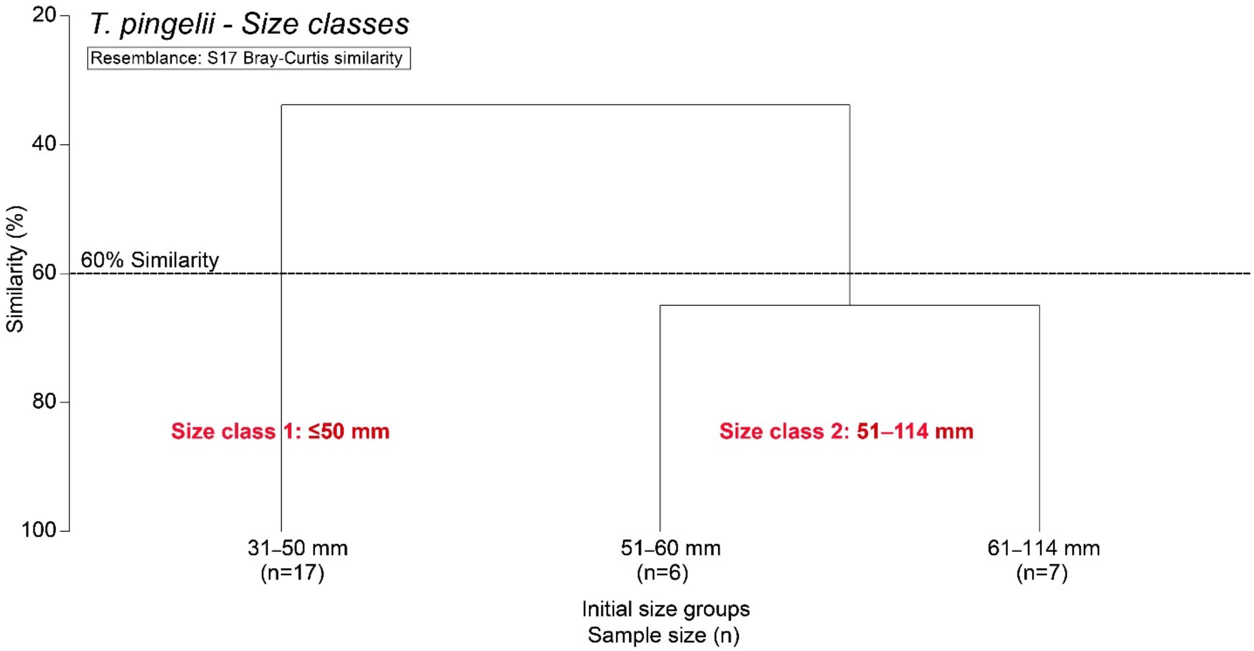
Appendix G Figure 17. Results of nMDS (3D Stress: <0.01), using a Bray-Curtis distance matrix, to approximate *A. olrikii* size classes. At a similarity of 80%, two size groups were determined: Size class one (≤60 mm) and size class two (60–80 mm).



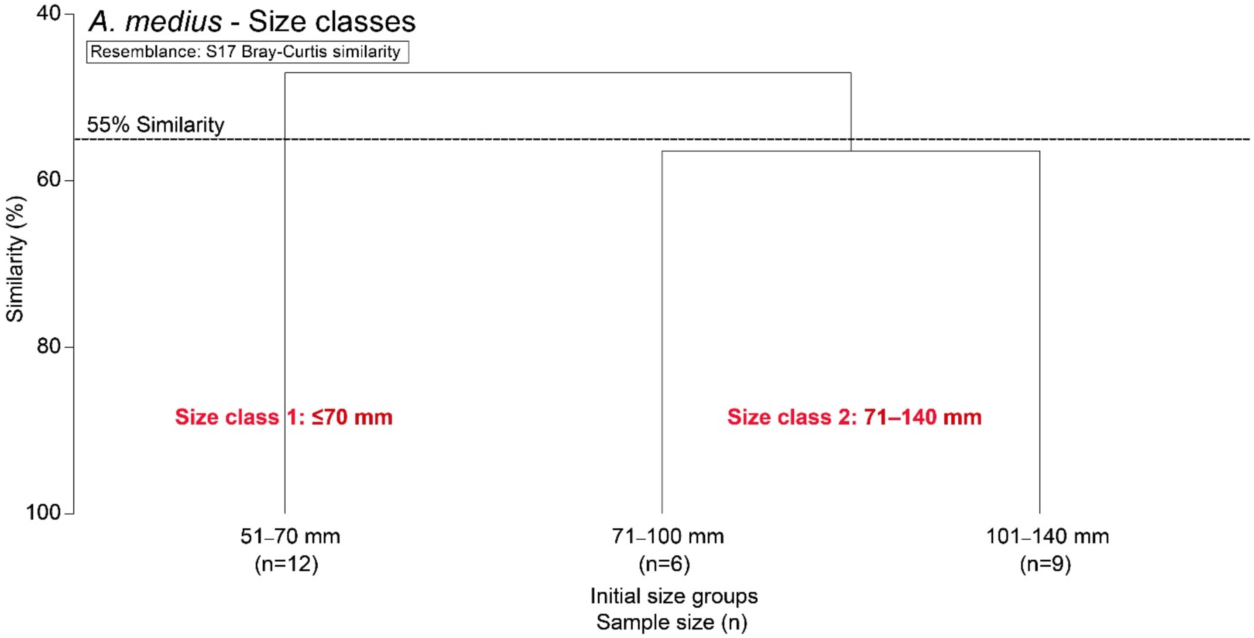
Appendix G Figure 18. Results of nMDS (3D Stress: 0.02), using a Bray-Curtis distance matrix, to approximate *G. tricuspis* size classes. At a similarity of 60%, three size classes were determined: Size class one (≤70 mm), size class two (71–90 mm), and size class three (91–150 mm).



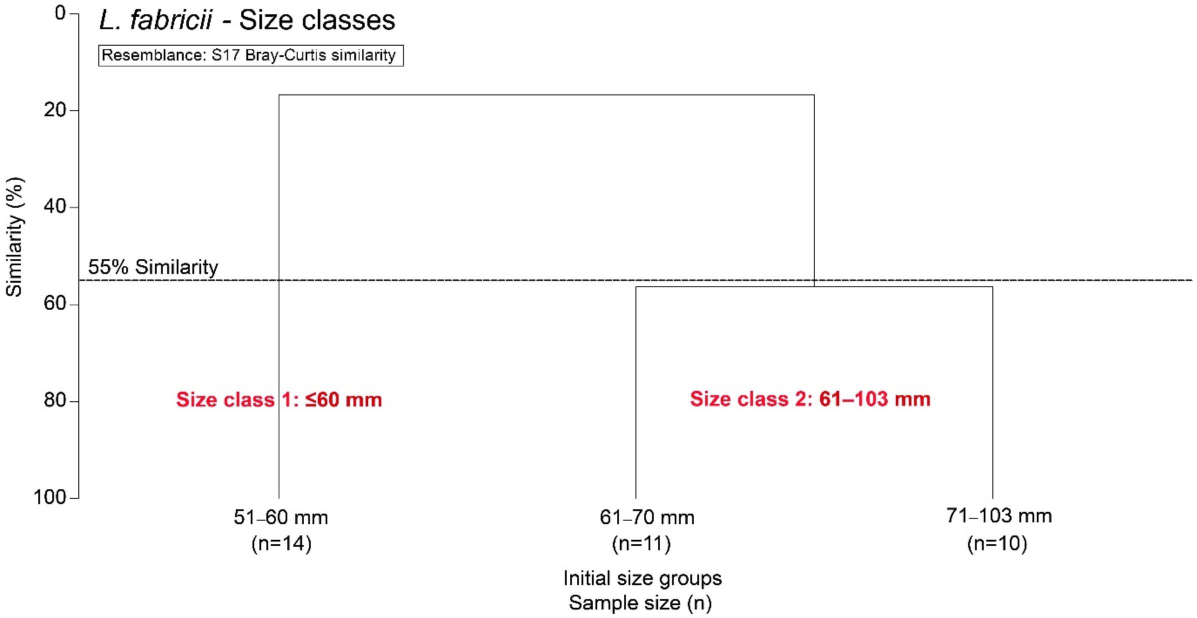
Appendix G Figure 19. Results of nMDS (3D Stress: <0.01), using a Bray-Curtis distance matrix, to approximate *I. spatula* size classes. At a similarity of 70%, two size classes were determined: Size class one (≤50 mm) and size class two (51–80 mm).



Appendix G Figure 20. Results of Cluster analysis, using a Bray-Curtis distance matrix, to approximate *T. pingelii* size classes. At a similarity of 60%, two size classes were determined: Size class one (≤50 mm) and size class two (51–114 mm).



Appendix G Figure 21. Results of Cluster analysis, using a Bray-Curtis distance matrix, to approximate *A. medius* size classes. At a similarity of 55%, two size classes were determined: Size class one (≤70 mm) and size class two (71–140 mm).



Appendix G Figure 22. Results of Cluster analysis, using a Bray-Curtis distance matrix, to approximate *L. fabricii* size classes. At a similarity of 55%, two size classes were determined: Size class one (≤60 mm) and size class two (61–103 mm).

Appendix G Table 1. Average weight per individual prey item determined using prey count, size, and weight data from fish stomach contents. Sample sizes indicate the amount of individual prey items per taxon used in the average weight per individual calculations. If it was not possible to estimate a prey weight, one was assigned using peer-reviewed literature. Weights of polychaetes, decapods, euphausiids, and marine worms were not estimated due to fragmentation and/or non-sufficient, prey-size data.

Estimated average wt./individual			
Prey	Size (mm)	Avg wt./individual (mg)	Sample size (n)
Amphipods (unid.)	≤5.0	0.270	n=75
	5.0–8.0	3.880	n=65
	10.0–15.0	20.45	n=158
Benthic amphipods			
Acanthostepheia spp	4.0	0.300	n=1
	10.0	127.0	n=1
Aceroides spp.	5.0–6.0	2.580	n=17
	7.0–9.0	3.550	n=24
	10.0–15.0	29.88	n=7
	16.0–22.0	43.44	n=4
Ampeliscidae	10.0–15.0	21.10	n=9
Anonyx spp.	<5.0	1.260	n=5
	5.0–8.0	7.190	n=8
	10.0–12.0	15.40	n=4
	25.0	611.4	n=1
Byblis spp.	4.0	0.100	n=1
	5.0–9.0	2.550	n=4
	12.0–13.0	13.67	n=3
Caprellidae	5.0–8.0	1.240	n=45
	10.0–15.0	4.140	n=17
	20.0	11.50	n=1
Dyopedos arcticus	<5.0	0.160	n=4
	5.0–7.0	0.900	n=6
Erichthonius spp.	5.0–7.0	4.610	n=4
	8.0–9.0	8.510	n=10
	10.0–15.0	34.47	3
Gammaracanthus spp.	23.0	140.7	n=1
	30.0	340.2	n=1
Haploops spp.	3.5	0.500	n=1
Lysianassidae	2.0–4.0	0.600	n=2
	5.0–7.0	5.560	n=12
Melita spp.	7.0–8.0	5.400	n=2
	12.0–13.0	21.44	n=5
	21.0–25.0	72.27	n=12
	27.0	99.70	n=1
Onisimus spp.	1.0	0.500	n=1
	5.0–9.0	12.02	n=19
	15.0	36.70	n=1
Oedicerotidae	2.0–4.0	0.110	n=13
	5.0	0.630	n=3
	6.0–9.0	9.850	n=7
Orchomene spp.	6.0–11.0	6.600	n=4
Photis spp.	3.0–4.0	0.480	n=6
	5.0	1.030	n=4
Phoxocephalidae	3.0–4.0	0.800	n=8
	5.0	1.590	n=2
Priscillina armata	7.0	5.900	n=1
Protomedeia spp.	3.0–4.0	0.800	n=3
	5.0–6.0	3.000	n=2
Stenothidae	1.5–2.5	0.170	n=6
Synopidae	7.0	4.300	n=1
Calanoid copepods			
Calanus glacialis	3.0–3.5	0.220	n=299
	4.0–4.5	0.270	n=4,773
Calanus spp.	5.0–5.5	0.730	n=184
	6.0–8.5	1.460	n=44

Appendix G Table 1 continued. Average weight per individual determinations.

Estimated average wt/individual			
Prey	Size (mm)	Avg wt/individual (mg)	Sample size (n)
Calanoid copepods continued			
Unid. Calanoid copepods	0.5	0.020	n=27
	1.0–2.0	0.040	n=4,468
	>2.0–3.0	0.310	n=118
	>3.0–4.0	0.630	n=159
	>4.0–5.0	0.740	n=111
	>5.0–6.0	0.840	n=106
	7.0–8.0	3.150	n=4
	9.0–13.0	4.420	n=11
Cumaceans			
Brachydiastylis spp.	4.5	1.000	n=1
	12.0	15.40	n=1
Diastylis spp.	3.0–4.0	0.540	n=8
	5.0	0.650	n=6
	6.0–7.0	1.820	n=11
	8.0–10.0	6.100	n=10
	12.0–15.0	10.65	n=8
Leptostylis spp.	15.0	16.70	n=1
Leucon spp.	2.0–4.0	0.280	n=7
	5.0–8.0	1.640	n=5
	10.0	6.000	n=1
Unid. Cumaceans	≤4.5	0.740	n=118
	5.0–9.5	1.080	n=34
	10.0–12.0	7.870	n=23
	26.0	69.90	n=1
Fish prey			
Cottidae	15.0	16.90	n=1
	30.0	233.0	n=19
Hyperiid amphipods			
Themisto spp.	3.5–4.5	0.662	n=189
	5.0–7.0	4.420	n=30
	10.0–15.0	32.92	n=38
	3.0–4.5	1.617	n=41
Unid. Hyperiid amph	8.0–9.0	6.880	n=23
Isopods	3.0–4.0	1.125	n=12
	5.0–7.0	6.638	n=16
	10.0	17.64	n=9
	13.0	48.90	n=1
	15.0	61.40	n=1
Ostracods	≤1.0	0.010	n=4
	2.0–3.0	0.761	n=76
	3.5–4.0	0.831	n=18
Other copepods			
Cyclopoid copepods	0.5–1.0	0.001	Castellani et al. 2008
Harpacticoid copepod	0.5–1.0	0.075	n=1,774
Polychaetes	NA	as listed	n=282
Other prey			
Ascidians	NA	as listed	n=5
Bivalves	0.5–1.0	1.120	n=11
	3.0–4.0	6.010	n=9
Chaetognaths	>10.0	2.400	n=237
Crab-Pagurid zoea	5.0–7.0	2.890	n=34
Cyprids	0.5–1.5	0.050	n=8
Decapods	NA	as listed	n=1
Euphausiids	10.0–15.0	as listed	n=4
Gastropoda	0.5–1.0	0.004	n=27
Marine worm	NA	as listed	n=2
Mysids	10.0–19.0	12.30	n=2
Nematodes	1.0–4.0	0.050	n=23
	5.0–9.0	1.400	n=3
Shrimp	7.0	6.000	n=1
	35.0	175.6	n=1
Tanaidecea	1.0–2.0	0.210	n=27
	4.0–5.0	2.730	n=3

Appendix G Table 2. Diet of *A. olrikii* (Family Agonidae) within the Transboundary study area summarized by %MW, %MN, and %O. Major prey categories are in boldface; prey items contributing to the major categories are listed underneath. Summary information including total number of identifiable prey, total prey weight (g), and total stomachs is listed at the end of the table.

	Agonidae		
	A. olrikii		
Prey group or taxon	%MW	%MN	%O
Amphipods (unid.)	**50.2**	**54.1**	**70.0**
Benthic amphipods	**12.0**	**9.5**	**19.4**
Aceroides spp.	0.6	0.6	0.6
Anonyx spp.	1.8	1.1	2.3
Erichthonius spp.	2.7	1.7	4.1
Melita spp.	0.6	0.2	1.2
Photis spp.	1.4	1.1	2.3
Caprellidae	3.3	2.1	5.9
Gammaridae	0.1	0.7	1.2
Podoceridae	0.7	0.7	1.2
Lysianassidae	0.6	0.6	0.6
Stenothoidae	0.2	0.6	1.2
Calanoid copepods	**<0.1**	**0.2**	**0.6**
Other copepods	**<0.1**	**0.2**	**1.8**
Cyclopoid copepod	<0.1	0.1	1.2
Harpacticoid copepod	<0.1	0.1	0.6
Cumaceans	**0.1**	**<0.1**	**0.6**
Isopods	**1.5**	**1.9**	**8.2**
Ostracods	**<0.1**	**0.3**	**0.6**
Polychaetes	**0.7**	**1.1**	**2.3**
Other prey	**<0.1**	**0.1**	**0.6**
Tanaid	<0.1	0.1	0.6
Unidentifiable prey	**35.3**	**32.7**	**59.4**
Unid. animal tissues	20.0	15.4	37.1
Unid. crustacean fragmenst	14.7	16.8	32.3
Other unidentified	0.6	0.5	1.2
Total number of identifiable prey	583		
Total prey weight (g)	0.79		
Total stomachs	170		

Appendix G Table 3. Diets of *A. scaber*, *G. tricuspis*, *I. spatula*, and *T.pingelii* (Family Cottidae) within the Transboundary study area summarized by %MW, %MN, and %O. Major prey categories are in boldface; prey items contributing to the major categories are listed underneath. Summary information including total number of identifiable prey, total prey weight (g), and total stomachs is listed at the end of the table. A dash (–) indicates a prey item was not consumed by a sculpin species.

	Cottidae											
	A. scaber			*G. tricuspis*			*I. spatula*			*T. pingelii*		
Prey group or taxon	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O
Amphipods (unid.)	**14.8**	**16.1**	**44.4**	**10.8**	**11.0**	**25.5**	**38.6**	**44.7**	**79.2**	**8.5**	**11.1**	**22.4**
Benthic amphipods	**10.1**	**4.1**	**22.2**	**6.0**	**4.2**	**10.5**	**19.1**	**14.5**	**36.8**	**2.0**	**2.7**	**8.2**
Acanthostepheia spp.	2.3	2.2	11.1	0.2	0.1	0.2	–	–	–	–	–	–
Aceroides latipes	–	–	–	0.2	0.1	0.6	3.4	1.3	4.9	–	–	–
Anonyx spp.	–	–	–	1.0	0.6	1.7	0.2	0.2	0.7	–	–	–
Erichthonius spp.	–	–	–	0.2	0.1	0.6	6.5	3.0	9.7	–	–	–
Melita spp.	–	–	–	0.9	0.5	1.3	0.5	0.4	1.4	–	–	–
Photis spp.	–	–	–	–	–	–	0.2	0.4	2.1	0.2	1.0	2.0
Protomedeia spp.	–	–	–	0.5	0.4	0.8	–	–	–	–	–	–
Ampeliscidae	–	–	–	0.3	0.2	0.6	3.5	3.6	9.7	–	–	–
Caprellidae	–	–	–	–	–	–	1.2	2.0	5.6	–	–	–
Gammaridae	–	–	–	0.4	0.2	0.8	1.3	0.5	1.4	–	–	–
Phoxocephalidae	–	–	–	0.1	<0.1	0.2	1.5	1.3	5.6	–	–	–
Podoceridae	–	–	–	0.2	0.2	0.8	–	–	–	0.1	0.3	2.0
Lysianassidae	–	–	–	0.5	0.3	1.7	–	–	–	1.5	1.0	2.0
Oedicerotidae	7.9	1.9	11.1	1.0	1.0	1.9	0.7	1.3	4.9	0.1	0.3	2.0
Stenothoidae	–	–	–	0.1	0.1	0.4	<0.1	0.4	1.4	–	–	–
Uristidae	–	–	–	0.3	0.3	0.8	–	–	–	–	–	–
Other benthic amphipods	–	–	–	0.2	<0.1	0.2	0.1	0.1	0.7	–	–	–
Calanoid copepods	**–**	**–**	**–**	**1.4**	**0.9**	**3.0**	**1.3**	**3.1**	**11.8**	**13.8**	**14.8**	**20.4**
Other copepods	**1.3**	**2.0**	**11.1**	**7.0**	**11.9**	**25.3**	**<0.1**	**0.5**	**2.1**	**<0.1**	**0.1**	**2.0**
Cyclopoid copepod	–	–	–	<0.1	0.3	1.1	<0.1	0.3	1.4	–	–	–
Harpacticoid copepod	1.3	2.0	11.1	7.0	10.6	21.9	–	–	–	–	–	–
Unidentifiable copepods	–	–	–	0.1	1.0	3.6	<0.1	0.2	0.7	<0.1	0.1	2.0
Cumaceans	**9.6**	**4.7**	**22.2**	**8.8**	**6.7**	**17.9**	**1.5**	**1.8**	**7.6**	**2.0**	**2.0**	**2.0**
Diastylis spp.	–	–	–	1.6	1.1	3.0	–	–	–	–	–	–
Leucon spp.	–	–	–	0.5	0.3	1.1	–	–	–	–	–	–
Diastylidae	–	–	–	0.1	0.1	0.4	–	–	–	–	–	–
Other cumaceans	9.6	4.7	22.2	6.6	5.1	14.6	1.5	1.8	7.6	2.0	2.0	2.0
Fish prey	**–**	**–**	**–**	**0.6**	**0.2**	**0.6**	**–**	**–**	**–**	**2.8**	**2.0**	**4.1**
Cottidae	–	–	–	0.6	0.2	0.6	–	–	–	1.9	1.0	2.0
Other fish prey	–	–	–	–	–	–	–	–	–	0.9	1.0	2.0
Hyperiid amphipods	**–**	**–**	**–**	**0.7**	**0.7**	**1.3**	**0.1**	**0.1**	**0.7**	**11.1**	**8.8**	**20.4**
Themisto spp.	–	–	–	0.6	0.6	0.8	–	–	–	2.8	2.4	4.1
Other hyperiids	–	–	–	0.1	0.1	0.4	0.1	0.1	0.7	8.3	6.4	16.3
Isopods	**1.4**	**2.2**	**11.1**	**0.8**	**0.5**	**2.7**	**5.2**	**5.5**	**20.1**	**–**	**–**	**–**
Gnathia spp.	1.4	2.2	11.1	<0.1	<0.1	0.2	–	–	–	–	–	–
Munnopsis typica	–	–	–	–	–	–	1.7	1.2	2.8	–	–	–
Saduria spp.	–	–	–	0.3	0.1	0.6	–	–	–	–	–	–
Synodotea spp.	–	–	–	0.2	0.1	0.8	0.1	0.2	0.7	–	–	–
Munnidae	–	–	–	<0.1	0.1	0.4	–	–	–	–	–	–
Other isopods	–	–	–	0.3	0.2	1.1	3.4	4.1	17.4	–	–	–
Ostracods	**0.1**	**7.8**	**22.2**	**5.3**	**14.6**	**29.7**	**0.1**	**0.8**	**4.2**	**–**	**–**	**–**
Polychaetes	**16.4**	**10.4**	**33.3**	**16.7**	**10.7**	**31.2**	**14.1**	**9.9**	**34.7**	**3.1**	**1.7**	**8.2**
Darvilleidae	3.3	2.2	11.1	<0.1	0.1	0.6	–	–	–	–	–	–
Maldanidae	–	–	–	0.3	0.3	0.8	–	–	–	–	–	–
Onuphidae	–	–	–	<0.1	0.1	0.6	–	–	–	–	–	–
Phyllodocidae	–	–	–	0.5	0.4	1.3	–	–	–	–	–	–
Polynoidae	–	–	–	0.8	0.5	1.5	4.8	2.5	6.3	–	–	–
Spionidae	–	–	–	0.1	0.1	0.4	0.7	0.3	0.7	–	–	–
Sternaspidae	–	–	–	0.2	0.1	0.2	–	–	–	–	–	–
Syllidae	–	–	–	<0.1	0.1	0.2	–	–	–	–	–	–
Terebellidae	–	–	–	0.1	<0.1	0.4	–	–	–	–	–	–
Tricholoranchidae	–	–	–	0.2	0.1	0.2	–	–	–	–	–	–
Other polychaetes	13.1	8.1	33.3	14.1	8.9	27.4	8.7	7.0	27.8	3.1	1.7	8.2

Appendix G Table 3 continued. Family Cottidae diet summarized by %MW, %MN, and %O.

	Cottidae											
	A. scaber			*G. tricuspis*			*I. spatula*			*T. pingelii*		
Prey group or taxon	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O	%MW	%MN	%O
Other prey	**17.9**	**26.1**	**44.4**	**4.6**	**4.8**	**16.7**	**2.4**	**2.2**	**6.9**	**10.9**	**11.3**	**18.4**
Ascidiacea	–	–	–	0.3	0.2	0.6	–	–	–	–	–	–
Bivalves	–	–	–	1.8	0.9	3.4	0.5	0.5	2.1	–	–	–
Chaetognaths	–	–	–	0.3	0.2	0.4	–	–	–	2.9	3.1	4.1
Crabs	–	–	–	–	–	–	–	–	–	0.5	0.3	2.0
Cyprids	0.4	6.1	11.1	<0.1	0.1	0.4	–	–	–	–	–	–
Decapods	–	–	–	<0.1	<0.1	0.2	–	–	–	–	–	–
Euphausiids	<0.1	2.2	11.1	0.1	<0.1	0.2	0.7	0.7	0.7	3.7	2.7	4.1
Gastropods	–	–	–	0.1	1.1	3.6	–	–	–	0.2	2.0	2.0
Marine worms	12.5	11.1	11.1	0.2	0.2	0.2	–	–	–	–	–	–
Mysids	–	–	–	0.5	0.2	0.6	0.6	0.3	1.4	1.6	2.0	4.1
Nematodes	0.5	4.4	22.2	0.1	0.3	0.8	0.2	0.2	0.7	–	–	–
Shrimps	4.6	2.2	11.1	–	–	–	–	–	–	1.9	1.0	2.0
Tanaid	–	–	–	1.1	1.4	7.4	0.4	0.5	2.1	–	–	–
All other prey	–	–	–	0.1	0.3	1.1	–	–	–	0.1	0.2	2.0
Unidentifiable prey	**28.4**	**26.7**	**66.7**	**37.3**	**33.7**	**67.5**	**17.6**	**17.0**	**41.7**	**45.8**	**45.4**	**73.5**
Unid. animal tissues	22.2	22.2	44.4	14.8	11.4	29.7	6.2	5.2	15.3	14.4	15.0	20.4
Unid. crustacean frags	6.1	4.4	22.2	22.4	22.1	51.3	11.1	11.6	34.7	31.4	30.5	53.1
Other unidentified	–	–	–	0.1	0.2	0.8	0.2	0.3	0.7	–	–	–
Total no. identifiable prey	33			2,050			554			286		
Total prey weight (g)	0.05			8.3			3.4			0.5		
Total stomachs	9			473			144			48		

—

Appendix G Table 4. Diets of *A. medius* and *L. fabricii* (Family Stichaeidae) within the transboundary study area summarized by %MW, %MN, and %O. Major prey categories used in the analysis are in boldface; prey items contributing to the major categories are listed underneath. Summary information including total number of identifiable prey, total prey weight (g), and total stomachs is listed at the end of the table. A dash (–) indicates a prey item was not consumed by *A. medius* or *L. fabricii*.

	Stichaeidae					
	A. medius			*L. fabricii*		
Prey group or taxon	%MW	%MN	%O	%MW	%MN	%O
Amphipods (unid.)	**7.8**	**5.3**	**21.2**	**3.5**	**2.5**	**11.8**
Benthic amphipods	**3.0**	**2.8**	**9.1**	**1.4**	**0.2**	**11.8**
Aceroides latipes	2.9	1.8	6.1	0.9	0.1	3.9
Ampeliscidae	0.1	1.0	3.0	–	–	–
Oedicerotidae	–	–	–	0.5	0.1	7.8
Calanoid copepods	**3.6**	**2.0**	**6.1**	**5.9**	**5.9**	**5.9**
Other copepods	**18.3**	**25.2**	**48.5**	**27.4**	**43.7**	**54.9**
Cyclopoid copepod	<0.1	1.7	9.1	<0.1	<0.1	2.0
Harpacticoid copepod	18.2	22.8	45.5	4.3	4.4	5.9
Unidentifiable copepods	<0.1	0.8	3.0	23.0	39.3	51.0
Cumaceans	**6.6**	**2.7**	**15.2**	**5.3**	**0.7**	**19.6**
Diastylis spp.	–	–	–	2.2	0.4	5.9
Leucon spp.	–	–	–	3.0	0.3	15.7
Other cumaceans	6.6	2.7	15.2	0.1	<0.1	2.0
Hyperiid amphipods	**1.3**	**1.0**	**3.0**	**–**	**–**	**–**
Themisto spp.	1.3	1.0	3.0	–	–	–
Ostracods	**9.0**	**12.5**	**30.3**	**6.4**	**7.2**	**23.5**
Polychaetes	**10.2**	**9.3**	**30.3**	**0.5**	**0.2**	**11.8**
Darvilleidae	–	–	–	–	–	3.9
Polychaete	10.2	9.3	30.3	0.3	0.1	9.8
Polynoidae	–	–	–	0.1	<0.1	2.0
Other prey	**11.3**	**11.9**	**24.2**	**14.1**	**9.4**	**35.3**
Ascidiacea	–	–	–	0.8	<0.1	2.0
Bivalves	1.2	0.6	3.0	–	–	–
Gastropods	–	–	–	1.8	3.0	9.8
Nematodes	6.1	9.0	21.2	8.9	5.4	31.4
Tanaid	4.1	2.3	9.1	2.6	1.0	17.6
Unidentifiable prey	**28.9**	**27.3**	**57.6**	**35.5**	**30.2**	**52.9**
Unid. animal tissues	6.1	3.2	15.2	15.3	13.0	31.4
Unid. crustacean fragmenst	22.8	24.1	45.5	20.2	17.2	25.5
Total number of identifiable prey	154			2,059		
Total prey weight (g)	0.07			0.12		
Total stomachs	33			51		

Appendix G Table 5. Results of the permutation tests used in determining whether relationships between the multivariate diet data and the biological (i.e., fish length) and environmental variables (i.e., depth, latitude, longitude, and year) were significant at α=0.05.

Family	Species	Df	F	p
Agonidae	*A. olrikii*	5	2.952	0.004
Cottidae	*A. scaber*	2	0.947	0.519
	G. tricuspis	5	6.673	0.001
	I. spatula	5	2.775	0.001
	T. pingelii	5	1.253	0.182
Stichaeidae	*A. medius*	5	1.014	0.435
	L. fabricii	2	2.478	0.031

Appendix G Table 6. Correlations of the explanatory variables fish length, depth, latitude, longitude, and year with the first two axes of the canonical correspondence analysis (i.e., CCA1 and CCA2) of *A. olrikii*, *G. tricuspis*, *I. spatula*, and *L. fabricii* diets within the Transboundary study area. The significance of each variable (α=0.05) is listed next to its corresponding axis correlation value. The cumulative percent variance explained by the first two CCA axes is listed underneath the CCA2 column in each figure.

	A. olrikii			*G. tricuspis*			*I. spatula*			*L. fabricii*		
Variables	CCA1	CCA2	p	CCA1	CCA2	p	CCA1	CCA2	p	CCA1	CCA2	p
Fish length	0.06	0.05	0.529	-0.41	-0.26	0.001	0.23	0.13	0.012	0.67	-0.16	0.005
Depth	0.16	-0.11	0.171	-0.28	-0.23	0.005	-0.01	0.19	0.593	0.07	0.99	0.254
Latitude	0.26	0.18	0.480	-0.23	0.26	0.004	-0.41	0.05	0.001	NA		
Longitude	0.18	0.26	0.007	-0.25	0.32	0.001	-0.43	-0.04	0.267	NA		
Year	-0.31	-0.21	0.001	0.27	-0.36	0.001	0.10	-0.39	0.001	NA		
Cumul. (%)	6.02	9.73		4.50	6.65		5.30	7.80		9.39	12.72	
Total (%)		10.27			8.15			9.78			12.72	

Appendix G Table 7. Size class recommendations for *A. olrikii*, *G. tricuspis*, *I. spatula*, *T. pingelii*, *A. medius*, and *L. fabricii*. Recommendations for each species are based on size groupings at similarity percentages >55% as calculated by Bray-Curtis distance matrices. Size classes were unable to be determined for the cottid, A. scaber, due to small sample sizes.

Family	Species	n	Size class 1	Size class 2	Size class 3	Method
Agonidae	*A. olrikii*	135	≤ 60	61–80	–	nMDS (80% Sim)
Cottidae	*A. scaber*	8	Insufficient sample size			–
	G. tricuspis	382	≤ 70	71–90	91–150	nMDS (60% Sim)
	I. spatula	134	≤ 50	51–80	–	nMDS (70% Sim)
	T. pingelii	34	≤ 50	51–114	–	Cluster (60% Sim)
Stichaeidae	*A. medius*	27	≤ 70	71–140	–	Cluster (55% Sim)
	L. fabricii	37	≤ 60	61–103	–	Cluster (55% Sim)

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix H

Diets of Four Eelpout Species (Genus Lycodes) in the US Beaufort Sea Based on Analyses of Stomach Contents and Stable Isotopes of Nitrogen and Carbon

Author
Sarah Apsens

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Table of Contents

List of Figures

List of Tables

List of Appendices

Page

DIETS OF FOUR EELPOUT SPECIES (GENUS LYCODES) IN THE U.S. BEAUFORT SEA BASED ON ANALYSES OF STOMACH CONTENTS AND STABLE ISOTOPES OF NITROGEN AND CARBON

A

THESIS

Presented to the Faculty

of the University of Alaska Fairbanks

in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Sarah J. Apsens, B.S.

Fairbanks, AK

December 2017

Abstract

Eelpouts of the genus *Lycodes* are an abundant group of demersal fishes in the U.S. Beaufort Sea. Currently eelpout diet and the exact role of eelpouts in the Arctic food web are poorly understood. Additionally, if and how eelpouts avoid intra- and interspecific competition for resources is unknown. In this study, diets of four common Beaufort Sea eelpout species were analyzed with respect to along-shelf (longitude) gradients, across-shelf (depth) gradients, and ontogeny (fish body length) to determine diet composition and patterns of resource partitioning. Diets of the four most numerous eelpout species were analyzed using a combination of stomach contents and nitrogen and carbon stable isotope analyses: Adolf's Eelpout *Lycodes adolfi,* Canadian Eelpout *L. polaris,* Archers Eelpout *L. sagittarius,* and Longear Eelpout *L. seminudus*. Nitrogen stable isotopes of fish tissue were analyzed to determine trophic level and carbon stable isotopes to determine if origin sources of carbon in food web pathways of eelpout diets differed among species. Fishes were collected in the central (2012) and eastern (2013 and 2014) Beaufort Sea in August and September as part of the U.S.-Canada Transboundary program. Prey groups Polychaeta, Amphipoda, Isopoda, Ophiuroidea, and Copepoda composed a large proportion of the diet by percent weight for all four species of *Lycodes*, but their relative contributions differed among the species examined. This study indicated that eelpouts feed almost exclusively on benthic prey and avoid interspecific competition by occupying different habitat space and having different diets. Intraspecific similarity in diet composition was low suggesting these fish have diverse diets even among individuals of the same species. Fish length was associated with changes in diet composition for *L. adolfi* and *L. sagittarius*, but not *L. polaris* and *L. seminudus*. Longitude and depth were correlated with shifts in diet composition for *L. sagittarius*, but not the other three species. *Lycodes polaris* occupied a lower trophic level than the other three eelpout species based on nitrogen stable isotope values. Despite differences in the across-shelf distribution between *L. polaris* and the three deep-water eelpout species, carbon sources of diet were indistinguishable among the four eelpout species. Ecological information on abundant Arctic fish species like eelpouts is needed for long-term ecosystem monitoring, which is especially important in light of pronounced climate changes and increased human activities in the Arctic.

Introduction

Arctic fishes are important links between lower and upper trophic levels (Lowry and Frost 1981). Fish consume plankton, benthic invertebrates, and smaller fishes. These fish are then available to higher trophic level organisms like birds, whales, ice seals, polar bears, and humans. Basic ecological information on abundant but poorly studied fish species is needed as state and federal agencies prepare for multispecies management practices in the Arctic, such as the potential development of commercial fisheries (NPFMC 2009). Here, I provide new insights into the diet and trophic ecology of four abundant eelpout species thus providing a valuable benchmark for long-term, multispecies ecosystem monitoring in a changing Arctic.

Understanding the current statuses and processes of the abiotic and biotic components of the Arctic ecosystem is becoming increasingly urgent under unprecedented environmental change (Linden 2016; IPCC 2014). Climate change is expected to alter Arctic Ocean ice cover, which in turn will impact existing patterns of primary production, which will reverberate throughout the associated food web (Carmack and Macdonald 2002; Bluhm and Gradinger 2008; Grebmeier 2012). An ecosystem-wide shift is expected, resulting in higher transfer of organic carbon to pelagic consumers rather than to benthic communities (Grebmeier et al. 2006). Understanding the role of abundant organisms that form essential ecological links in the current Arctic food web is necessary to better predict changes to how the Arctic ecosystem currently functions.

Zoarcidae is a large and species-rich family of fishes commonly known as eelpouts. Approximately 240 species in this family are recognized globally (Anderson and Fedorov 2004). Eelpouts are found in both the Arctic and Antarctic seas and in boreal regions across both hemispheres, usually in deep waters off continental shelves (Anderson 1988; Mecklenburg et al. 2011). In the Arctic, eelpouts are circumpolar in distribution and primarily represented by two genera: *Lycodes* and *Gymnelus* (Mecklenburg et al. 2011). *Lycodes* is the more species-rich genus of the two, and includes 24 of the 34 known Arctic species in the family Zoarcidae (Møller and Gravlund 2003; Mecklenburg et al. 2011). In addition to being species rich, Zoarcidae is one of the most abundant demersal fish families in the U.S. Beaufort Sea, superseded only by the families Gadidae and Cottidae (Rand and Logerwell 2011; Giraldo et al. 2015; Norcross et al. 2016). Approximately 13 fish families are represented in the central and eastern U.S. Beaufort Sea (Norcross et al. 2016). The shelf (≤ 100 m) is dominated by Gadidae and Cottidae, but on the central and eastern Beaufort Sea slope (≥ 200 m in depth) zoarcids of the genus *Lycodes* compose over half of the total fish biomass (>60%) and abundance (>60% in 2013 and52% in 2014) (Norcross et al. 2016). Due to their abundance, eelpouts may be an important component of the ecosystem, potentially competing with other fish for resources, serving as prey themselves, and/or actively preying on other fish species (Møller and Jørgensen 2000). Despite their potential ecological importance in the Arctic Ocean and adjacent seas, surprisingly little is known about zoarcid diet and trophic position in the western Arctic.

Similar to other Arctic fish species, eelpouts serve as prey for higher trophic level Arctic organisms. Seabirds like Black-Legged Kittiwakes *Rissa tridactyla* and Northern Fulmars *Fulmarus glacialls* occasionally consume *Lycodes* spp. (Phillips et al. 1999; Paredes et al. 2014). Marine mammals, including bearded seals *Erignathus barbatus* and belugas *Delphinapterus leucas* consume eelpouts in the Bering and Chukchi seas (Lowry et al. 1980; Finley and Evans 1983; Quakenbush et al. 2015). Greenland Shark *Somniosus microcephalus* in the Atlantic Arctic consume eelpouts (Yano et al. 2007). Eelpouts are occasionally consumed elsewhere by humans (Love 2011), but they are not used for subsistence in the Pacific Arctic. Due to the lack of commercial fishing for eelpouts globally, the development of commercial fishing for Arctic eelpouts is unlikely; however, eelpouts could be bycatch if commercial fisheries were to develop in the region.

Eelpouts of the genus *Lycodes* have relatively long lifespans compared with other fishes in the region. For example, the Glacial Eelpout (*Lycodes frigidus*) is thought to achieve a maximum age of 33 years, while other eelpouts species likely reach maximum ages between 6 and 24 years (Balanov et al. 2006; Hildebrandt et al. 2011; Norcross et al. 2016). In contrast, the most abundant Arctic forage fish, Arctic Cod *Boreogadus saida*, only lives 5 to 8 years in the Beaufort Sea (Gillispie et al. 1997; Frothingham personal communication). Due to their relatively long lifespans, eelpout populations may respond more slowly phenotypically to environmental perturbations than organisms with shorter generation times and thus more adaptive potential (Davis et al. 2005; Somero 2009). Eelpouts may be susceptible to bioaccumulation of toxins due to their long lifespans. Mercury (Atwell et al. 1998) and persistent organochlorine (OC) contaminants (Borgå et al. 2004) are shown to bioaccumulate in some long-lived members of the Arctic food web. Microplastics have been observed in high concentrations in Arctic Sea ice (Obbard et al. 2014), and consumption of released microplastics could expose fishes to physiological stress and toxins that could accumulate in tissues (Rochman et al. 2013).

The eelpout species examined in this study are the most numerous of the zoarcids collected as part of a joint U.S. and Canada effort to document fish and invertebrate species in the Beaufort Sea called the U.S.-Canada Transboundary Fish and Lower Trophic Communities project; the eelpout species have overlapping distribution ranges in the Beaufort Sea (Norcross et al. 2016). *Lycodes adolfi* is typically found in high numbers between 800 and 1,200 m deep off Greenland and Norway (Møller and Jørgensen

2000; Byrkjedal et al. 2011), and only recently was discovered to occupy the western Arctic (Mecklenburg et al. 2011). It spawns in the summer, while most other Arctic eelpout species spawn in late fall or winter (Møller and Jørgensen 2000). *Lycodes sagittarius* and *L. seminudus*, found from the Beaufort Sea to the Kara Sea, commonly occur on the slope (> 100 m) on muddy substrates (McAllister et al. 1981). *L. polaris* is circumpolar in distribution (Mecklenburg et al. 2002) and is found in both marine and brackish nearshore waters (Craig 1984) at shallower depths than the other three *Lycodes* species in this study (Norcross et al. 2016). The abundance and potential niche overlap of the four eelpout species in the Beaufort Sea warrants further investigation of their diet and trophic roles to address questions of competition and resource partitioning.

Diet information is limited for the four eelpout species examined here. In general, eelpouts are demersal, and all *Lycodes* have cartilaginous stationary crests on their chins that are believed to be used to skid through the sediment while looking for prey (Anderson 1994). *Lycodes polaris* in the Chukchi Sea feed heavily on demersal, gammarid amphipods (Whitehouse et al. 2017). In contrast, *L. polaris* in the neighboring Beaufort Sea may have a more pelagic-based diet, and is characterized as a low-trophic position generalist (Giraldo et al. 2016). The differences in diet composition for *L. polaris* between seas enforces the need for regional diet studies such as this one. *Lycodes adolfi* diet in the Canadian Beaufort Sea consists of demersal prey (Giraldo et al. 2016) but is highly variable among individuals. *Lycodes sagittarius* stomachs collected in the far eastern Beaufort Sea contained annelid worms, mollusks, and crustaceans; the presence of vomerine teeth often used for crushing prey in other fish species suggest that *L. sagittarius* may specialize in preying on hard-shelled prey (McAllister et al. 1981). *Lycodes seminudus* is characterized as a mid- to high-trophic level benthic generalist, potentially feeding on overwintering *Calanus* spp. copepods(Giraldo et al. 2016). Amphipods, decapods, isopods, and polychaetes have been observed in *L. seminudus* stomachs collected in the Barents Sea (McAllister et al. 1981). Fatty acid and stable isotope signatures consistent with a diet of *Calanus* copepods were observed for *L. adolfi* and *L. seminudus* collected in the Canadian Beaufort Sea, suggesting copepods like *Calanus hyperboreus* may be important diet components for the two eelpout species (Giraldo et al. 2016).

Two common ways to study diet are stomach content analysis and stable isotope analysis, which together provide complementary information about trophic ecology. Analyzing stomach contents provides high taxonomic resolution of prey species as well as abundance (e.g., counts) or size of prey (Pinkas et al. 1971; Hyslop 1980). Reliable prey identification during stomach content analysis, however, can be biased towards prey items with hard, indigestible body parts (Baker et al. 2014). Prey organisms with soft bodies, like polychaete worms, are digested rapidly compared with hard-bodied prey. Therefore, while stomach content analysis gives a detailed taxonomic account of a consumer's diet, this information represents a short time period, i.e., hours or days after consumption, and is biased toward prey that have identifiable hard structures. Application of DNA to identify heavily digested prey in fishes (Dunn et al. 2010) can be useful in stomachs with highly digested prey, but has drawbacks including cost and the biases introduced in the application of the need for prey species-specific primers (Jarman et al. 2004). Stable nitrogen isotope analysis can give time-integrated information on diet and relative trophic level of a species based on feeding strategies, but does not provide information on specific prey composition without additional ancillary data (i.e., stable isotope values of prey consumed) (Vander Zanden and Rasmussen 1999; Kelly 2000). Ultimate carbon sources from pelagic, sea-ice associated, and terrestrial production can be distinguished isotopically (Iken et al. 2005; Dunton et al. 2006; Gradinger 2009; Bell et al. 2016). Stable isotope ratios integrate fish diet information over weeks to possibly even months (Sakano et al. 2005; Buchheister and Latour 2010). Therefore, stable isotope analysis complements taxonomically-detailed results from stomach content analysis with a broader temporal picture of the trophic ecology of *Lycodes* species.

Physical features of a habitat, e.g., water mass characteristics and depth, can influence epibenthic prey distribution (Ravelo et al. 2015) and potentially the diet composition of predators like fish or large invertebrates (Fahrig et al. 1993; Jaworski and Ragnarsson 2006; Divine et al. 2015). In this study, fish were collected across the shelf and the slope habitats of the Beaufort Sea. The steep slope cuts through multiple, layered water masses that create different environments based on salinity, temperature and nutrient regimes (Pickart et al. 2011). The changes in water masses across depth are closely linked to changes in benthic infauna and epifauna communities that can serve as prey for eelpouts (Nephin et al. 2014; Roy et al. 2015). Terrestrial organic matter input from major rivers also results in longitudinal differences in trophic structure, carbon isotopic signatures, and benthic invertebrate food web length on the Beaufort shelf (Bell et al. 2016). Regional variation in trophic structure and carbon sources as shown for invertebrates (Divine et al. 2015; Bell et al. 2016) may also be reflected in eelpouts.

Intra- and interspecific interactions among fishes influence diet composition (Chipps and Garvey 2007). Fishes that share the same habitat and trophic level often compete for resources (Parish 1975). Eelpouts consume epifauna (Bjelland et al. 2000; Dissen 2015; Giraldo et al. 2016). Epifauna biomass is greater than fish biomass in the U.S. Beaufort Sea, is highest at the shelf break, and decreases with increasing depth (Norcross et al. 2016). Although epifauna prey availability may not be a limiting factor, the four eelpouts species in this study could be competing for the same resources if they share the same trophic level and habitat unless resource partitioning is occurring. Decreasing epifauna abundance with increasing depth may increase inter- and intraspecies competition for resources. Resource partitioning among sympatric Arctic fishes of the order Scorpaeniformes that share habitat space has been observed in northern Norway (Källgren et al. 2015) and in the Beaufort Sea (Gray et al. 2017). Eelpouts may also interact with other demersal fish species either through competition or predation. Some evidence for interspecific interaction exists. In the Canadian Beaufort Sea, *L. polaris* diet overlaps with Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*), another abundant demersal fish species (Giraldo et al. 2016). Examining diet of these four eelpout species will elucidate patterns of resource partitioning or diet overlap.

In order to distinguish the intraspecific diet and trophic roles of eelpouts in the ecosystem it is necessary first to have a robust understanding of species and population divisions. Eelpout species' boundaries and taxonomic descriptions have traditionally been based on morphological features (Anderson 1994; Møller and Gravlund 2003). However, the extensive phenotypic variability with size and sex documented in some species of *Lycodes* points to potential problems with current taxonomic designations (McAllister et al. 1981; Møller and Jørgensen 2000; Balanov and Kukhlevskii 2011; Mecklenburg et al. 2011). For example, one eelpout species from the Sea of Japan occurs in five different major color variations (Balanov and Kukhlevskii 2011). Spatial differences in color patterns at the population level have also been described for *L. seminudus* (Møller and Jørgensen 2000; Mecklenburg et al. 2014), and polymorphic populations of *Lycodes* exist in the Northern Hemisphere (Anderson and Fedorov 2004). Genetic analysis using mitochondrial DNA (mtDNA) is one method commonly used to assign individuals to species when morphological characteristics are not reliable, though this approach has limitations. MtDNA analysis has been used to clarify identification of the Arctic eelpout species *L. yamatoi* (Balanov and Kukhlevskii 2011) and the overall structure of Arctic eelpout phylogeny (Møller and Gravlund 2003) and diversity (Turanov et al. 2016). An important limitation of mtDNA is that it only provides a partial description of genetic variability entirely restricted to the mitochondrial genome; in addition, it is susceptible to error in populations where hybridization occurs (Ward et al. 2005). Though not a conclusive measure in itself mtDNA can aid in identifying individuals when other methods are not reliable. Sequences from mtDNA were employed in the present project to ensure that results on diet, trophic position, and potential resource partitioning or competition were placed in the appropriate species context.

The objective of this study was to characterize diet of *L. adolfi*, *L. polaris*, *L. sagittarius*, and *L. seminudus*, four common eelpout species on the Beaufort Sea shelf and slope, and to look for evidence of resource partitioning. To accomplish this, I described the diet and inferred trophic level (TL) using stomach content and stable nitrogen and carbon isotope analyses. Sampling over three years afforded the opportunity to evaluate interannual variability. In addition, stomach contents and stable isotopes were compared across fish length to see if resource partitioning changes through eelpout ontogeny, and by depth to test for resource partitioning by habitat. Detailed information on diet is needed for abundant fish species such as eelpouts to better understand patterns of resource use and partitioning and to inform ecological models for the Arctic (Whitehouse et al. 2017; Källgren et al. 2015). This type of information is also needed for understanding current ecosystem functioning and for establishing baseline information required for long-term monitoring of the ecosystem.

Methods

Fish collection and processing

Eelpouts were collected over three years during the U.S.-Canada Transboundary cruises in the central and eastern Beaufort Sea (Figure 1). The central U.S. Beaufort Sea was sampled in 2012 (September 20 to October 1, between 151.5° – 150.5° W and 70.5° – 72° N), and the eastern Beaufort Sea in 2013 (August 12 to September 2, 146.1° – 136.7° W, 70° – 72°N) and 2014 (August 17 to September 2, 146.1° – 140.1° W, 70° – 72°N). Sampling occurred on eleven predetermined across-shelf transects (approximately following lines of longitude) and along-shelf, at depths of 20, 50, 100, 200, 350, 500, 750, and 1,000 m, except for 2014 when also one 1,500 m station was sampled. An otter trawl (38 mm mesh in body), and three beam trawls (BT; 7 – 10 mm mesh in body and 4 – 6 mm mesh in codend) were used to collect fish (for description of nets see Norcross et al. 2016). All nets were towed at 1–2 kts for approximately 3–15 min. Total time the net was on the bottom was determined from a Star-Oddi time depth recorder (TDR) attached to the net, and haul distance was calculated from GPS locations of the vessel at the start and end time of the net on the bottom. Effort was comparable for the three BT nets (Norcross et al. 2016). Catch per unit effort (CPUE) was calculated for eastern Beaufort Sea (2013 and 2014) BT catches as (# fish x 1,000) / (haul distance (m) x 2.26 m net swath). CPUE was not calculated for central Beaufort Sea (2012) and OT catches because swaths were inconsistent and equipment issues resulted in unreliable haul information. Fishes from both regions (central and eastern) and all net types were used in subsequent stomach content and stable isotope analyses.

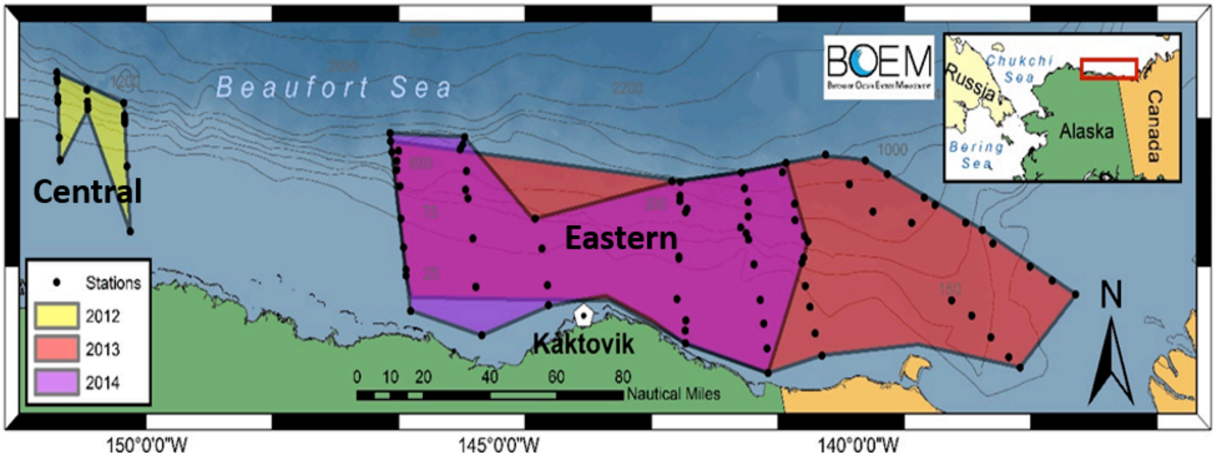


Figure 1. Area sampled. Sampling stations (black dots) occurred along transects oriented perpendicular to shore. Polygons cover areas sampled in each year.

Eelpouts obtained at sea were identified, euthanized, and frozen for later processing. Eelpouts were identified to species when possible or to the genus or family level when they were too small or damaged to identify accurately in the field. A lethal dose of MS-222 was used to euthanize the fish (Institutional Animal Care and Use Committee protocol #07–047). Eelpouts were then frozen in the field for later processing at the Fisheries Oceanography Lab (FOL) at the University of Alaska Fairbanks.

At FOL morphometric measurements and tissue samples were collected. Wet weight to the nearest 0.01 g and total length (mm) of each fish were measured before the stomach was removed. Whole stomachs were removed from each eelpout by making an incision on the ventral side and cutting at the esophagus and pyloric valve and stomachs were frozen in water. In total, stomachs from 466 eelpout specimens were examined from the three cruises (Table 1). Gape height to the nearest 0.01 mm was measured from the top of the dentary to the bottom of the premaxilla using digital calipers while the mouth was at maximum extension (Scharf et al. 2000). Gape height was only measured for the four eelpouts collected in 2014 (n=184). Fishes from 2012 and 2013 were not measured for gape size because repeated freezing and thawing may have compromised gape morphology. Fish with broken jaws or fish whose jaws were too small for accurate measurement were not measured.

Table 1. Number of fish stomachs by eelpout species and sampling year. Excluded were those stomachs that were empty, non-quantitative (burst stomachs), or contained only parasites.

Species, Cruise	**Available**	**Excluded**	**Empty**	**Parasites**	**Burst**	**Used in Analysis**
Lycodes adolfi	164	41	39	1	1	123
2012	25	9	9	0	0	16
2013	47	9	9	0	0	38
2014	92	23	21	1	1	69
Lycodes polaris	44	10	10	0	0	34
2012	30	5	5	0	0	25
2013	1	1	1	0	0	0
2014	13	4	4	0	0	9
Lycodes sagittarius	151	21	18	3	0	130
2012	75	12	10	2	0	63
2013	18	2	2	0	0	16
2014	58	7	6	1	0	51
Lycodes seminudus	107	25	16	9	0	82
2012	39	7	5	2	0	32
2013	33	12	6	6	0	21
2014	35	6	5	1	0	29
TOTAL	**466**	**97**	**83**	**13**	**13**	**369**

Species identification

Consultation with an Arctic fish taxonomist (C.W. Mecklenburg, Point Stephens Research, Auke Bay, AK) revealed difficulties with accurately identifying specimens of *Lycodes* to species. Because morphological re-identification was impossible after individuals had been cut up during processing, mtDNA barcoding was used to aid in fish species identification. DNA isolated from muscle samples from 205 specimens was used to determine DNA sequences from a segment of the mitochondrial *cox1* gene (commonly termed the DNA barcode). Briefly, total genomic DNA was isolated from frozen tissue samples using standard molecular biology protocols. Genomic DNA preparations were then used as templates in amplification reactions using the Fish F1/R1 primer set of Ward et al. (2005). Reaction products were purified and sequenced in both directions using the Sanger protocol. Raw sequencing data were reviewed, edited, and assembled to exclude artifacts introduced during sequence determination procedures. Finished sequences were used in match queries against the Barcode of Life Database (BOLD; *barcodeoflife.org*) to determine their species assignations. A match was deemed acceptable when query sequences from this study matched published sequences from vouchered specimens at levels of >99.0%. In cases where sequences representing multiple species in BOLD matched a sequence from the study specimen, the individual fish was deemed to belong to a species complex. Here, a species complex is defined as a group of closely related species, or species that show very little genetic differentiation based on the barcode gene. BOLD results were compared to the previous species identifications based on morphology. In total, 204 fishes originally identified by FOL as one of the four species of *Lycodes* examined were successfully sequenced for mtDNA, and an additional 40 minimally processed and voucher specimens were identified based on morphological features by the expert taxonomist. The estimated agreement between molecular and morphometric methods, here referred to more generally as percent accuracy, in identification for each eelpout species was determined by dividing the number of fishes identified correctly by FOL by the total number of fishes identified to species by mtDNA or an expert taxonomist.

Stomach Content Identification

Each stomach was thawed and opened under a dissecting microscope (6x to 100x magnification). Prey were identified to the lowest taxonomic level possible, length measured (mm) and weighed to the nearest 0.0001 g. Heavily digested prey were designated as either unidentified crustacean carapace fragments or as other unidentified animal soft tissue. In total, stomachs of 369 individual fish were analyzed; 97 stomachs were excluded because they were empty, non-quantitative (burst stomachs), or contained only parasites (Table 1).

Individual prey taxa were clustered into coarse prey groups to ensure adequate description of eelpout diet. Prey were initially identified to the lowest taxonomic level possible. Prey-accumulation curves were used to assess how adequately diet was described at fine-scale taxonomic levels. A species' diet was considered adequately described when the prey-accumulation curve reached an asymptote (Chipps and Garvey 2007). Asymptotes were not achieved with prey identified to the lowest taxonomic level possible, indicating eelpout diet was not sufficiently described, so prey were aggregated into coarse taxonomic groups at either phylum, order, class, or subclass level. Rare prey were grouped as "other". A prey item was considered rare if it occurred fewer than five times across all stomachs analyzed across all four eelpout species. All prey-accumulation plots were created using bootstrapping with 999 permutations as implemented in PRIMER v.7.

Percent wet weight (%W) of prey was chosen to describe diet for each eelpout species because of its potential ecological significance. This index can be indicative of the nutritional importance of a prey item (Hyslop 1980, Macdonald and Green 1983, Chipps and Garvey 2007) and was calculated for each prey group *i* and predator stomach *j* as follows:

$$\%W_{ij} = \frac{W_{ij}}{\sum_i W_{ij}} * 100$$

where W_{ij} is the weight (g) of all members in a prey group *i* in the stomach of a predator *j*, divided by the sum of all prey group weights in the stomach of predator *j*.

An additional index, percent mean weight (%MW), was used to describe overall diet composition for each eelpout species by averaging $\%W_{ij}$ over all individual stomachs *j*:

$$\%MW_i = \frac{1}{P}\sum_{j=1}^{P}[\%W_{ij}]$$

where *P* is the total number of non-empty stomachs.

Interannual Differences in Diet

A permutational analysis of variance (PERMANOVA, PRIMER v.7) based on Bray-Curtis dissimilarity matrices using %W was used to test for interannual differences in diet composition for fishes collected in 2013 and 2014 (eastern Beaufort Sea). Sampling year was used as a fixed factor, and tests between years were run separately for each eelpout species. Significance level was set at $\alpha = 0.05$. If diet did not differ between years for a given eelpout species then diet data were pooled across years. Cumulative prey curves of each eelpout species in each sampling year were used to see if pooled data were necessary to more comprehensively describe diet. Because of the different sampling area, 2012 fish diet was analyzed separately to avoid confounding effects between space and time (Figure 1).

Gape size

Analysis of covariance (ANCOVA) models were used to determine the relationship between fish length and gape height among the four eelpout species. The relationship between fish length and gape height is linear (Scharf et al. 2000), but three alternative models were compared to determine how best to describe variations in gape size with length. The first model assumed that a single linear relationship between length and gape height adequately described the relationship for all four eelpout species. The second model allowed for different intercepts, but assumed the same rate of increase for gape height with length for the four eelpout species. The third model allowed for different intercepts and rates of increase for each eelpout species. The best model was chosen using the Akaike Information Criterion (AIC). All analyses were done in R version 3.0.3 (R Core Team 2016).

Overall Diet Composition

Multivariate tools were used to test for dissimilarities in diet composition among the four eelpout species and to investigate the influence of along-shelf (longitude, represented by transect, Fig. 1) and across-shelf (depth) spatial differences and total fish length on diet. Eastern (2013 and 2014) and central (2012) fishes were analyzed separately to avoid confounding effects of geographical dissimilarities and time. Diet information of eastern Beaufort Sea fishes was pooled and analyzed together if no interannual differences were detected. A Bray-Curtis dissimilarity matrix based on %W in individual stomachs was used in a PERMANOVA, with significance level set at $\alpha = 0.05$. Fish species, depth, and transect were included as fixed factors in the model, and fish length was included as a covariate. Due to the bathymetry over the sampling region, changes in latitude were closely associated with changes in depth. Therefore, latitude was excluded from the analysis to avoid issues with multicollinearity. Non-metric multidimensional scaling (nMDS) plot, based on the same Bray-Curtis dissimilarity matrix were created to show the similarities among individual stomach samples. All nMDS plots used Kruskal fit scheme 1 and were considered adequate when they had a maximum stress ≤ 0.2. A similarity percentage (SIMPER) analysis was used to determine what percentage a given prey species contributed to the similarity (within groups) or dissimilarity (between groups) in diet composition of each *Lycodes* species. The prey items that contributed at least 70% of the cumulative observed similarities or dissimilarities in diet were reported. PERMANOVA, nMDS, and SIMPER analyses were conducted in PRIMER v.7.

Canonical correspondence analysis (CCA) was used to directly relate environmental (depth, along shelf (i.e., longitude), bottom temperature, and bottom salinity) and biological (fish total length) factors to diet composition. Due to smaller sample sizes in 2012 and less available corresponding environmental data, only pooled 2013 and 2014 data were used for CCA. In this analysis, prey composition (%W) of the coarse prey groups in each stomach was used as the multivariate response variable. All environmental variables were normalized to mean zero and standard deviation one prior to analysis. A permutation test of the CCA axes at a 5% significance level was used to test the null hypothesis that there is no overall association between the biotic (i.e., stomach contents) and environmental (i.e., fish length and environmental data) matrices. If the overall test was significant, permutation tests were used to assess the significance of each individual term in the model, as well as the significance of each (constrained) CCA axis. In addition, results were examined graphically using a CCA plot, in which the length of a vector for a continuous factor indicates the magnitude of its effect on diet composition, and its direction in relation to a canonical axis indicates how much of the variability of the axis was explained by the given factor. The location of the weighted averages of each coarse prey group in the CCA plot in relation to these vectors was indicative of a variable's association with a given factor (Ter Braak 1986). All CCA analyses were conducted using the vegan 2.2-1 package in R, version 3.0.3.

Size Class Analysis

A combination of nMDS plots and clustering based on Bray-Curtis dissimilarity was used to determine size classes and ontogenetic shift in diet for three of the four eelpout species *L. adolfi, L. sagittarius*, and *L. seminudus*. The sample size for *L. polaris* was too small to use in this analysis. For each of the remaining eelpout species, fish were grouped into 10 mm size bins (e.g., 11 – 20, 21–30 mm size bin). A minimum of four fish was required for each size bin. If fewer than four fish were available for a 10-mm bin, consecutive size bins were combined with the next larger consecutive bin. Similarities among stomach samples grouped by fish size and described by %MW for each size group were visually examined using ordination plots. Cluster overlays were examined at varying resemblance levels (e.g., 40%, 50%, and 60% similarity) until ecologically reasonable groupings appeared.

Stable Isotope Analysis

Muscle tissue samples were collected for nitrogen and carbon stable isotope analyses from all individuals of the four species of *Lycodes* collected in 2014 (Table 2). Muscle clips were taken from above the lateral line towards the anterior end of each fish. A 5 x 5 mm section of muscle tissue was removed from each fish, making sure to exclude skin or bone as these tissues can have different isotopic signatures (Tieszen et al. 1983). Tissue samples were then placed in 0.5 ml microcentrifuge tubes and stored frozen until further processing. Subsamples of ten individual fish were selected within a 10-mm length bin for each eelpout species (e.g., 10–19 mm, 20–29 mm, 30–39 mm) to ensure sampling across the entirety of each species length range. Tissue samples for nitrogen stable isotope analysis were freeze-dried, crushed, and weighed. Tissue samples for carbon isotope analysis required additional processing. High lipid content in some fish muscle tissue impacts stable carbon isotope values, so lipid extraction (LE) was used to circumvent this issue (Pinnegar and Polunin 1999). Lipids were removed with a 2:1 chloroform: methanol solution. LE samples were allowed to dry overnight before being crushed and weighed. LE processing can potentially impact stable nitrogen isotope signatures (Pinnegar and Polunin 1999), so samples to be measured for stable nitrogen isotope ratios were not lipid extracted. If an individual fish had insufficient tissues for both LE and non-LE analysis, only nitrogen values were determined. Isotope ratios were measured using Elemental Analysis-Isotope Ratio Mass Spectrometry (EA-IRMS) at the Alaska Stable Isotope Facility, using a Costech Elemental Analyzer (ECS 4010) and ThermoScientific Conflo IV interfaced with a ThermoScientific DeltaV Mass Spectrometer.

Table 2. Number of fish tissue samples for stable isotope analysis by species. Samples were collected in 2014. Two tissue samples were collected from each fish when possible, one each for nitrogen ($\delta^{15}N$) and carbon ($\delta^{35}C$).

Species	**Samples for $\delta^{15}N$**	**Samples for $\delta^{13}C$**
Lycodes adolfi	85	84
Lycodes polaris	16	10
Lycodes sagittarius	60	58
Lycodes seminudus	37	36
TOTAL	**198**	**188**

Stable isotope values were reported in standard delta notation ($\delta^{15}N$ and $\delta^{13}C$). Values were calculated with the equation:

$$\delta X = [(R_{sample} / R_{standard}) - 1] \times 1000$$

where X is ^{15}N or ^{13}C of a sample, and R is the corresponding isotopic ratio ($^{15}N/^{14}N$ or $^{13}C/^{12}C$). Standards used were atmospheric N_2 (atm) for nitrogen and Vienna Pee Dee Belemnite (VPDB) for carbon. Peptone was used as a laboratory standard and was analyzed every ten samples. A standard bi-plot was used to visualize differences in mean nitrogen and carbon isotope values among the four eelpout species. Stable isotope values were also plotted against total fish length to determine presence of ontogenetic shifts in eelpout TL ($\delta^{15}N$) and carbon source ($\delta^{13}C$).

Nitrogen and carbon stable isotope ratios from fish tissue were used to estimate TL and carbon sources, respectively, and to analyze ontogenetic changes in diet. Trophic level (TL) was calculated using the following equation:

$$TL_{fish} = (\delta^{15}N_{fish} - \delta^{15}N_{primary\ consumer})/3.4 + 2$$

Where $\delta^{15}N_{fish}$ is the stable nitrogen isotope signature for an individual eelpout, $\delta^{15}N_{primary\ consumer}$ is the stable nitrogen isotope value for a primary consumer (site specific average), in this case the brittle star *Ophiocten sericeum* (Bell et al. 2016), and 3.4‰ is the assumed enrichment step between trophic levels. The $\delta^{15}N$ values for individual brittle stars were averaged by habitat (shelf vs. slope, i.e., $\leq$ 100 m and $\geq$ 200 m) and transect to account for spatial variability in $\delta^{15}N$ with across- and along-shelf sampling, which was evident in previous studies (Divine et al. 2015). A primary consumer instead of an actual primary producer source was used as baseline to integrate over the high spatial and temporal variability of primary producers, as it compares better to the time-integrated values of the fish consumers (Vander Zanden and Rasmussen 1999). Ophiuroids were assumed to have a TL of 2 for TL calculations. A stepwise enrichment of 3-4‰ in $\delta^{15}N$ was expected between subsequent trophic levels, and the widely used enrichment step of 3.4‰ was used for TL calculations (Hobson et al. 2002). A one-way ANOVA was used to test for significant differences in average TL among the four eelpout species. Comparisons of trophic levels among eelpout species and with changes in eelpout lengths were conducted to test for ontogenetic changes in trophic levels. An analysis of covariance (ANCOVA) using both linear and quadratic models was used to test if the relationship between length and $\delta^{15}N$, $\delta^{13}C$, or TL was different among the four eelpout species.

Results

Eelpout Species Confirmation

The percentage of individuals with species identification agreement between morphometric methods and genomic/taxonomic ranged from 78% (*L. polaris*) to 85% (*L. seminudus*) (Table 3). *Lycodes adolfi* exhibited the second highest percent agreement between morphometric and genomic methods (84% overall percent agreement). The 15 fishes initially misidentified as *L. adolfi* were reassigned based on mtDNA as *L. sagittarius* (n=7), *L. seminudus* (n=7), and by the taxonomist as *L. squalmiventer* (n=1). The lowest percent agreement between morphometric and genomic methods was observed for *L. polaris* (78% overall). Fishes originally identified as *L. polaris* were re-identified based on mtDNA as *L. sagittarius* (n=1), *L. seminudus* (n=3), *L. eudipleurostictus* (n=1), *L. reticulatus* (n=1), and Shulupaoluk (*L. jugoricus*) (n=2) by the taxonomist. The six *L. seminudus* initially incorrectly identified were reassigned based on mtDNA as *L. adolfi* (n=1), Doubleline Eelpout (*L. euidipleurostictus*) (n=1), Arctic Eelpout (*L. reticulatus*) (n=2), Scalebelly Eelpout (*L. squalmiventer*) by taxonomist (n=1), and one was left at the genus level by the taxonomist because morphometric identification confirmation was not possible. *Lycodes sagittarius* exhibited the second lowest identification agreement of the four target *Lycodes* species (83% overall). Fishes originally identified as *L. sagittarius* by FOL were re-identified based on mtDNA as *L. adolfi* (n=1), *L. seminudus* (n=6), *L. euidipleurostictus* (n=1), and by the taxonomist as *L. squalmiventer* (n=1).

Of the 204 specimens included in the mtDNA analysis, 189 were conclusively identified as a single species; 15 individuals examined could not be unambiguously assigned to a single species. Sequences from those 15 samples yielded perfect or nearly perfect matches to those from more than one species represented in BOLD when the search was performed. For example, seven fish were identified as both *L. adolfi* and Pale Eelpout (*L. pallidus*) (n=4 for 2012, and n=3 for 2013). Sequences from all seven fish were most similar (> 99%) to barcode sequences of fish identified as *L. adolfi* in the BOLD database, but individuals identified as *L. pallidus* were also included in the BOLD list of potential matches. The cluster of BOLD sequence records that includes *L. adolfi* and *L. pallidus* includes variants as divergent as 1.9%. Sequences of seven eelpouts assigned as *L. seminudus* based on sequence match to BOLD archived specimens also closely matched with either Estuarine Eelpout (*L. tuneri*) and Saddled Eelpout (*L. mucosus*), but the degree of matching did not allow for a conclusive match to either species (n=4 for 2012 and n=3 for 2-13). Lastly, the cytochrome c oxidase 1 gene (COI) sequence from a specimen assigned as *L. polaris* was not distinguishable from *L. knipowitschi* (no common name; a potential synonym for *L. mucosus*), and *L. tanakae* (no common name), two putative species that mtDNA sequences could not differentiate from each other or from *L. polaris*. In addition to the 15 fish discussed above, all fish (n=67) identified as *L. sagittarius* by mtDNA analysis were also matched to individuals identified as *L. marisalbi* in BOLD (these two species are not differentiated at the barcode DNA sequence). The inability to unambiguously match some barcode sequences to one recognized *Lycodes* species, and the low percent variation in base pairs across multiple species of eelpout indicates that there is significant genetic overlap between some currently recognized species of *Lycodes*, and suggests the presence of poorly differentiated species lineages in *Lycodes* where mtDNA lacks the level of genetic resolution to identify taxonomic or population boundaries. Based on the objectives of this project on biology and distribution, each individual fish that was identified as belonging to a species complex was treated as either *L. adolfi* (for the *L. adolfi* and *L. pallidus* complex), *L. polaris* (for the *L. polaris*, *L. knipowitschi*, and *L. tanakae* species complex), *L. sagittarius* (for the *L. sagittarius* and *L. marisalbi* complex), or *L. seminudus* (for the *L. seminudus, L. turneri,* and *L. mucosus* complex) based on currently available information on the genetic variability from BOLD and distinctiveness of these groups.

Table 3. Species confirmation results for four *Lycodes* species. The numbers of fish for mtDNA analysis are only those whose DNA was successfully isolated, amplified, and sequenced. The number identified by the University of Alaska Fisheries Oceanography Lab (FOL) or a taxonomist, the number of fish whose identity was confirmed as that identity assigned by FOL or a taxonomist, and the percent accuracy (% Accuracy) are given. Some individual fish could not be conclusively matched with only one known species by the Barcode of Life Database (BOLD), and instead were assigned to a species complex. No individual fishes were confirmed by both DNA and a taxonomist.

	***L. adolfi*[1]**	***L. polaris*[2]**	***L. sagittarius*[3]**	***L. seminudus*[4]**
Confirmed by mtDNA				
Total ID by FOL	90	19	63	32
ID Confirmed by mtDNA	76	13	52	28
% Accuracy	84%	68%	83%	88%
Confirmed by Taxonomist				
Total ID by FOL	6	17	9	8
ID Confirmed by Taxonomist	5	15	8	6
% Accuracy	83%	88%	89%	75%
Total Confirmed by mtDNA and Taxonomist				
Total ID by FOL	96	36	72	40
ID Confirmed	81	28	60	34
%Accuracy	84%	78%	83%	85%

[1] *L. adolfi* includes fishes identified as *L. adolfi*, and fishes identified as part of the *L. adolfi/pallidus/esmarkii* species complex.
[2] *L. polaris* includes fishes identified as *L. polaris* and fishes identified as *L. polaris/tanakae/knipowitchi*.
[3] *L. sagittarius* includes fishes identified as *L. sagittarius* and as *L. sagittarius/marisalbi*.
[4] *L. seminudus* includes fishes identified as *L. seminudus* and fishes identified as *L. seminudus/mucosus/turneri*.

Distribution and Length

Eelpout distribution by species differed with depth but not longitude. The majority (94%) of all *L. polaris* by CPUE were collected at stations < 350 m depth (Figure 2). In 2012, five *L. polaris* were observed at 500 m (Figure 3). The other three eelpout species were collected mainly at depths ≥ 350 m; four *L. seminudus* collected between 10 and 100 m, and one *L. sagittarius* at 35 m were the exceptions (Figure 3). With respect to longitudinal distribution, all species except *L. adolfi* were found at all transects sampled.

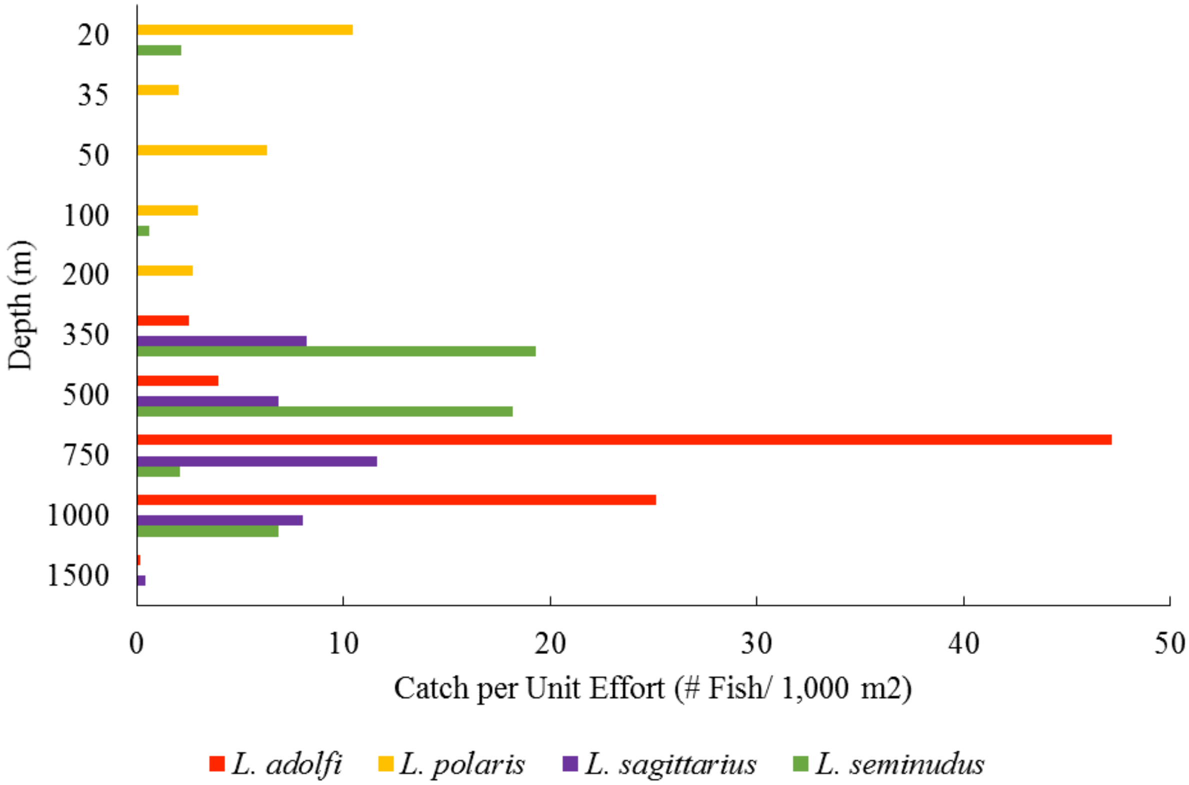


Figure 2. Catch per unit effort (CPUE) of *Lycodes* spp. collected at each sampling depth in 2013 and 2014. CPUE is presented as number of fish per 1,000 m^2 at each depth. Central (2012) Beaufort Sea trawls were non-quantitative, and are excluded from CPUE calculations.

All four eelpout species differed in body size ranges. *Lycodes sagittarius* had the largest observed individual at 472 mm total length (observed range: 56-472 mm; average 76 ± standard deviation of 33 mm). *Lycodes seminudus* had the second largest individual observed at 465 mm (52-465 mm; ± 111 mm). *Lycodes polaris* (42–205 mm; 76 ± 33 mm) had the second smallest maximum total length observed and *L. adolfi* (38–182 mm; 103 ± 39 mm) had the smallest. The largest fishes were collected at depths ≥ 350 m (Figure 3). A Kruskal-Wallis one-way ANOVA based on ranks indicated differences in mean length among the four eelpout species (H = 199.668, p = < 0.001). Subsequent paired tests based on Dunn's method indicated all combinations of the four eelpout species were significantly different from each other ($p < 0.05$).

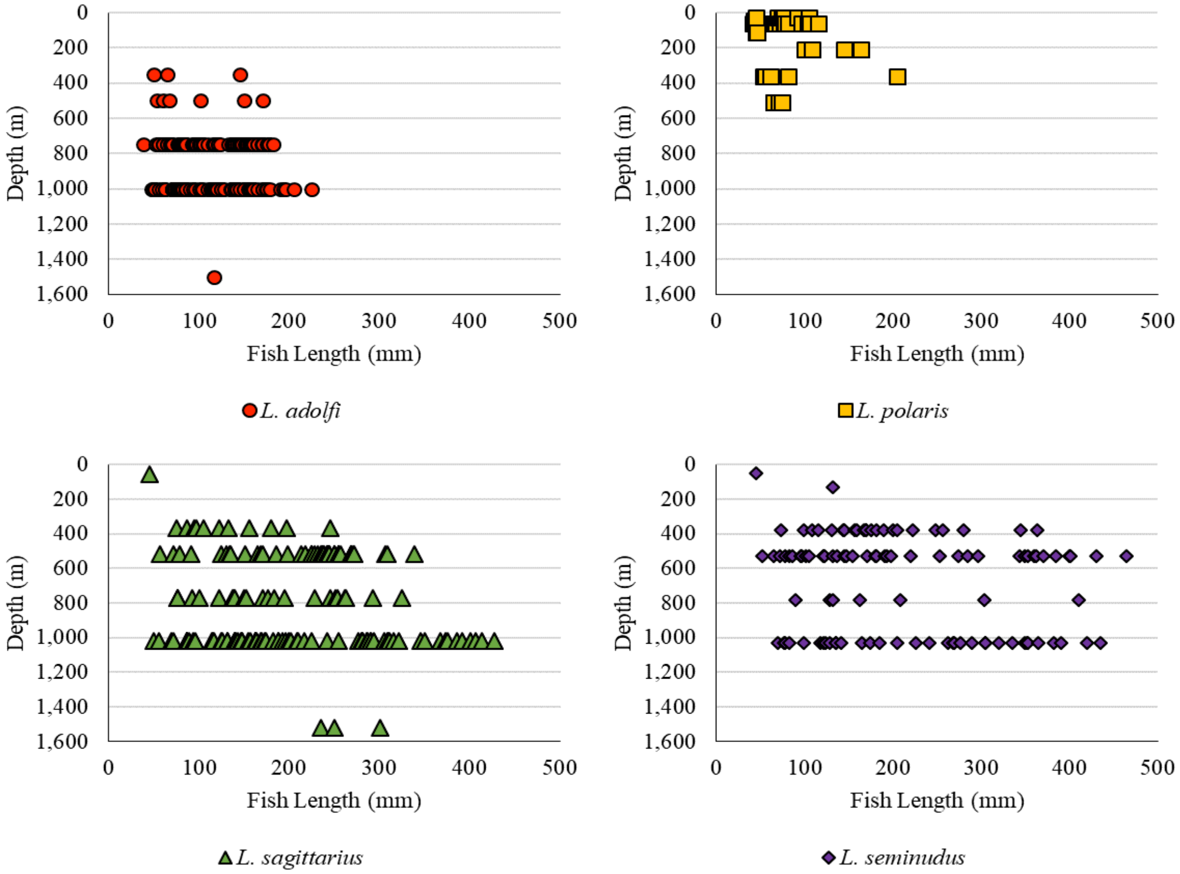


Figure 3. Total fish length at depth for all of the four eelpout species collected in the central (2012) and eastern (2013/2014) Beaufort Sea. Each point represents an individual fish at a specific depth.

Gape Size

Gape size increased linearly with total fish length for all four eelpout species, but the best model (smallest AIC) indicated that the rate of increase differed among species (Figure 4). Maximum gape height was largest for *L. seminudus* (67 mm) and smallest for *L. polaris* (12 mm) (Table 4). *Lycodes sagittarius* and *L. adolfi* had maximum gape heights of 20 and 38 mm, respectively. *Lycodes seminudus* had the largest gape height at a given length, followed by *L. adolfi, L. polaris* and lastly *L. sagittarius* (Figure 4). Coefficients of determination of the linear relationship ranged from $R^2 = 0.68$ for *L. polaris* to $R^2 = 0.89$ for *L. sagittarius*. The slope was lowest for *L. sagittarius* (0.09), and similar for all other eelpouts (0.1 for *L. adolfi* and *L. seminudus*, 0.104 for *L. polaris*). It is important to note that *L. adolfi* and *L. polaris* were, on average, smaller than *L. seminudus* and *L. sagittarius*, and they did not reach similar maximum lengths observed for the other two eelpout species. Length of prey consumed increased with increase in gape height at length, though outliers were present for all four *Lycodes* species (Figure 4).

Table 4. Gape height (mm) measurements and relation to total fish length (mm) for four eelpout species collected in 2014. Sample size (n), maximum (Max), minimum (Min), average, and standard deviation (StdDev) for gape height for each eelpout species. Results of comparison of analysis of covariance (ANCOVA) for the best model according to AIC are given.

Gape Height Summary

Species	n	Max	Min	Average	StdDev
Lycodes adolfi	74	19.7	4.3	11.4	4.3
Lycodes polaris	18	11.7	3.0	5.5	2.4
Lycodes sagittarius	55	37.6	5.2	15.5	7.4
Lycodes seminudus	37	67.2	4.1	25.6	15.5
Grand Total	184				

Comparison of ANCOVA Models - All Four Eelpout Species

	AIC	Model
Model 1	1,084.9	Gape Height = b * Length
Model 2	1,022.5	Gape Height = Species_k + b*Length
Model 3	**1,014.9**	**Gape Height = Species_k + b_k*Length**

ANCOVA for Model 3

	DF	SumSq	MeanSq	F value	Pr(>F)
Species	3	5,874.5	1,958.2	138.5	< 2.2e-16
Length	1	11,268.3	11,268.3	797.2	< 2.2e-16
Species:Length	3	199.9	66.6	4.7	0.003436
Residuals	175	2,473.5	14.1		

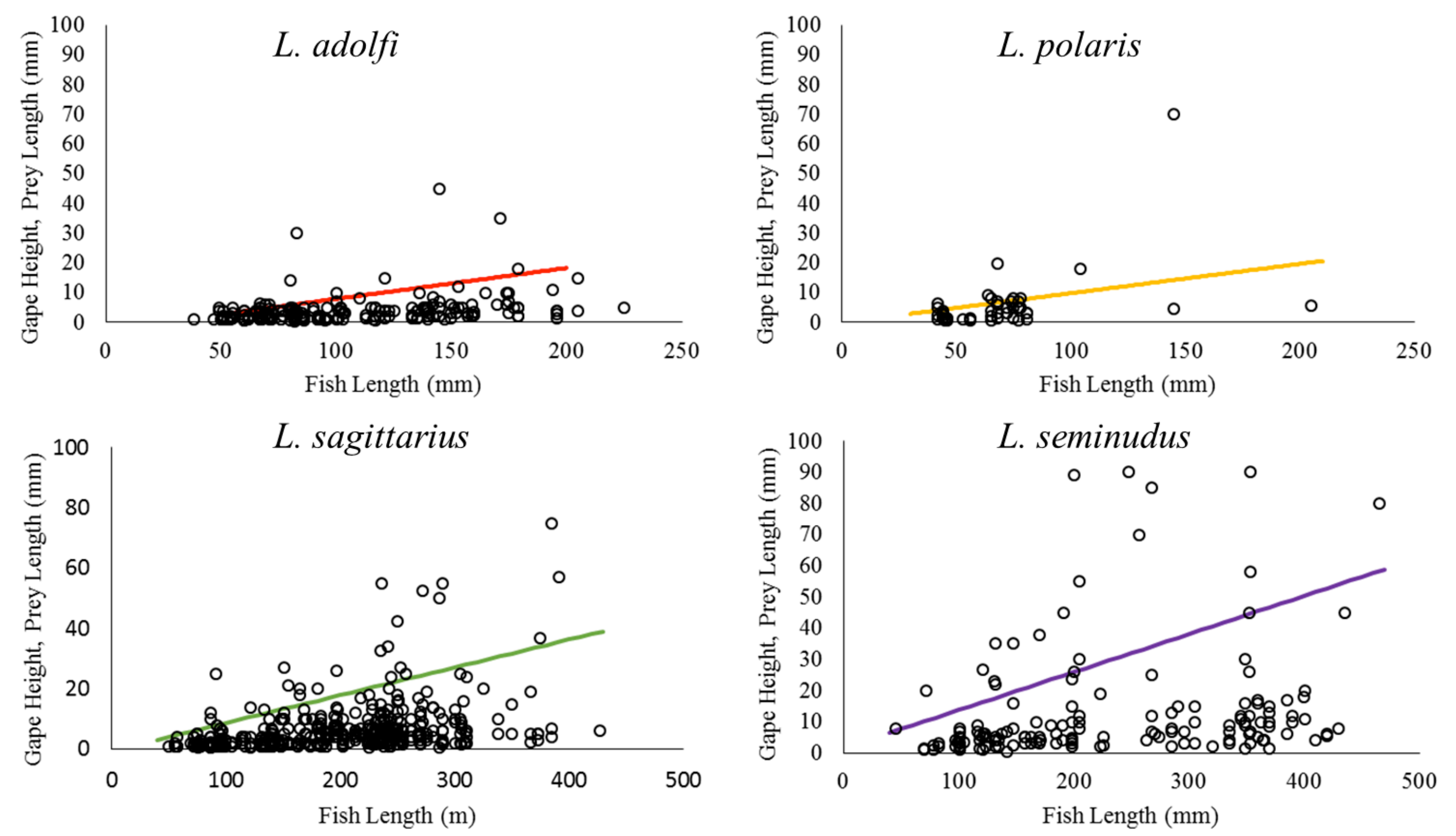


Figure 4. Mean estimated gape height (lines, mm) and individual prey lengths (circles, mm) at a given length for each eelpout species. Gape height was estimated by linear regression on length with species-specific slopes.

Stomachs Processed

Out of 466 available stomachs for the four eelpout species, 97 (21% of total available stomachs) were excluded. Excluded stomachs were empty, burst or contained only parasites (Table 1). Parasitic nematodes were the only contents of 13 (3% of total available) of the stomachs; these resident parasites were not actively consumed, so the stomachs were excluded from the analysis. The proportion of non-empty stomachs was highest for *L. sagittarius* (86%), and similar among *L. adolfi* (75%), *L. polaris* (77%), and *L. seminudus* (77%). The percent of non-empty stomachs differed with changes in depth and fish length (Figure 5). There were more empty stomachs at depths of 350, 500, 750, and 1,000 m (n = 81, 17% of total available stomachs) than at shallower depths (n = 9 at ≤ 200 m, 1.9% of total available stomachs). However, the proportion of empty stomachs was highest at the two shallowest depths (20 m and 35 m). Average fish length increased with increasing depth.

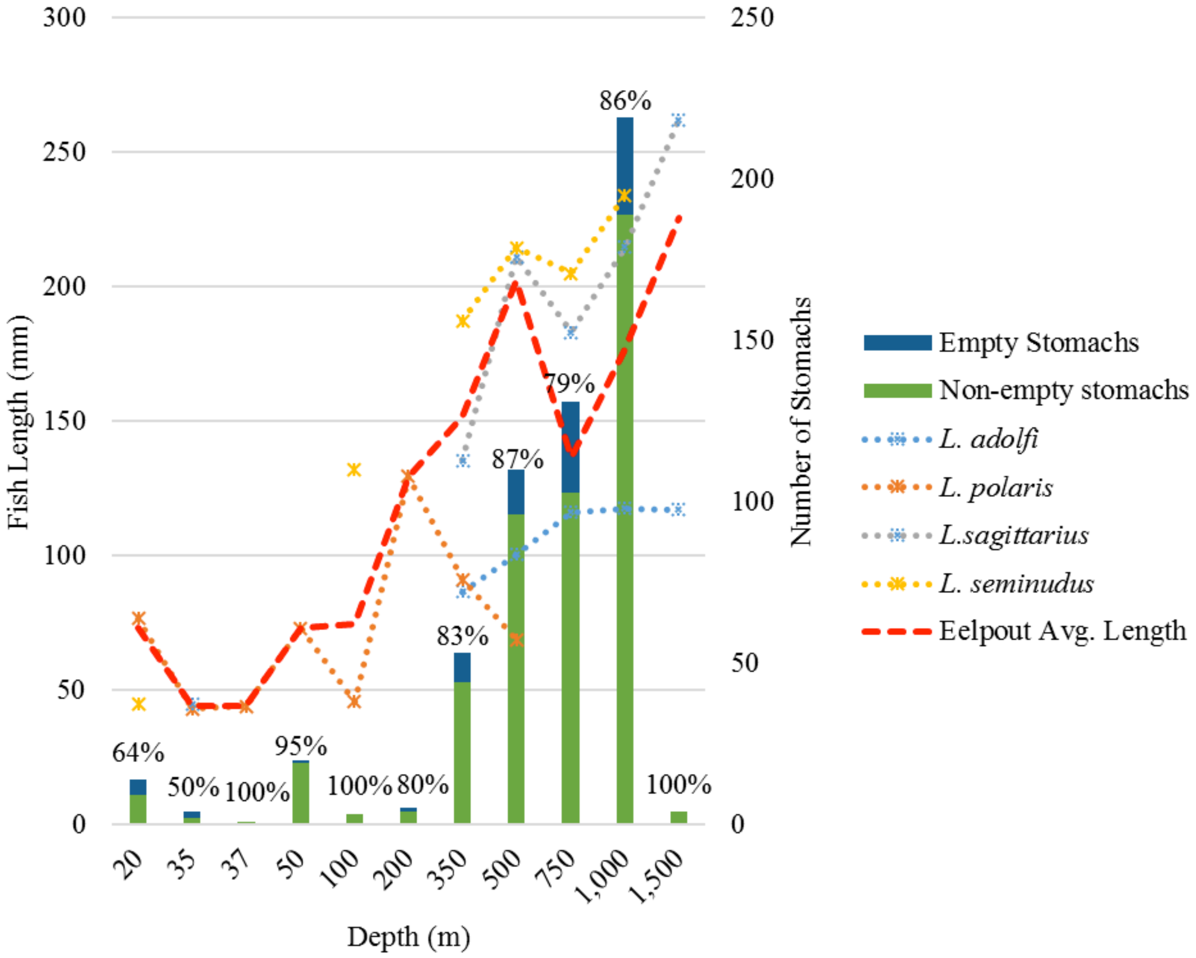


Figure 5. Number of empty (blue bars) and non-empty (green) stomachs at each collection depth and average length by species and depth (lines). The percent of non-empty stomachs at collection depth is given above each bar. Average length (mm) of all four eelpout species at depth is given by the red dashed line.

Prey Groups

In total, 106 distinct fine resolution prey types were observed, representing 14 coarse prey groups (Table 5 and 6). The greatest number of distinct fine resolution prey items (n = 15 in 2012 and n = 19 in 2013/2014) were types of polychaetes. The next most diverse group was Amphipoda (n = 8 in 2012 and n = 11 in 2013/2014). The majority of amphipods that could be identified to family, genus, or species level were benthic (98%). The exception was the pelagic genus *Themisto* (n=1 in 2013/2014). Other pelagic amphipod species may be represented in the unidentified amphipod group (Amphipoda Unid.). Teleost prey were found in *L. seminudus* stomachs. Of the five fish prey observed, four were identified as Arctic Cod (*Boreogadus saida*) and one could not be identified. Length of prey ranged from very small Foraminifera (average 1.4 ± 0.6 SD mm) and Ostracoda (average 1.0 ± 0.7 SD mm) to large Polychaeta (average 16 ± 15.3 SD mm) and fish (90.0 mm for the one individual measured) (Table 7 and Figure 6).

The average number of fine resolution prey items per fish stomach differed among eelpout species in the central (Kruskal-Wallis one-way ANOVA: H = 33.173, P = <0.001) and eastern (Kruskal-Wallis one-way ANOVA: H = 42.997, P = <0.001) Beaufort Sea. On average, *L. sagittarius* had the largest number of fine resolution prey items per stomach (4.0 in 2012 and 8.7 prey per individual fish in 2013/2014). The lowest average number of prey per stomach was observed in *L. adolfi* (1.1 in 2012) and *L. seminudus* (2.5 in 2013/2014). The number of prey items per stomach for *L. sagittarius* in the central Beaufort Sea was significantly higher than *L. adolfi* (Dunn's method: Diff. of Ranks = 61.9, Q = 5.478), but not *L. polaris* (Diff. of Ranks = 27.2, Q = 2.575), and *L. seminudus* could not be tested due to unequal sample size. In the eastern Beaufort Sea, the number of prey items per stomach for *L. sagittarius* differed from *L. seminudus* (Diff. of Ranks = 75.1, Q = 5.151), *L. adolfi* (Diff. or Ranks = 74.7, Q = 6.054), and *L. polaris* (Diff. of Ranks = 71.8, Q = 2.866). The number of items in each stomach of *L. polaris* in the central Beaufort Sea did not differ significantly from *L. adolfi* (Diff. of Ranks = 34.6, Q = 2.617) and could not be tested for *L. seminudus*. In the eastern Beaufort Sea, *L. polaris* did not differ from *L. seminudus* (Diff. of Ranks = 3.3, Q = 0.123) and could not be tested against *L. adolfi*.

Prey types were then grouped into 14 coarse taxonomic groups for all subsequent analyses. Cumulative prey curves for the eastern Beaufort Sea illustrated the need for aggregating prey at a coarser taxonomic level (Figure 7). Similar results were seen for the central Beaufort Sea.

Table 5. Prey groups found in eelpout stomachs collected in the central Beaufort Sea (2012). Coarse prey groups are presented in phylogenetic order and indicated in boldface. Prey contributing to each coarse prey group are listed below. Numbers of prey collected from stomachs of each eelpout species are also presented, where n is the number of stomachs of each *Lycodes* spp. examined, excluding those that were empty or contained only parasites.

Prey Group	*L. adolfi* (n=25)	*L. polaris* (n=30)	*L. sagittarius* (n=75)	*L. seminudus* (n=39)
Foraminifera			**1**	
Mollusca	**1**		**15**	**4**
Bivalvia Unid.			3	
Ennucula tenuis			1	1
Thyasira flexuosa			1	
Thyasiridae			5	2
Yoldiidae	1		5	1
Polychaeta	**3**	**10**	**89**	**22**
Cossura spp.			1	
Harmothoe spp.		1		
Levinsenia gracilis			1	
Lumbrineridae			3	1
Lumbrineris spp.			1	
Maldane sarsi			1	
Maldanidae			1	
Nephtyidae			3	1
Nephtys spp.		1	1	
Opheliidae			1	2
Ophelina spp.			4	
Paraonidae			1	
Polychaeta Unid.	2	8	52	10
Polynoidae	1		3	2
Spionidae			16	6
Copepoda	**5**	**5**	**17**	**5**
Aetideidae	1		1	
Calanus glacialis			1	
Copepoda Unid.		4	1	
Harpacticoida	4	1	11	5
Metridia longa			3	
Ostracoda		**2**		**1**
Cumacea	**1**	**10**	**18**	
Campylopus spp.		1		
Cumacea Unid.	1	4	2	
Diastylis spp.		1		
Ektonodiastylis robusta			1	
Eudorella emarginata			9	
Eudorella spp.			1	
Leucon spp.		4	3	
Leuconidae			2	
Tanaidacea		**1**	**3**	**1**
Isopoda	**4**	**1**	**38**	**15**
Gnathiidae				1
Idoteidae			1	
Isopoda Unid.	4	1	37	14
Amphipoda	**4**	**16**	**69**	**11**
Aceroides latipes	2		35	7
Aceroides spp.			3	
Amphipoda Unid.	1	11	17	3
Anonyx spp.			2	
Gammaridea			1	
Lysianassidae	1		8	
Oedicerotidae		5	3	
Rhachotropis spp.				1
Crustacea Unid.	**8**	**14**	**27**	**12**
Ophiuroidea		**1**		**2**
Ophiura sarsii		1		
Ophiuroidea				2

Table 5. Continued from previous page.

Prey Group	*L. adolfi* (n=25)	*L. polaris* (n=30)	*L. sagittarius* (n=75)	*L. seminudus* (n=39)	Prey Group	*L. adolfi* (n=25)	*L. polaris* (n=30)	*L. sagittarius* (n=75)	*L. seminudus* (n=39)
Teleost			**1**	**1**	**Other - continued**	**1**	**1**	**3**	**3**
Teleost Unid.			1	1	Mysidacea Unid.				2
Animal Unid.		**2**	**3**		Nemertea			1	
Other	1	1	3	3	Paguridae	1			
Caridea			1	1					
Decapoda Unid.			1						
Diptera		1			**Total**	**27**	**67**	**302**	**91**
					Avg.	**1.1**	**2.2**	**4.0**	**2.3**

Table 6. Prey groups found in eelpout stomachs collected in the eastern Beaufort Sea (2013/2014). Coarse prey groups are presented in phylogenetic order and indicated in boldface. Prey contributing to each coarse prey group are listed below. Numbers of prey collected from stomachs of each eelpout species are also presented, where n is the number of stomachs of each *Lycodes* spp. examined, excluding those that were empty of contained only parasites.

Prey Group	*L. adolfi* (n=139)	*L. polaris* (n=13)	*L. sagittarius* (n=76)	*L. seminudus* (n=68)
Foraminifera	**24**		**19**	
Mollusca	**7**		**33**	**1**
Bivalvia	6		22	
Gastropoda			1	
Mollusca Frag.			1	
Musculus spp.			1	
Nuculana spp.			1	
Rhabdidae			1	
Scaphopoda			3	
Yoldiidae	1		3	1
Polychaetea	**36**	**4**	**229**	**49**
Lumbrineridae			1	
Maldane sarsi	2		46	19
Maldanidae			2	
Nephtyidae	3		7	3
Onuphis parva			4	
Onuphis spp.			4	1
Opheliidae	2		51	
Ophelina spp.			5	
Oweniidae				7
Paradiopatra parva				1
Paradiopatra spp.			1	
Paraonidae			1	
Phyllodocidae				1
Polychaeta Unid.	18	2	33	5
Polychaeta Frag.	8	1	16	5
Polynoidae	1		4	5
Polynoidae Frag.	1	1		1
Sabellidae			2	
Polychaetea - Continued				
Spionidae	1		25	
Terebellidae			24	
Terebellides spp.			2	1
Trichobranchidae			1	
Copepoda	**124**	**14**	**100**	**3**
Aetideidae	1			
Calanoida	10			
Calanus hyperboreus	1			
Copepoda Unid.	5		2	1
Cyclopoida	2		8	
Euchaeta spp.				1
Harpacticoida	98	14	90	
Metridia longa	4			1
Metridia spp.	2			
Paraeuchaeta norvegica	1			
Ostracoda	**37**	**3**	**28**	**1**
Cumacea	**9**	**3**	**9**	**1**
Cumacea Unid.	6	3	4	
Diastylis spp.			2	
Ektonodiastylis robusta	1		3	1
Eudorellopsis spp.	2			
Tanaidacea	**32**	**1**	**43**	**4**
Isopoda	**48**		**138**	**24**
Gnathiidae	4		4	2
Isopoda Unid.	42	0	134	19
Isopoda Frag.	1			1
Saduria entomon	1			1
Synidotea spp.				1

Table 6. Continued from previous page.

Prey Group	*L. adolfi* (n=139)	*L. polaris* (n=13)	*L. sagittarius* (n=76)	*L. seminudus* (n=68)
Amphipoda	**25**	**7**	**25**	**10**
Aceroides latipes	7	1	4	
Aceroides spp.	4		2	1
Amphipoda Unid.	8	4	6	8
Haploops spp.			2	
Hippomedon spp.	1			
Lysianassidae	5		6	
Oedicerotidae		2	1	1
Orchomene spp.			1	
Phoxocephalidae			1	
Rhachotropis spp.			1	
Themisto spp.			1	
Crustacea Unid.	**41**	**3**	**18**	**11**
Ophiuroidea			**6**	**60**
Ophiuroidea			6	55
Ophiuroidea Frag.				5
Teleost				**4**
Boreogadus saida				4
Animal Unid.	**5**	**1**	**2**	**2**
Other	**2**		**9**	**1**
Euphausiacea				1
Fish egg			1	
Mysidacea	2			
Sipuncula			8	
TOTAL	**390**	**36**	**659**	**171**
Avg. TOTAL	**2.8**	**2.8**	**8.7**	**2.5**

Table 7. Length of coarse prey groups consumed. Length (mm) was measured for individuals in each prey group. Minimum (Min), maximum (Max), average (Avg), and standard deviation (StDev) of length of each prey group are presented.

Prey Groups	n	Min Length (mm)	Max Length (mm)	Avg Length (mm)	StDev
Foraminifera	26	1.0	3.0	1.4	0.6
Mollusca	35	1.0	13.0	3.0	3.1
Polychaeta	207	2.5	70.0	16.0	15.3
Copepoda	213	0.3	14.0	1.8	1.8
Ostracoda	64	0.5	3.0	1.0	0.7
Cumacea	40	2.0	9.0	4.9	1.8
Tanaidacea	66	1.0	7.0	3.6	1.6
Isopoda	165	1.0	45.0	5.6	9.0
Amphipoda	53	2.0	35.0	6.9	5.8
Ophiuroidea	44	3.0	6.0	4.5	0.9
Teleost	1	90.0	90.0	90.0	-
Other	11	4.0	42.5	17.9	15.8

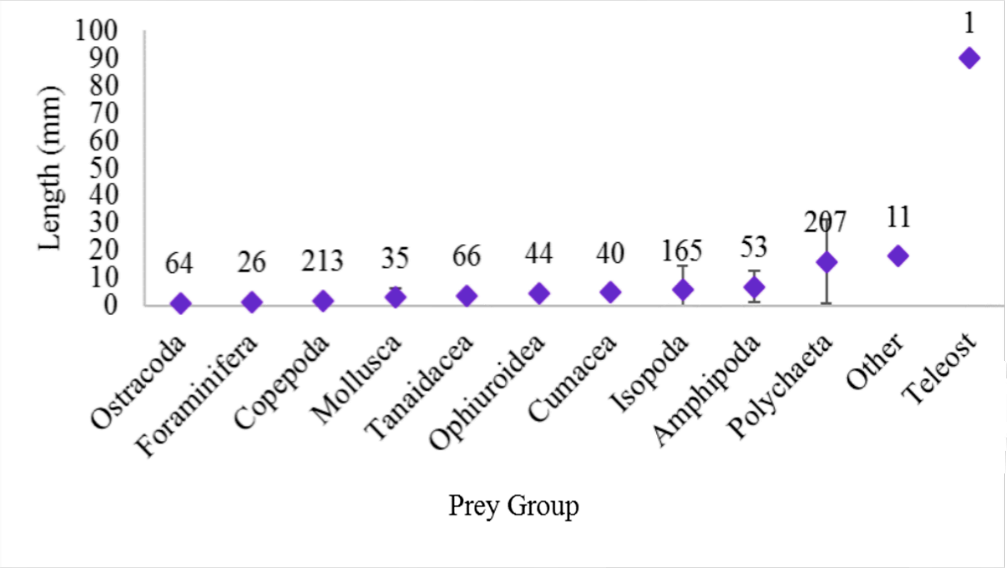


Figure 6. Average prey lengths of coarse prey groups consumed. Standard deviation is indicated by error bars. Number of individual prey represented by each group is displayed. Length was not measured for unidentified crustaceans (Crustacea Unid.) or unidentifiable animals (Animal Unid.).

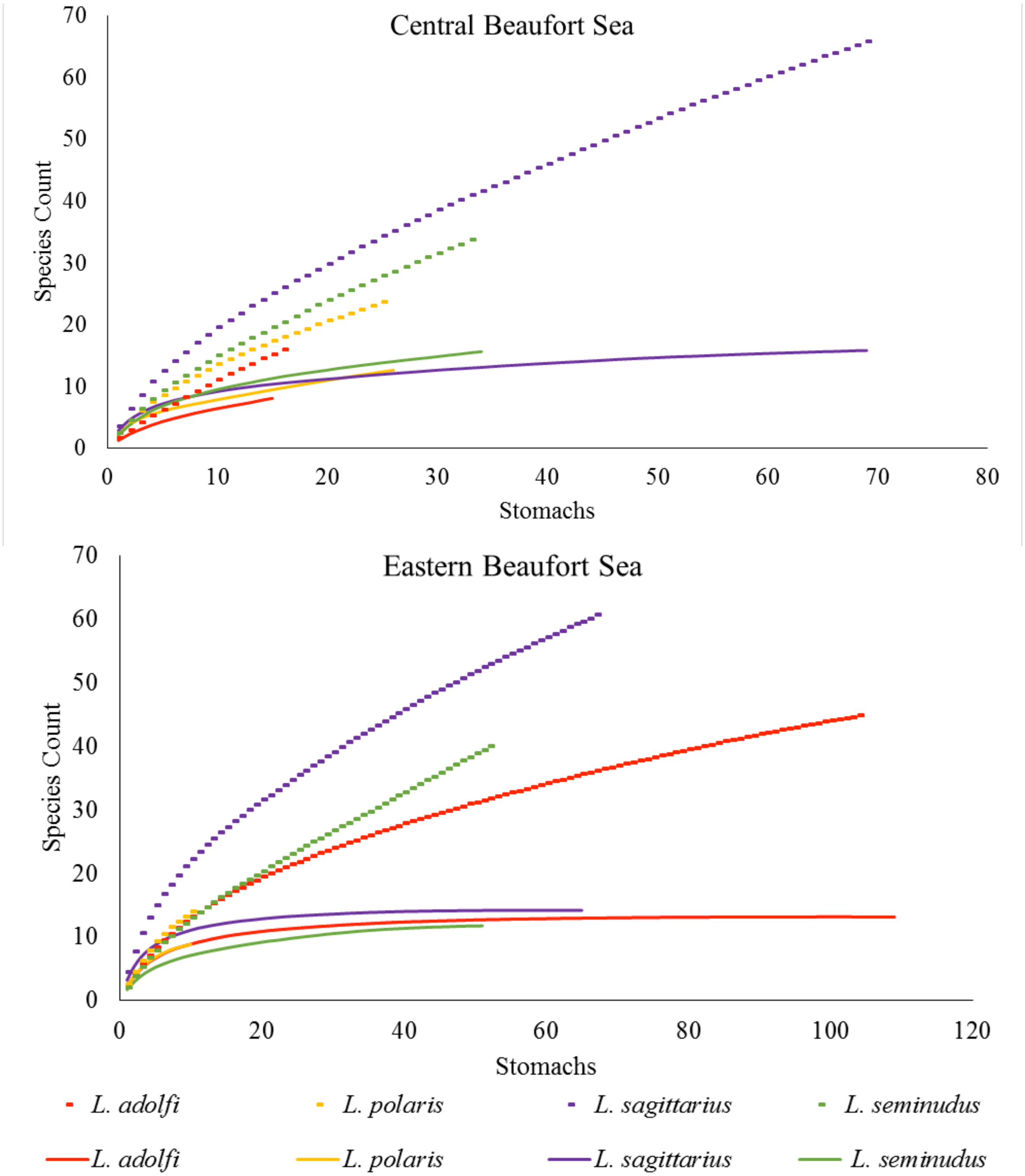


Figure 7. Cumulative prey curves for the four eelpout species collected in the central and eastern Beaufort Sea. Prey grouped at the lowest taxonomic level possible are indicated by dashed lines. Coarse grouped prey are represented by solid lines.

Interannual Differences in Diet

Samples collected were pooled across years when interannual differences were not significant.

Interannual diet composition did not differ significantly in the eastern Beaufort Sea, between 2013 and 2014 (*L. adolfi*: PERMANOVA, t = 0.98, p = 0.44; *L. polaris*: no test; *L. sagittarius*: t = 1.24, p = 0.14; *L.*

seminudus: t = 0.88, p = 0.58). The central Beaufort Sea was only sampled in 2012, so no interannual comparison was possible for this region. In the eastern Beaufort Sea only one *L. polaris* stomach was available from 2013, and, therefore, *L. polaris* was not included in the interannual analysis. Pooling of samples collected in the same region (central or eastern) was done if cumulative prey curves indicated pooling was necessary. Prey curves indicated that sample size in 2013 was too small to be adequately described for three of the four *Lycodes* species, but adequate for all species in 2014 except *L. polaris* (Figure 8). Cumulative prey curves of pooled eastern Beaufort Sea specimens indicated diet for all species except *L. polaris* was adequately described with the available sample sizes.

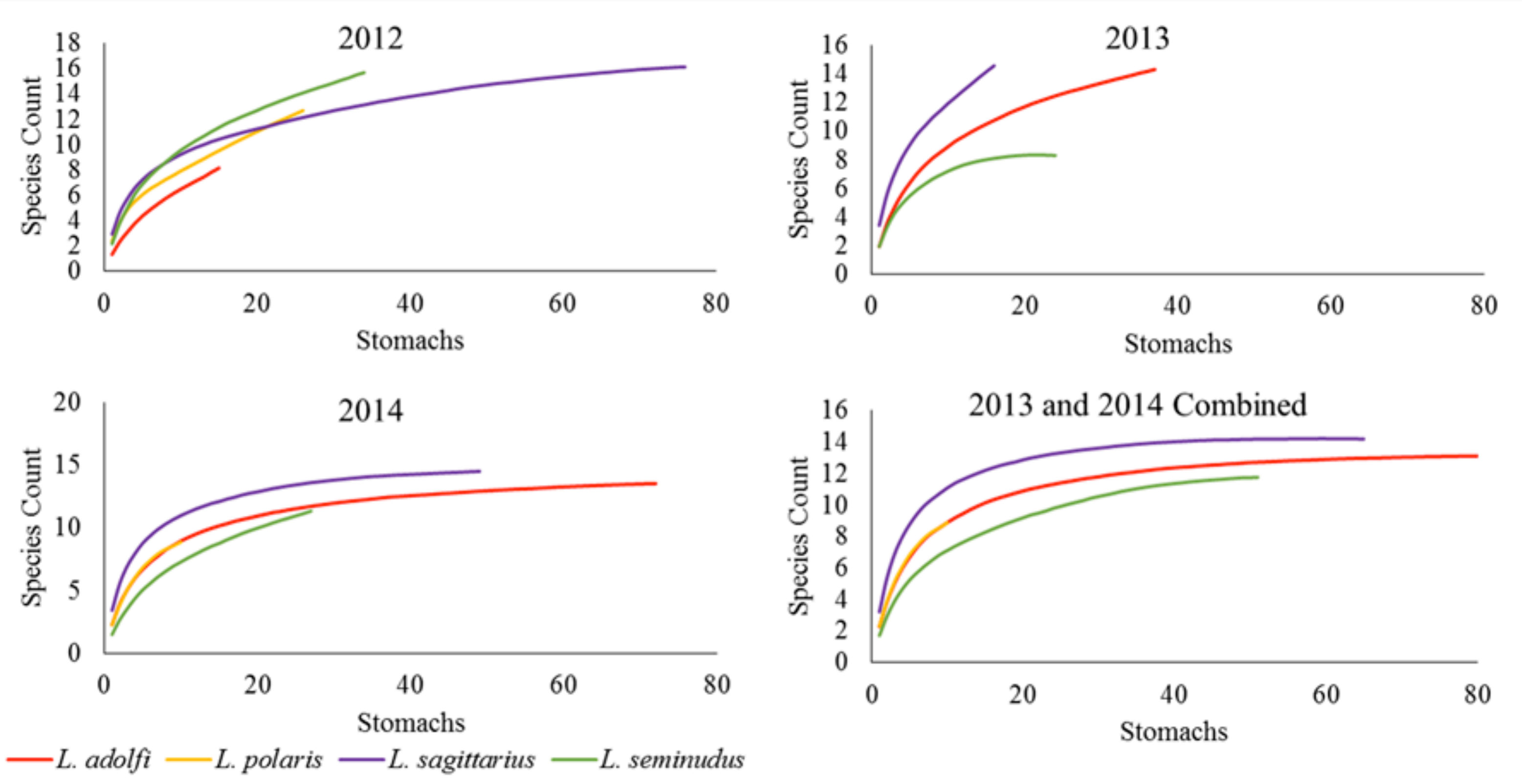


Figure 8. Cumulative prey curves for four *Lycodes* species using coarse prey groups. The sampling years 2012, 2013, 2014, and combined 2013 and 2014 are represented. Diet is adequately described at a sample size that corresponds to the cumulative prey curve reaching an asymptote. In 2013, only one *L. polaris* was available and was not included in this analysis.

Overall Diet Composition

Diet composition was significantly related to eelpout species, length, depth, and transect. Diets varied significantly with total length and with depth, while differences among transects were only significant in 2012 (Table 8) and not in 2013/2014 (Table 9). The interaction between fish length and fish species was significant for both 2012 and 2013/2014 fishes. An additional interaction between depth and transect was significant for 2012, as was the interaction between species and transect for 2013/2014. For 2012 samples, diet composition was significantly different between *L. polaris* and *L. adolfi* and between *L. polaris* and *L. sagittarius*. Pair-wise tests in 2013/2014 indicated that diet composition was different between all pairings except between *L. adolfi* and *L. polaris* and between *L. polaris* and *L. seminudus.* The scatter of points in the nMDS plots indicated a high level of intraspecific variability in diet compositions within each of the four eelpout species and considerable overlap among species (Figures 9 and 10).

Table 8. Permutational analysis of variance (PERMANOVA) results for diet composition among four eelpout species collected in the central Beaufort Sea in 2012 using percent weight (%W) of prey items. Species, depth, and transect were fixed factors. Length was a continuous covariate. Analysis used Type 1 sums of squares and permutation of residuals under a reduced model. Pair-wise tests were conducted for factors that were significant (α=0.05). For pair-wise tests of depth and transect, all combinations were tested but only significant pairs are presented. Degrees of freedom (df), sums of squares (SS), mean squares (MS), pseudo F statistic (Pseudo-F), t statistic (t), P values (P(perm)), and the number of unique permutations (Perm) are given.

Source	df	SS	MS	Pseudo-F	p(Perm)	Perm
Length	**1**	**19628**	**19628.0**	**6.6587**	**0.001**	**999**
Species	**3**	**21165**	**7055.1**	**2.3935**	**0.004**	**998**
Depth	**5**	**47354**	**9470.9**	**3.2130**	**0.001**	**998**
Transect	**2**	**18009**	**9004.5**	**3.0548**	**0.004**	**998**
Length x Species	**3**	**26429**	**8809.7**	**2.9887**	**0.002**	**996**
Length x Depth	3	10105	3368.4	1.1427	0.334	999
Length x Transect	2	8491	4245.2	1.4402	0.155	999
Species x Depth	1	3120	3119.9	1.0584	0.357	998
Species x Transect	3	8392	2797.5	0.9490	0.506	999
Depth x Transect	**2**	**18297**	**9148.3**	**3.1036**	**0.001**	**998**
Species x Depth x Transect	1	1332	1331.6	0.4517	0.825	997
Residuals	115	3.39E+05	2948			
Total	141	5.21E+05				
Pair-Wise Test: Species				t	p(Perm)	Perm
Lycodes adolfi, Lycodes polaris				**1.6195**	**0.035**	**999**
Lycodes adolfi, Lycodes sagittarius				1.1617	0.208	998
Lycodes adolfi, Lycodes seminudus				0.8363	0.679	998
Lycodes polaris, Lycodes sagittarius				**1.7995**	**0.009**	**999**
Lycodes polaris, Lycodes seminudus				1.2008	0.200	996
Lycodes sagittarius, Lycodes seminudus				1.4967	0.053	999
Pair-Wise Test: Depth				t	p(Perm)	Perms
500, 1000				**3.1097**	**0.001**	**999**
Pair-Wise Test: Transect				t	P(perm)	Perms
B1, B2				**1.6345**	**0.023**	**998**
B1, BX				**1.8092**	**0.014**	**999**

Table 9. Permutational analysis of variance (PERMANOVA) results for diet composition among four eelpout species collected in the eastern Beaufort Sea in 2013 and 2014 using percent weight (%W) of prey items. Species, depth, and transect were included as fixed factors. Length was included as a covariate. Analysis used Type 1 sums of squares and permutation of residuals under a reduced model. Pair-wise tests were conducted for significant factors (α=0.05). For pair-wise test of depth all combinations were tested, but only significant pairs are presented. Degrees of freedom (df), sums of squares (SS), mean squares (MS), pseudo F statistic (Pseudo-F), t statistic (t), P values (P(perm)), and the number of unique permutations (Perm) are given.

Source	df	SS	MS	Pseudo-F	p(Perm)	Perm
Length	**1**	**37801**	**37801**	**11.4670**	**0.001**	**999**
Species	**3**	**38774**	**12925**	**3.9206**	**0.001**	**999**
Depth	**9**	**77429**	**8603**	**2.6097**	**0.001**	**996**
Transect	6	25795	4299	1.3041	0.110	998
Length x Species	**3**	**30884**	**10295**	**3.1228**	**0.001**	**999**
Length x Depth	8	24498	3062	0.9289	0.624	997
Length x Transect	6	17178	2863	0.8685	0.705	996
Species x Depth	**7**	**30741**	**4392**	**1.3321**	**0.071**	**997**
Species x Transect	**13**	**61070**	**4698**	**1.4250**	**0.009**	**997**
Depth x Transect	14	50903	3636	1.1029	0.263	997
Species x Depth x Transect	**9**	**41599**	**4622**	**1.4021**	**0.028**	**997**
Residuals	154	5.08E+05	3297			
Total	233	9.44E+05				

Pair-Wise Test: Species	t	p(Perm)	Perm
Lycodes adolfi, Lycodes polaris	1.2345	0.153	998
Lycodes adolfi, Lycodes sagittarius	**1.8933**	**0.003**	**999**
Lycodes adolfi, Lycodes seminudus	**1.7537**	**0.009**	**999**
Lycodes polaris, Lycodes sagittarius	**1.8629**	**0.011**	**998**
Lycodes polaris, Lycodes seminudus	1.3569	0.120	999
Lycodes sagittarius, Lycodes seminudus	**2.7484**	**0.001**	**996**

Pair-Wise Test: Depth	t	p(Perm)	Perm
350, 1000	**1.894**	**0.002**	**999**
500, 750	**1.881**	**0.006**	**997**
500, 1000	**3.260**	**0.001**	**998**
500, 1500	**1.696**	**0.047**	**998**
750, 1000	**1.482**	**0.037**	**999**
750, 1500	**1.532**	**0.028**	**998**

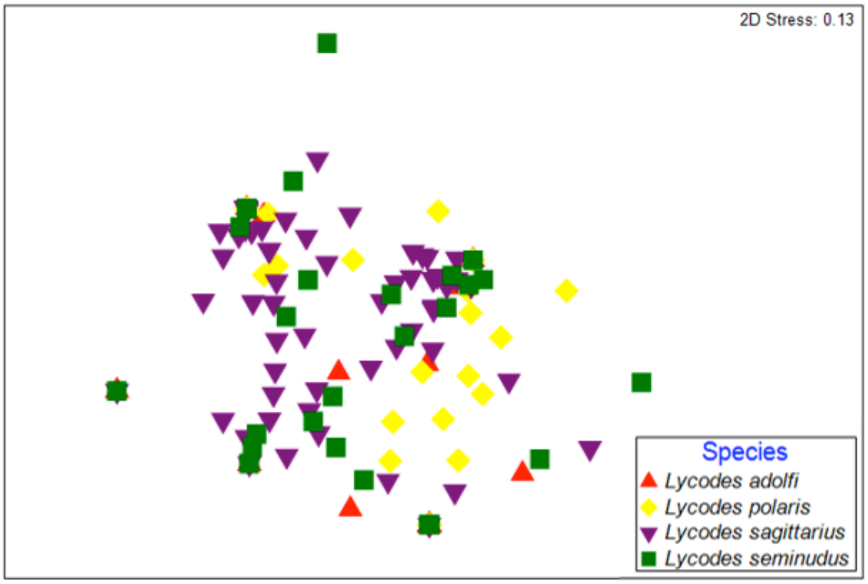


Figure 9. Non-metric multidimensional scaling (nMDS) plot of *Lycodes* spp. diet composition data by percent weight (%W) for central (2012) Beaufort Sea eelpouts. Each point represents one sample (stomach). Two outlier samples (*L. polaris, L. seminudus*) were excluded from the nMDS to better show distribution of remaining samples; outliers only contained 100% unidentified animal prey or teleost prey.

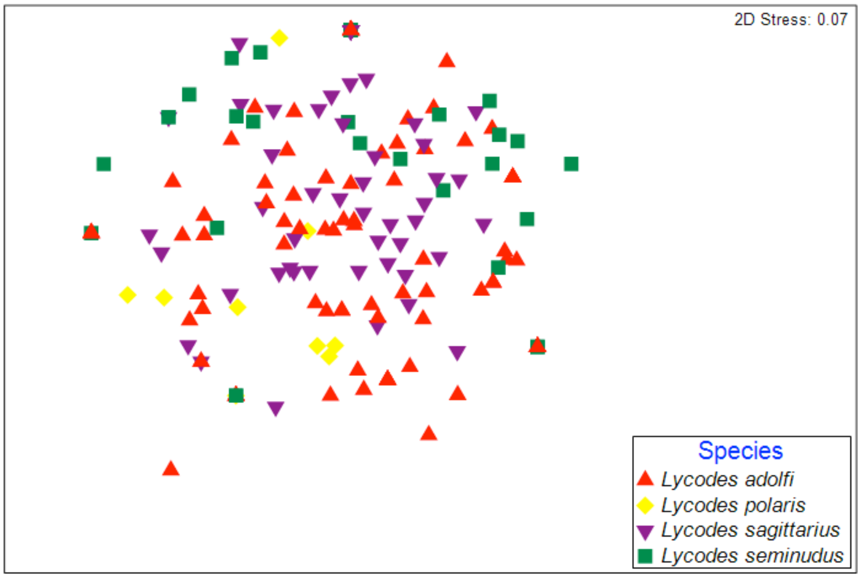


Figure 10. Non-metric multidimensional scaling (nMDS) plot of diet composition data by percent weight (%W) for eastern (2013/2014) Beaufort Sea eelpouts. Each point represents one sample (stomach). Two outlier *L. seminudus* stomachs that contained only teleost prey were excluded from the nMDS to better show distribution of remaining samples.

Similarity in diet composition within a species was low, 15% to 28.0% for 2012 fishes (Table 9), and 1.5% to 20% for 2013/2014 fishes (Table 10). Polychaeta and Crustacea were the main contributors to differences in diet composition for all pairings of eelpout species collected in 2012, while Polychaeta and Amphipoda were the main contributors to differences in diet composition among species for 2013/2014 fishes. In 2012, the prey group that contributed most to diet composition by %MW was unidentified Crustacea for *L. adolfi* (31%), Amphipoda for *L. polaris* (28%), and Polychaeta for both *L. sagittarius* (43%) and *L. seminudus* (27%) (Figure 11). In 2013 and 2014, Polychaeta was the most abundant prey group for *L. adolfi* (19%) and *L. sagittarius* (40%), Amphipoda for *L. polaris* (30%), and Ophiuroidea for *L. seminudus* (29%) (Figure 12).

Table 10. Percent mean weight (%MW) for coarse prey groups for eelpouts collected in central Beaufort Sea in 2012. In the upper section of the table average within group similarity (Avg. Sim.) is given for each eelpout species. Prey groups that together contributed at least 70% of the cumulative within-group similarity by %W are highlighted in bold, with the contributing percent similarity (%Sim.) indicated. The lower part of the table shows average between-eelpout species dissimilarity (Avg. Dis.) Prey groups that together contributed at least 70% of the cumulative percent dissimilarity are presented in descending order, followed by the cumulative percent dissimilarity (Cum. %) represented by those prey groups.

		L. adolfi		*L. polaris*		*L. sagittarius*		*L. seminudus*
Avg. Sim.		14.6%		20.8%		28.0%		17.2%
Prey Group	%Sim.	(n=16)	%Sim.	(n=25)	%Sim.	(n=63)	%Sim.	(n=32)
Foraminifera		0.0		0.0		0.0		0.0
Mollusca		3.9		0.0		4.8		4.3
Polychaeta		12.6		20.6	68%	**42.6**	41%	**27.2**
Copepoda		16.2		1.7		4.1		4.4
Ostracoda		0.0		0.2		0.0		0.4
Cumacea		0.1	21%	**19.1**		2.4		0.0
Tanaidacea		0.0		0.1		0.3		0.0
Isopoda		14.1		0.3		12.7	26%	**21.1**
Amphipoda	15%	**16.9**	40%	**27.5**	20%	**22.6**	22%	**20.0**
Crustacea Unid.	58%	**30.5**	21%	**21.0**		7.2		12.8
Ophiuroidea		0.0		4.0		0.0		2.9
Teleost		0.0		0.0		0.7		3.0
Animal Unid.		0.0		5.3		0.0		0.0
Other		5.7		0.3		2.6		3.9

Between Sp. Dissimilarities	Avg.	Contributing prey groups	Cum. %
L. sagittarius & L. seminudus	78.0	Polychaeta, Amphipoda, Isopoda, Crustacea	79.1
L. adolfi & L. sagittarius	84.7	Polychaeta, Crustacea, Amphipoda, Isopoda	77.4
L. adolfi & L. polaris	84.9	Crustacea, Amphipoda, Polychaeta, Cumacea	70.2
L. polaris & L. sagittarius	80.9	Polychaeta, Amphipoda, Crustacea, Cumacea	77.5
L. adolfi & L. seminudus	84.4	Crustacea, Polychaeta, Amphipoda, Isopoda	75.0
L. polaris & L. seminudus	84.7	Polychaeta, Amphipoda, Crustacea, Isopoda	71.2

Table 11. Percent mean weight (%MW) for coarse prey groups for eelpouts collected in eastern Beaufort Sea in 2013 and 2014. In the upper section of the table average within group similarity (Avg. Sim.) is given for each eelpout species. Prey groups that together contributed at least 70% of the cumulative within-group similarity by %W are highlighted in bold, with the contributing percent similarity (%Sim.) indicated. The lower part of the table shows average between-eelpout species dissimilarity (Avg.) Prey groups that together contributed at least 70% of the cumulative percent dissimilarity are presented in descending order, followed by the cumulative percent dissimilarity (Cum. %) represented by those prey groups.

		L. adolfi		*L. polaris*		*L. sagittarius*		*L. seminudus*
Avg. Sim.		14.5%		16.7%		20.3%		15.3%
Prey Group	%Sim.	(n=107)	%Sim.	(n=9)	%Sim.	(n=67)	%Sim.	(n=50)
Foraminifera		3.5		0.0		1.8		0.0
Mollusca		3.0		0.0	15%	**12.9**		0.0
Polychaeta	26%	**19.3**		21.6	60%	**40.3**	26%	**25.6**
Copepoda	23%	**15.7**	12%	**15.1**		2.6		5.0
Ostracoda		2.7		8.5		3.1		0.0
Cumacea		3.4		9.2		3.5		0.0
Tanaidacea		6.1		3.3		8.2		3.5
Isopoda	24%	**18.3**		0.0		12.4		12.9
Amphipoda		12.1	69%	**30.3**		5.0		6.8
Crustacea Unid.		11.5		12		1.9		7.7
Ophiuroidea		0.0		0.0		3.5	52%	**28.9**
Teleost		0.0		0.0		0.0		5.9
Animal Unid.		3.6		0.1		0.9		2.8
Other		0.8		0.0		3.9		0.9

Between Sp. Dissimilarity	Avg.	Contributing prey groups	Cum.%
L. sagittarius & L. seminudus	88.1	Polychaeta, Ophiuroidea, Ispopoda, Mollusca, Amphipoda, Tanaidacea	76.0
L. adolfi & L. sagittarius	86.1	Polychaeta, Isopoda, Copepoda, Mollusca, Amphipoda, Crustacea	74.6
L. adolfi & L. polaris	87.2	Amphipoda, Polychaeta, Copepoda, Crustacea, Isopoda	74.2
L. polaris & L. sagittarius	90.2	Polychaeta, Amphipoda, Copepoda, Mollusca, Crustacea, Isopoda	74.8
L. adolfi & L. seminudus	90.2	Polychaeta, Ophiuroidea, Isopoda, Copepoda, Crustacea, Amphipoda	78.3
L. polaris & L. seminudus	92.2	Amphipoda, Ophiuroidea, Polychaeta, Copepoda, Crustacea	71.3

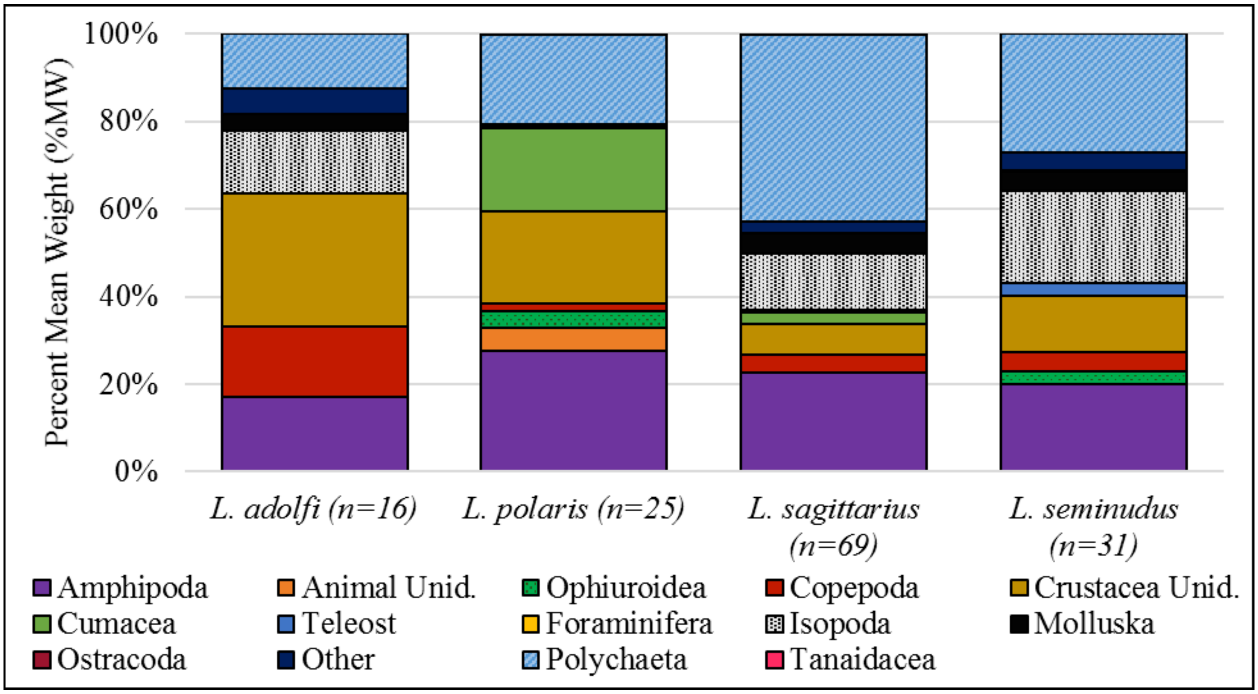


Figure 11. Percent mean weight (%MW) values for major prey groups observed in eelpout stomachs. Eelpouts were collected in the central Beaufort Sea (2012).

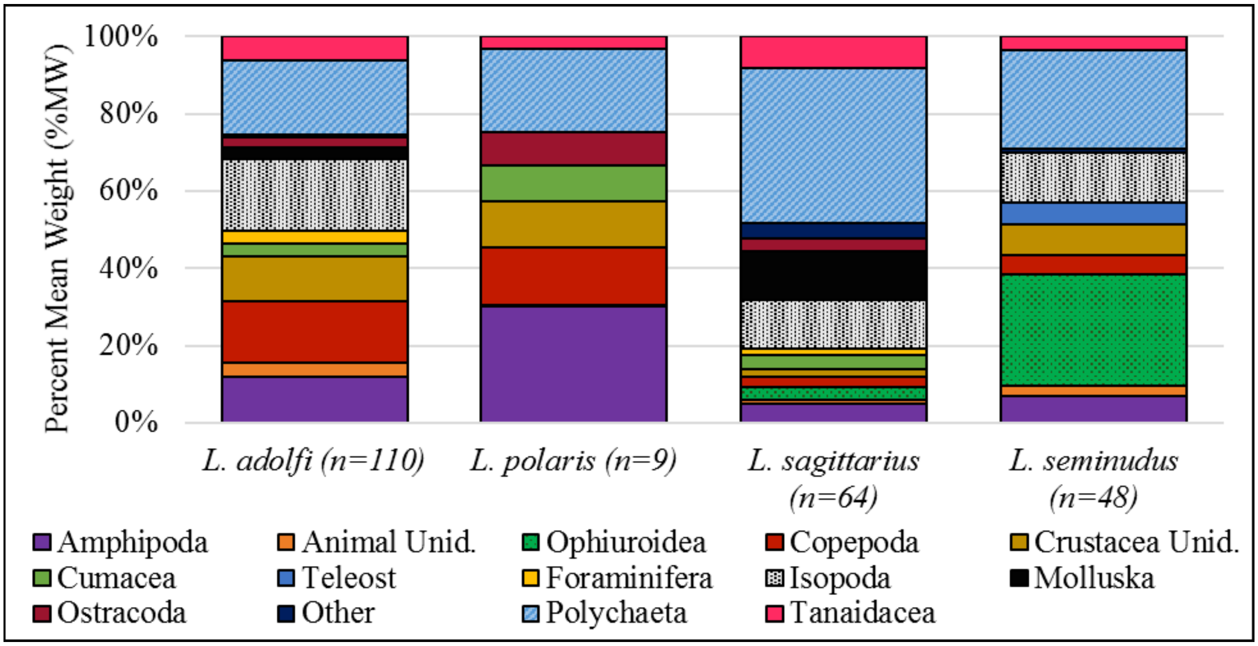


Figure 12. Percent mean weight (%MW) values for major prey groups observed in eelpout stomachs. Eelpouts were collected in the eastern Beaufort Sea (2013 and 2014).

An overall CCA permutation test indicated significant effects of environmental factors and fish length on the diets of *L. adolfi* and *L. sagittarius* (Table 11), but not on those of *L. polaris* and *L. seminudus*. After accounting for effects of all other variables by testing marginal effects, fish length was the only variable that had a significant effect on the diet composition of *L. adolfi* and *L. sagittarius*. (Table 12). Environmental variables (bottom temperature, depth, along shelf (i.e., longitude), and salinity) did not have significant effects when tested by marginal effects. Positioning of coarse prey groups in association with CCA axes indicated that Polychaeta was associated with increasing *L. adolfi* total length (Figure 13), while smaller *L. adolfi* were associated with Copepoda, Ostracoda, and Cumacea. For *L. sagittarius* unidentified animal tissue and Polychaeta were associated with increasing total fish length (Figure 14). Copepoda, Ostracoda, Tanaidacea, Isopoda, and unidentified Crustacea were all negatively associated with increasing total length.

Table 12. Results from overall permutation tests for canonical correspondence analysis (CCA) of the diet compositions (%W) of four eelpout species. Significant models (α = 0.05) are indicated in bold font. The degrees of freedom (DF), chi square value (ChiSquare), F-value (F), and P-value (Pr(>F) are given for each test.

	Df	ChiSquare	F	Pr(>F)
L. adolfi (n=107)				
Model	5	0.567	1.76	**0.006**
Residual	99	6.380		
L. polaris (n=9)				
Model	5	2.200	1.370	0.182
Residual	3	0.964		
L. sagittarius (n=67)				
Model	5	0.950	1.929	**0.003**
Residual	56	5.515		
L. seminudus (n=50)				
Model	5	1.046	1.434	0.071
Residual	45	6.342		

Table 13. Permutation tests for marginal effects of terms and for each constrained axis from canonical correspondence analyses (CCA) of the diet composition (%W) of *L. adolfi* and *L. sagittarius*.

L. adolfi	Df	ChiSquare	F	Pr(>F)	***L. sagittarius***	Df	ChiSquare	F	Pr(>F)
Fish Length	1	0.257	3.981	**0.001**	Fish Length	1	0.316	3.207	**0.001**
Temperature	1	0.071	1.103	0.330	Temperature	1	0.119	1.207	0.254
Salinity	1	0.038	0.589	0.679	Depth	1	0.056	0.564	0.660
Along Shelf	1	0.086	1.332	0.202	Along Shelf	1	0.064	0.664	0.778
Depth	1	0.105	1.626	0.078	Salinity	1	0.095	0.964	0.489
Residual	99	6.3802			Residual	56	5.5149		
CCA1	1	0.308	4.774	**0.001**	CCA1	1	0.550	5.585	**0.001**
CCA2	1	0.117	1.809	0.060	CCA2	1	0.180	1.823	**0.029**
CCA3	1	0.084	1.302	0.232	CCA3	1	0.152	1.539	0.151
CCA4	1	0.046	0.719	0.679	CCA4	1	0.043	0.438	0.907
CCA5	1	0.013	0.197	0.995	CCA5	1	0.026	0.262	0.992
Residual	99	6.3802			Residual	56	5.5149		

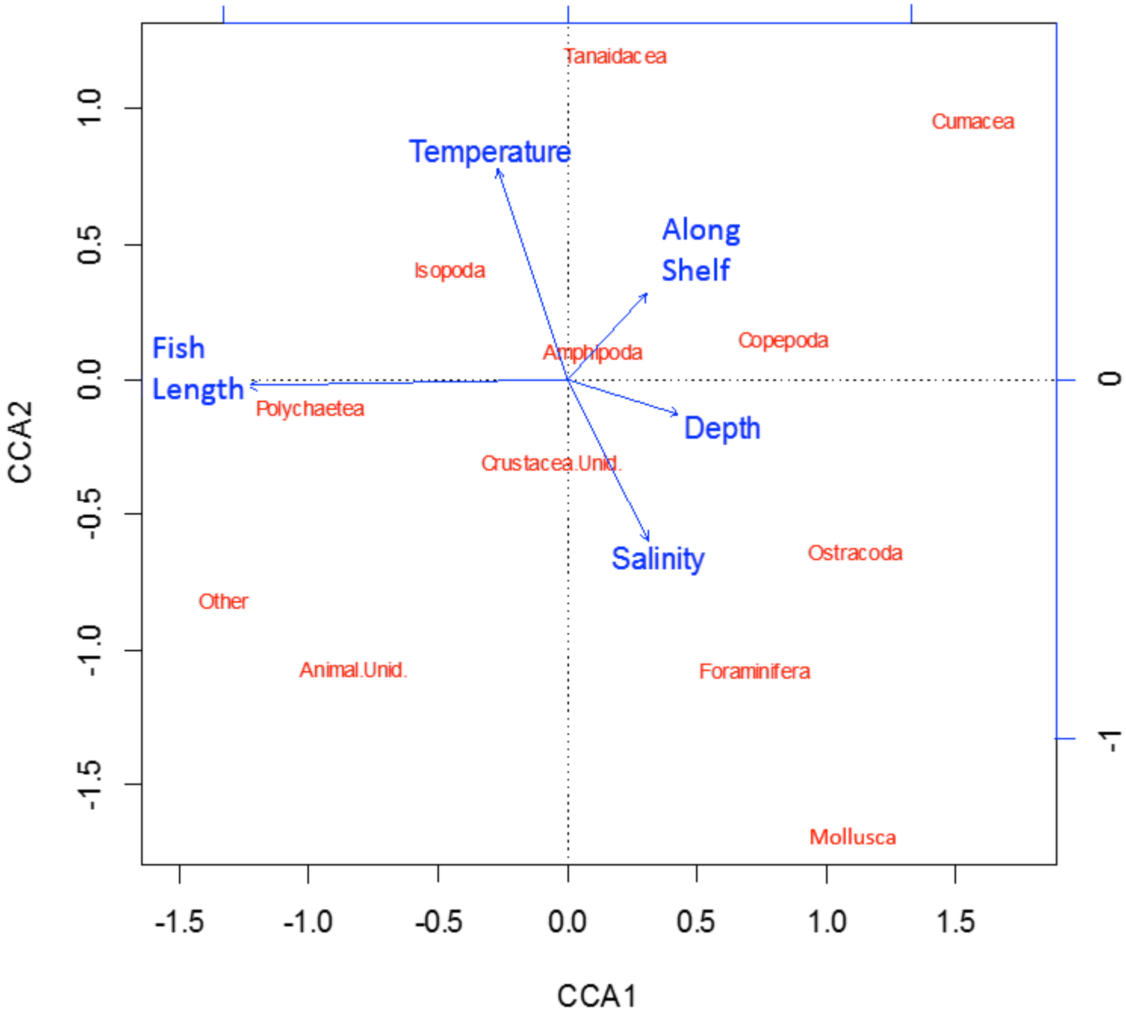


Figure 13. Canonical correspondence analysis (CCA) output for *L. adolfi* (2013 and 2014 sample years). The coarse prey groups (red) are multivariate response variables. Along-shelf (proxy for longitude), total fish length, temperature (^{o}C), salinity (g/kg), and depth (m) are continuous factors (blue). The location of the mean responses of the coarse prey groups in relation to the continuous vectors is indicative of a prey group's association with a given environmental factor.

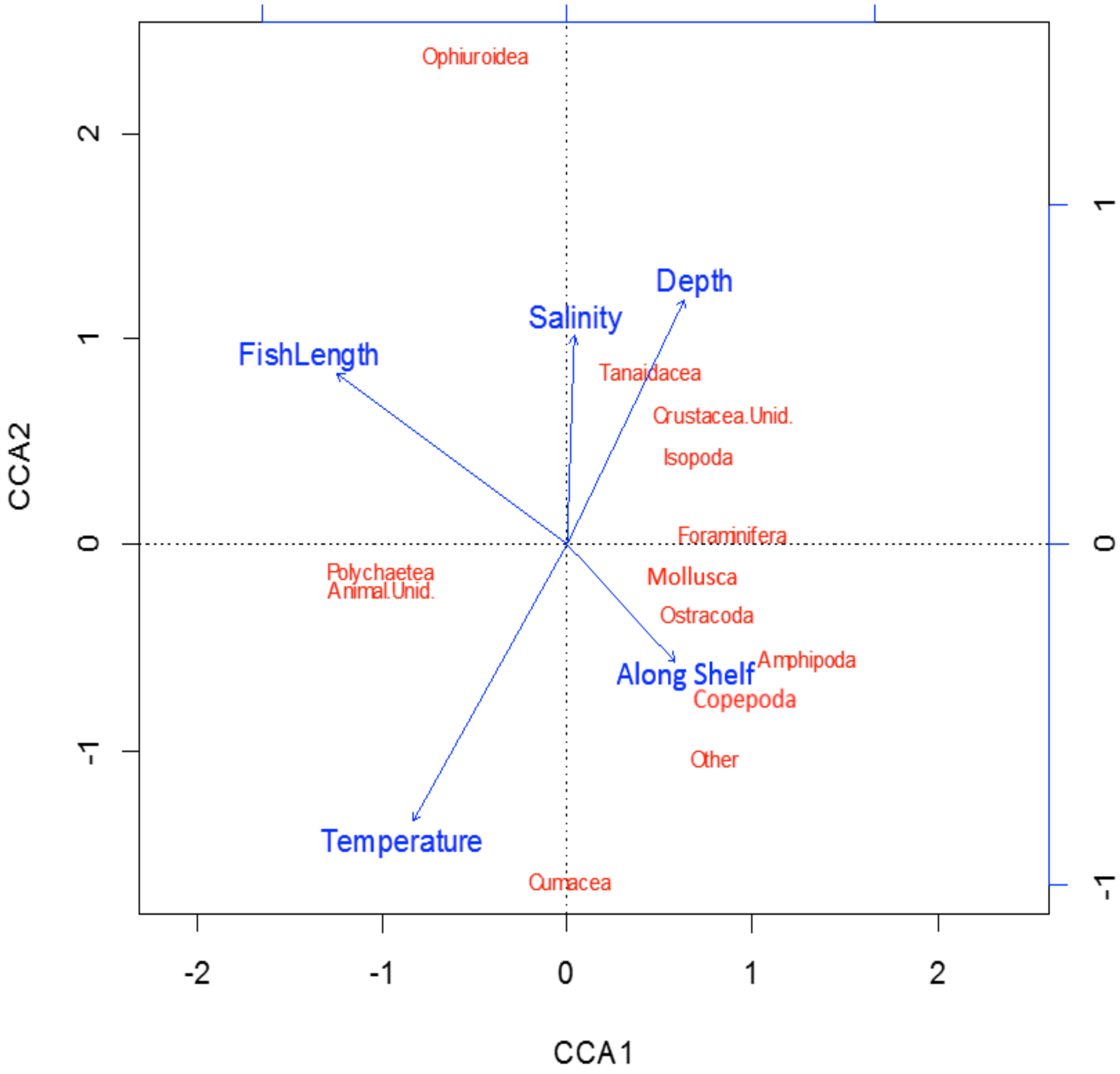


Figure 14. Canonical correspondence analysis (CCA) output for *L. sagittarius* (2013 and 2014 sample years). The coarse prey groups (red) are multivariate response variables. Along-shelf (proxy for longitude), total fish length, temperature (^{o}C), salinity (g/kg) and depth (m) are continuous factors (blue). The location of the mean responses of the coarse prey groups in relation to the continuous vectors is indicative of a prey group's association with a given environmental factor.

Size Class Analysis

Size class analysis using nMDS indicated differences in diet with length for two of the three eelpout species examined. Sample size for *L. polaris* was inadequate for this analysis. At 40% similarity, *L. adolfi* partitioned into two main clusters of roughly fish ≤ 100 mm and fish ≥ 101 mm (Figure 15). However, some fish < 90 mm grouped into the ≥ 101 mm cluster and the size group 111 – 120 mm was an outlier. At 40% similarity *L. sagittarius* grouped into two main clusters: ≤ 150 mm and fish ≥ 151 mm, with a separate 101 – 130 mm group as an outlier (Figure 16). *Lycodes seminudus* did not cluster into continuous size groups.

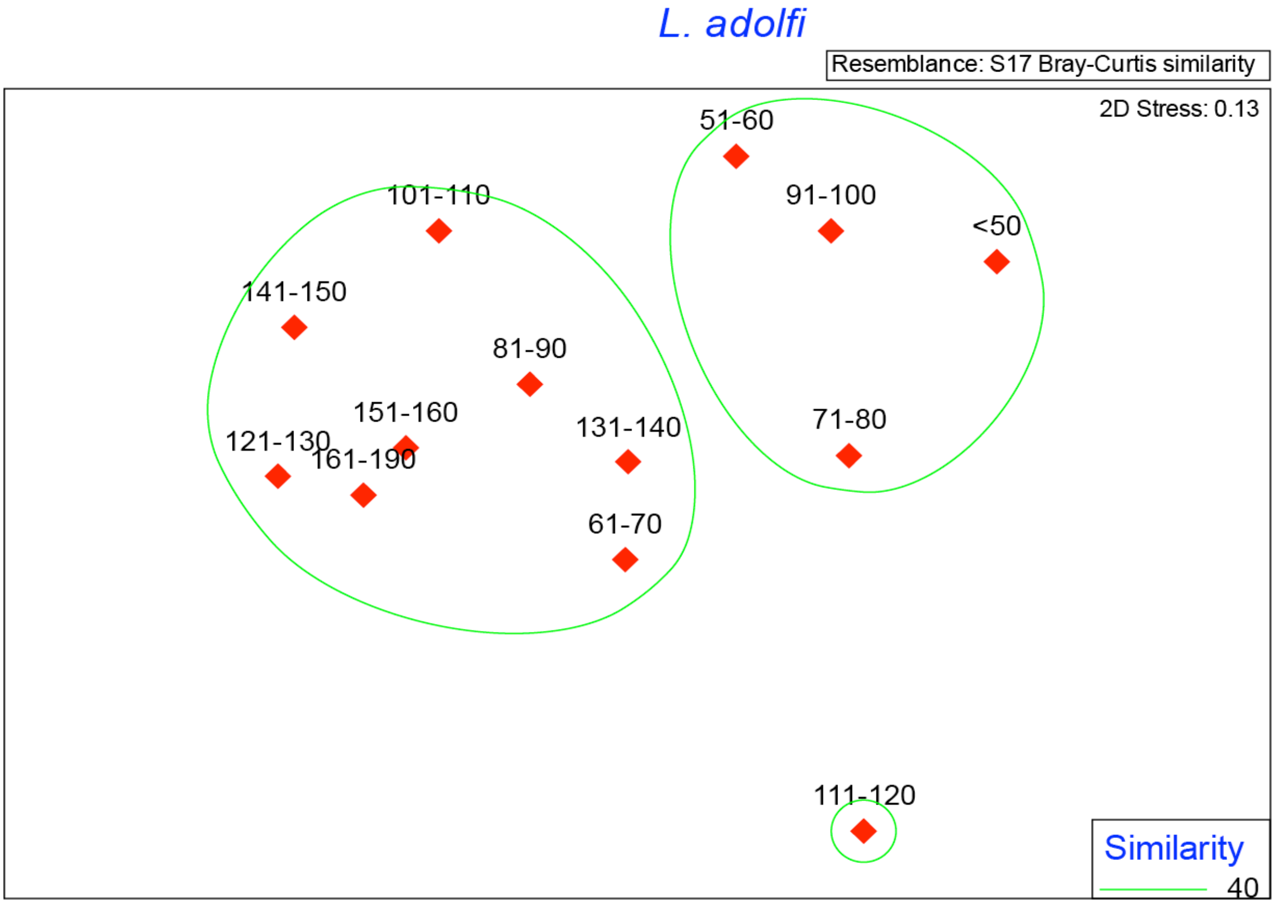


Figure 15. Similarity of *L. adolfi* prey composition by fish length bins. Percent similarity of 40% was used to detect consecutive sized groups of fish with similar diet composition.

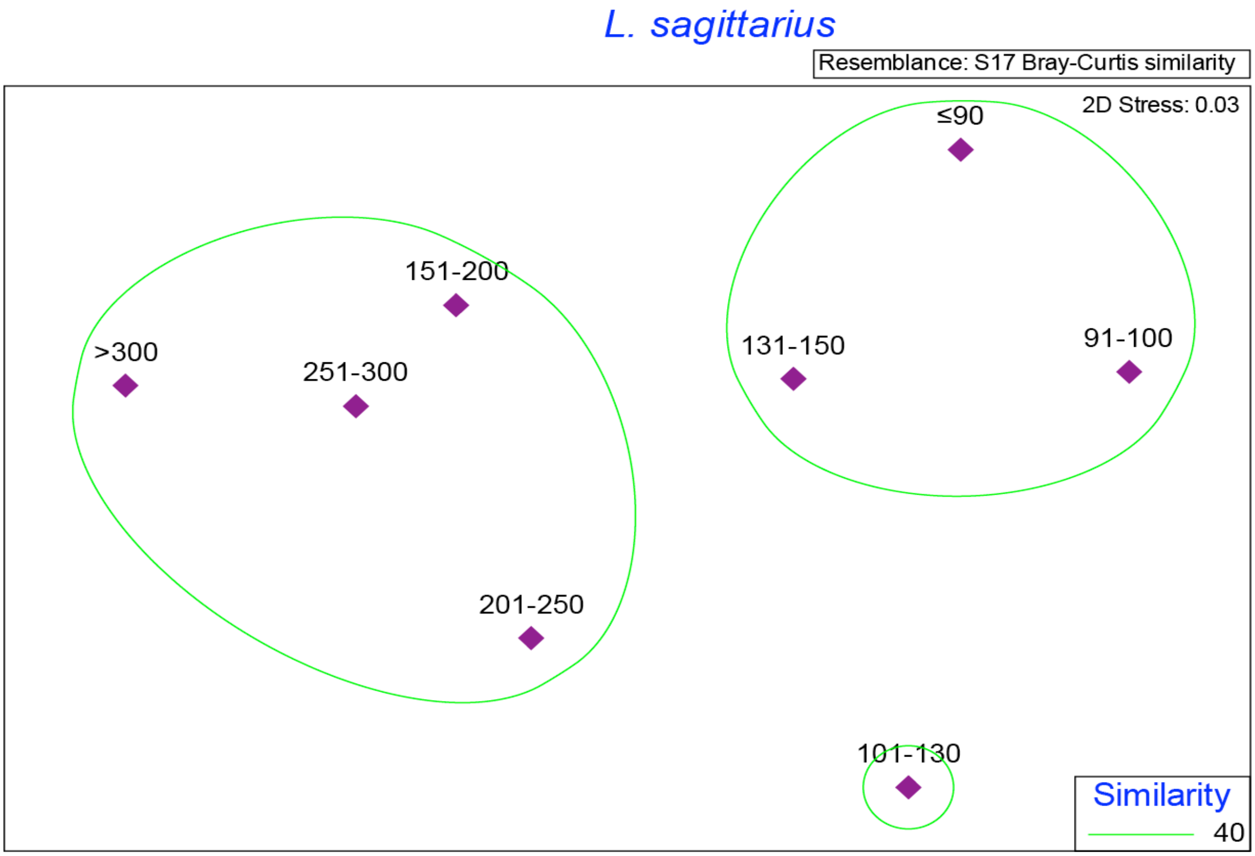


Figure 16. Similarity of *L. sagittarius* prey composition by fish length bins. Percent similarity of 40% was used to detect consecutive sized groups of fish with similar diet composition.

Trophic Level and Carbon Sourcing

Eelpout species differed significantly in their average nitrogen stable isotope values and the resulting trophic levels. The average nitrogen isotope value was lowest for *L. polaris* (15.0‰) and highest for *L. seminudus* (17.3‰) with intermediate values for *Lycodes adolfi* (17.0‰) and *L. sagittarius* (16.7‰). Nitrogen isotope values overlapped for the three deep-water species *L. adolfi, L. sagittarius*, and *L. seminudus,* but were significantly lower for *L. polaris* (Table 14, Figure 17). *Lycodes seminudus* and *L. sagittarius* also had significantly different δ^{15}N values despite considerable overlap. Similarly, calculated trophic levels (TL) overlapped for the three deep-water eelpouts, but were significantly lower for *L. polaris* (3.9 ± 0.2 SD, Table 15, Figure 18). TL was highest for *L. seminudus* (4.4 ± 0.4) and slightly lower (4.3 ± 0.3) for *L. adolfi* and *L. sagittarius*.

No significant differences in average carbon stable isotope values were detected among the four eelpout species (F = 2.37, P = 0.072), with large overlap in the ranges among species (Figure 17). This indicates similar carbon sources in diets among the four eelpout species. Average δ^{13}C signatures ranged from -20.7‰ (*L. adolfi* and *L. polaris*) to -20.2‰ (*L. seminudus*)) with an intermediate value for *Lycodes sagittarius* (-20.5‰).

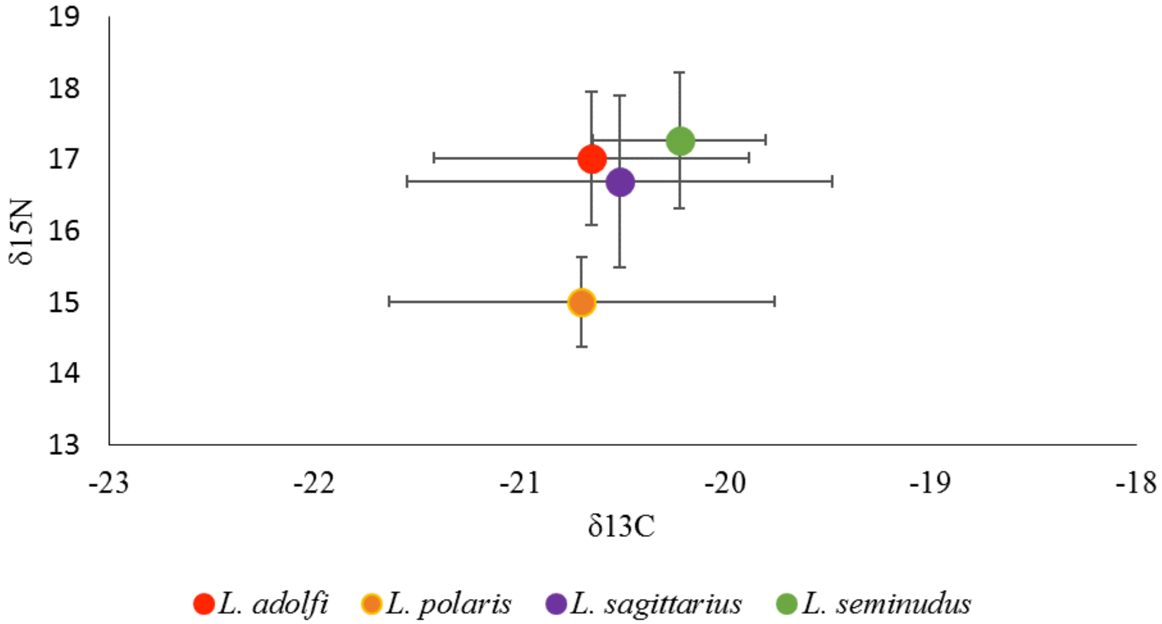


Figure 17. Stable nitrogen and carbon isotope values for four eelpout species. Dots are mean values and error bars are standard deviations. Fishes were collected in 2014.

Table 14. One-way ANOVA of differences between $\delta^{15}N$ and between $\delta^{13}C$ values for four eelpout species in 2014. Non-significant (NS) tests are indicated. Sums of squares (SS), degrees of freedom (df), mean squares (MS), the calculated F statistic (F), and the critical F statistic (F crit). Subsequent pairwise test were conducted using Dunn's method and gave a q-value (q).

ANOVA $\delta^{15}N$						
Source of Variation	SS	df	MS	F	p	F crit
Between Species	73.8	3	24.6	7.074	**0.0002**	2.652
Within Species	667.8	192	3.5			
Total	741.6	195				
ANOVA $\delta^{13}C$						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Species	4.8	3	1.6	2.371	0.072	2.654
Within Species	123.9	184	0.7			
Total	128.7	187				

Pairwise Test for $\delta^{15}N$	**Diff of Ranks**	**q**	**P<0.05**
L. polaris vs. *L. seminudus*	113.0	6.592	**P<0.05**
L. polaris vs. *L. adolfi*	95.0	6.081	**P<0.05**
L. polaris vs. *L. sagittarius*	75.9	4.706	**P<0.05**
L. seminudus vs. *L. sagittarius*	37.1	3.101	**P<0.05**
L. adolfi vs. *L. sagittarius*	19.1	1.974	NS
L. seminudus vs. *L. adolfi*	18.1	1.601	NS

Table 15. One-way ANOVA and pairwise test of rank-based calculated trophic level for the four eelpout species. Only 2014 fish were used for this analysis. Subsequent pairwise test were conducted using Dunn's method and gave a q-value (q).

ANOVA Trophic Level						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Species	3.67	3	1.22	15.09	**<0.0001**	2.651
Within Species	15.71	194	0.08			
Total	19.38	197				
Pairwise Test for Trophic Level				**Diff of Ranks**	**Q**	**P<0.05**
L. polaris vs. *L. sagittarius*				77.32	4.80	**P<0.05**
L. polaris vs. *L. seminudus*				92.29	5.38	**P<0.05**
L. polaris vs. *L adolfi*				87.96	5.63	**P<0.05**
L. seminudus vs. *L. sagittarius*				14.97	1.25	NS
L. adolfi vs. *L. sagittarius*				10.64	1.10	NS
L. seminudus vs. *L. adolfi*				4.33	0.38	NS

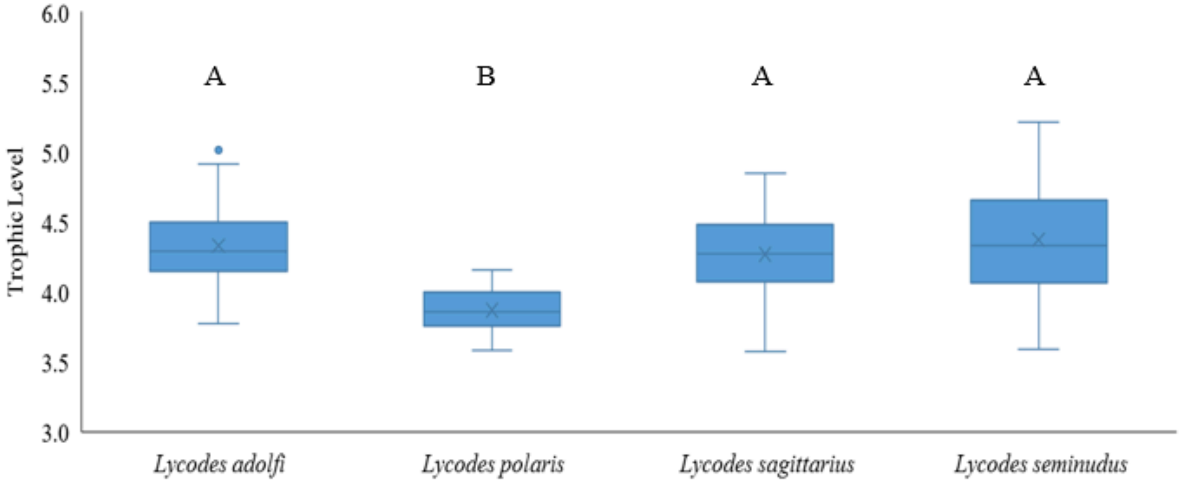


Figure 18. Calculated trophic levels for *L. adolfi* (n=85), *L. polaris* (n=16), *L. sagittarius* (n=60), and *L. seminudus* (n=37). The median is indicated with an **X** and average is indicated by a horizontal line. The first and fourth quartiles are represented by the vertical lines. Outliers are represented with individual dots. Species designated with the letter **A** were significantly different from species designated with **B**.

The relationship between increasing fish length and stable isotope value (TL or δ^{13}C) was curvilinear for eelpout species in which a significant relationship existed. The best fit model suggested a curved rather than linear relationship with TL (Table 16 and Figure 19) and increasing fish length. In addition, this curved relationship was different for each of the four eelpout species and was most pronounced for *L. adolfi* and *L. polaris*, which had lower TL values at intermediate sizes. The relationship for *L. sagittarius* was not significant. This could be due to smaller sample size and less statistical power. Similar to TL, carbon stable isotope also had a curvilinear relationship with increasing fish length (Table 17 and Figure 20), but the relationship was not significant for *L. polaris* or *L. seminudus*. Similar to TL, the carbon values for *L. adolfi* were lowest at intermediate values.

Table 16. Results of comparison of multiple analysis of covariance (ANCOVA) for trophic level and fish length. The presence and number of asterisk indicates the degree of statistical significance. A full ANCOVA for best model by AIC is given. Asterisk (*) indicates significance of linear, one degree polynomial (poly(Length, 2)1), or two degree polynomial (poly(Length, 2)2) term.

Comparison of ANCOVA Models for Trophic Level (TL)

	AIC	Model
Model 1	66.4	Differences among species, no length effect
Model 2	64.8	Linear model, single slope across species
Model 3	53.4	Quadratic model, same shape for each species
Model 4	71.1	Linear model, different line for each species
Model 5	20.0	Quadratic model, different shape for each species

ANCOVA for Model 5

	Estimate	Std. Error	t value	Pr(>|t|)	
Intercept	5.0	0.12	40.79	$<2\text{x}10^{-16}$	***
L. polaris	2.3	1.76	1.30	0.1950	
L. sagittarius	-0.8	0.13	-6.18	$4.43\text{x}10^{-9}$	***
L. seminudus	-0.7	0.13	--5.23	$4.69\text{x}10^{-7}$	***
L. adolfi poly(Length, 2)1	23.2	3.90	5.94	$5.94\text{x}10^{-8}$	***
L. polaris poly(Length, 2)1	92.6	45.26	2.05	0.0423	*
L. sagittarius poly(Length, 2)1	0.7	0.46	1.52	0.1308	
L. seminudus poly(Length, 2)1	-0.8	0.49	-1.54	0.1247	
L. adolfi poly(Length, 2)2	14.9	2.75	5.42	$1.80\text{x}10^{-7}$	***
L. polaris poly(Length, 2)2	35.9	20.07	1.79	0.0756	*
L. sagittarius poly(Length, 2)2	-0.01	0.67	-0.02	0.9853	
L. seminudus poly(Length, 2)2	2.0	0.41	4.91	$1.95\text{x}10^{-6}$	***

Table 17. Results of comparison of multiple analysis of variance (ANCOVA) for δ^{13}C and fish length. The presence and number of asterisk indicates the degree of statistical significance. A full ANCOVA for the best model by AIC is given. Asterisk (*) indicates significance of linear, one degree polynomial (poly(Length, 2)1), or two degree polynomial (poly(Length, 2)2) term.

Comparison of ANCOVA Models for δ^{13}C

	AIC	Model
Model 1	465.5	Differences among species, no length effect
Model 2	449.0	Linear model, single slope across species
Model 3	450.9	Quadratic model, same shape for each species
Model 4	442.3	Linear model, different line for each species
Model 5	432.1	Quadratic model, different shape for each species

ANCOVA for Model 5

	Estimate	Std. Error	t value	Pr(>|t|)	
Intercept	-19.2	0.37	-51.59	2.0x10^{-16}	***
L. polaris	-5.5	5.25	-1.04	0.29847	
L. sagittarius	-1.6	0.39	-4.15	5.21x10^{-5}	***
L. seminudus	-1.2	0.39	-2.98	0.00329	**
L. adolfi poly(Length, 2)1	49.9	11.67	4.27	3.18x10^{-5}	***
L. polaris poly(Length, 2)1	-103.8	135.4	-0.77	0.44425	
L. sagittarius poly(Length, 2)1	8.0	1.37	5.88	1.95x10^{-8}	***
L. seminudus poly(Length, 2)1	1.0	1.46	0.71	0.47849	
L. adolfi poly(Length, 2)2	32.5	7.67	4.23	3.59x10^{-5}	***
L. polaris poly(Length, 2)2	-46.7	59.6	-0.79	0.3366	
L. sagittarius poly(Length, 2)2	1.2	0.56	0.56	0.5694	
L. seminudus poly(Length, 2)2	0.5	1.19	0.44	0.6327	

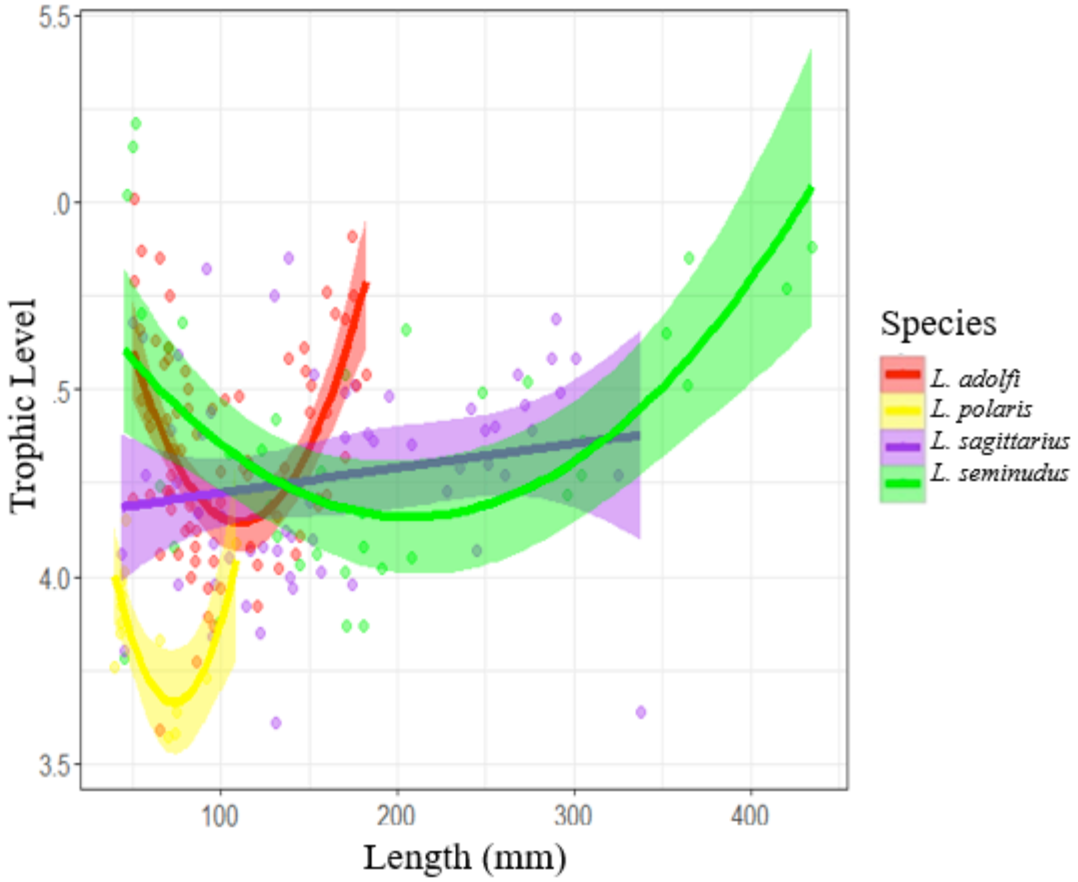


Figure 19. Trophic level (TL) against length for each of the four eelpout species. The model of best fit from the ANCOVA is shown as selected based on AIC.

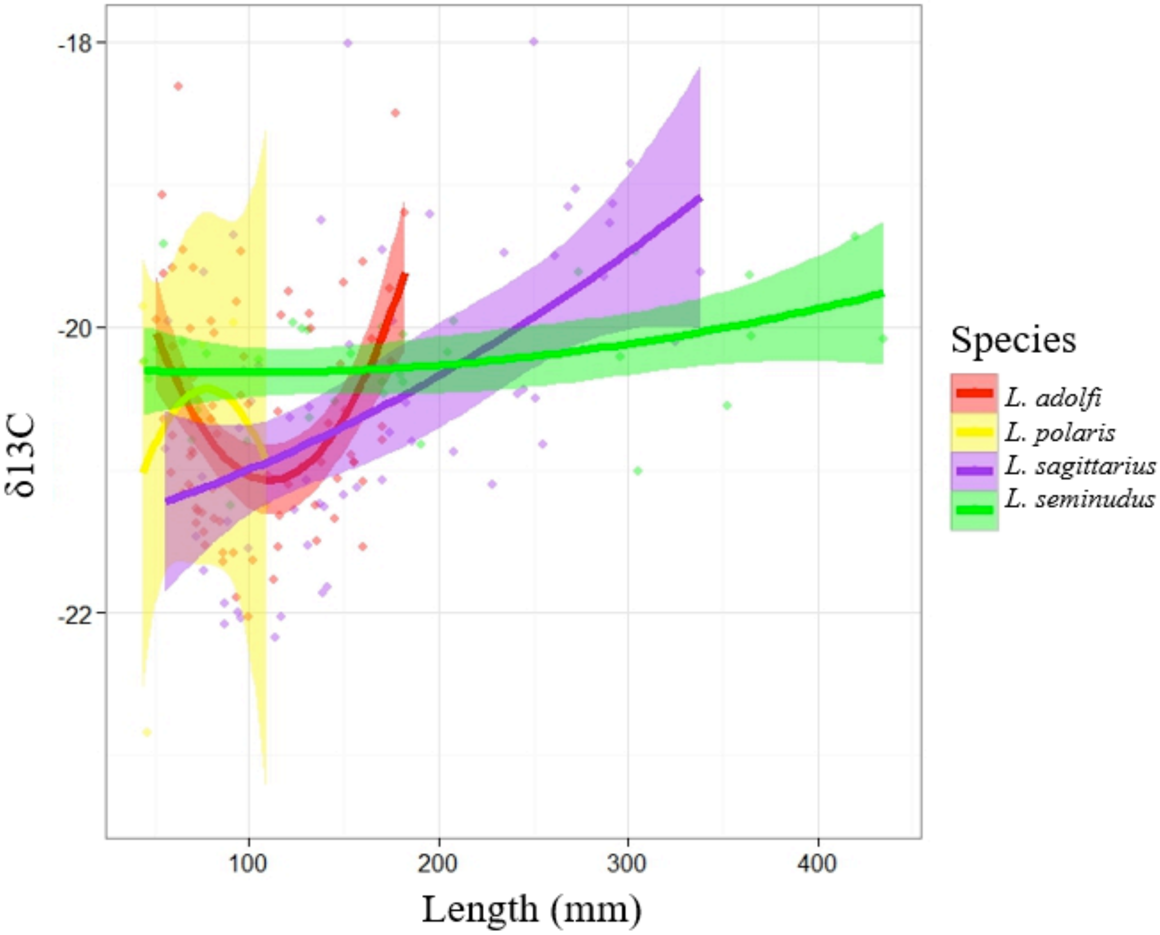


Figure 20. Carbon stable isotope ($\delta^{13}C$) against length for each of the four eelpout species. The model of best fit from the ANCOVA is shown as selected based on AIC.

Discussion

This study describes previously unknown diet composition for four eelpout species found in the U.S. Beaufort Sea: *L. adolfi*, *L. polaris*, *L. sagittarius*, and *L. seminudus*. Eelpout diets were dominated by demersal prey such as polychaetes, amphipods, isopods, and brittle stars. The prevalence of demersal prey in eelpout diet is consistent with previous studies of *Lycodes* diet in the Beaufort Sea (Dissen 2015; Giraldo et al. 2016), Chukchi Sea (Whitehouse et al. 2017), and Atlantic Arctic (Bjelland et al. 2000). A shift from benthic-directed energy flow to primarily pelagic food webs is expected to occur in the Arctic due to climate warming, and is already thought to be occurring in the nearby northern Bering Sea (Grebmeier et al. 2006). If the predicted shift from a benthic dominant to pelagic dominant food web occurs, eelpout dependence upon demersal prey may leave them susceptible to energy shortages due to decreased benthic prey and could result in smaller eelpout population sizes. Fish length and habitat depth were significant predictors of diet composition. Depth correlated with eelpout species distribution, with *L. polaris* being found primarily on the shelf and *L. adolfi*, *L. sagittarius*, and *L. seminudus* found on the slope. Diet composition based on stomach contents differed among eelpout species, but the observed patterns varied based on location of sampling. For example, in the central Beaufort Sea diet was different between *L. polaris* and *L. adolfi*, and *L. polaris* and *L. sagittarius*. No significant difference in diet composition was observed between all other eelpout species pairings in the central Beaufort. The opposite was true in the eastern Beaufort Sea where diets differed significantly between all pairings of eelpout species, the exception being *L. polaris* and *L. adolfi*, and *L. polaris* and *L. seminudus*. Average stable nitrogen isotope values, as a measure of eelpout diet and TL over a longer time scale than stomach content analysis (months vs. hours or days, respectively), indicated that the shelf species *L. polaris* fed at a lower TL than the three slope species. Average overall carbon isotope values were not significantly different among the four eelpout species despite sampling fishes from across a wide longitudinal range representative of differing conditions due to varying terrestrial and freshwater matter influences. This indicates similar basal carbon sources for all four eelpout species. Stable isotope values had a curvilinear relationship with increasing fish length, indicating TL changes over ontogeny in non-linear ways for some species. This study provides a detailed look into eelpout diet that is valuable for further understanding of the role and vulnerability of this genus in the current Arctic ecosystem.

Species Identification

Genetic testing used in this study for eelpout species identification indicated potential problems with the currently accepted taxonomy of *Lycodes*. Eelpout identification and current taxonomy is primarily based on morphology (Møller and Gravlund 2003) but a high degree of phenotypic plasticity is known to exist for some eelpout species (Balanov and Kukhlevskii 2011). Accuracy of identification based on genetics ranged from 68% to 89% for the four eelpout species included in this study. The difficulty to accurately identify species based on morphology observed in the present study confirmed that the four eelpout species may exhibit high phenotypic plasticity. Additionally, there also may be very little genomic differentiation between some of the currently accepted Arctic eelpout species, and some of these species may in fact represent synonyms. Genetic differentiation between *L. polaris* and *L. seminudus* was especially low (< 1.4%). For marine teleosts, average within-species variability is generally 0.39% (minimum 0%; maximum 14.08% Kimura 2-parameter (K2P) percent), average across-genus variability is 9.93% (minimum 0%; maximum 20.63%), and 15.46% across-family (minimum 1.39%; maximum 35.72%) (Ward et al. 2005). DNA sequence divergence of up to 1-2% is generally accepted within a single species (Ward et al. 2009). This suggests that individuals identified as *L. polaris* or *L. seminudus* may be closely related members of the same complex of currently recognized species. By itself, mtDNA is not enough to justify grouping these two species as one. However, the genetic closeness of *L. polaris* and *L. seminudus* means any interspecific differences in diet or TL between these two species may not be due to well defined species differences, and instead may be driven by differences in fish size or distribution with depth.

Inter- and intraspecific diet differences

The four eelpout species across both the central and the eastern Beaufort Sea had diets composed primarily of benthic prey reflective of their demersal habits. Diet information based on stomach contents for these four species in this region was absent before this study, but findings on diet composition are consistent with studies in neighboring regions. In the Chukchi Sea, gammarid amphipods comprise a significant proportion of the diet of *L. polaris* (Whitehouse et al. 2017), similar to the Beaufort Sea. Amphipods of the family Oedicerotidae, a family of gammaridean amphipods, were found in both Chukchi Sea and Beaufort Sea *L. polaris* stomachs, suggesting this amphipod family is an important prey source for *L. polaris* across a broad geographic range. Stable isotope and fatty acid analyses characterized *L. polaris* as a low-TL benthic generalist in the neighboring Canadian Arctic (Giraldo et al. 2016). *Lycodes adolfi* in the Canadian Arctic consume crustaceans and are benthic generalists (Coad and Reist 2004; Giraldo et al. 2016). Similar to Canadian Arctic *L. adolfi*, Beaufort Sea *L. adolfi* consumed benthic prey, with a high proportion of crustacean prey, but also Polychaeta (13% MW in 2012 and 19% MW in 2013/2014). Both *L. sagittarius* and *L. seminudus* in the Canadian Arctic consume polychaetes and crustaceans (Coad and Reist 2004), similar to those from Beaufort Sea studied here. Benthic feeding habits of *L. seminudus* in the Beaufort Sea also were confirmed by fatty acid analyses (Dissen 2015). The prevalence of benthic prey in diets of the four eelpout species agrees with studies of eelpout diets in neighboring seas, emphasizing the general importance of benthic prey to the diet of this genus.

In both the central and the eastern Beaufort Sea, *L. polaris* and *L. seminudus* diet compositions did not differ significantly from each other. Also, little genetic distance between *L. polaris* and *L. seminudus* was observed in the species confirmation section of this study. Low genetic distance, along with similar diet contents, may indicate that *L. polaris* and *L. seminudus* are recently diverged species. However, incorporating stable isotope biomarkers weakens this conclusion. Similar diets may indicate similar TL (Parish 1975), and based on stomach contents alone, it could be assumed that the two eelpout species are feeding across the same TL. However, in this study there were significant differences in TL between *L. polaris* and *L. seminudus*. The observed lack of significant difference in diet composition could be an artifact of the limited 'snapshot' time period represented by stomach contents versus longer-term biomarkers like stable isotopes and fatty acids. Stomach content analysis can also be biased towards hard bodied prey. Soft bodied prey are digested more quickly and are often only identifiable by residual body parts (e.g., polychaete chaetae), biasing stomach content analysis results and resulting in discrepancies with biomarker results (i.e., stable isotopes) (Weidner et al. 2017). Lastly, low sample numbers for *L. polaris* likely impacted power of statistical tests. *Lycodes polaris* and *L. seminudus* from the central and eastern Beaufort Sea have been shown to have differing diets (Dissen 2015), though both relied heavily on demersal prey. Subtle differences in diet composition were likely lost due to low sample sizes and high intraspecies variability.

Diet composition of all four eelpout species was driven by differences in the relative contributions of the same few prey groups. These prey groups: Polychaeta, Isopoda, Copepoda, Amphipoda, and Mollusca, were comprised of diverse, and primarily benthic associated prey items. Brittle stars (Ophiuroidea) were important, but only in the diet of *L. seminudus*. Polychaeta were particularly important for the two larger, deep-water eelpout species *L. sagittarius* and *L. seminudus*. The prevalence of Polychaeta and dominance of demersal prey groups in eelpout diet mirrors characteristics of the Arctic invertebrate community. Polychaeta, along with Mollusca, Amphipoda, and Echinodermata are the most numerous invertebrate groups in the Beaufort and neighboring seas (Rand and Logerwell 2011; Blanchard et al. 2013; Ravelo et al. 2015). Eelpout diets could be a reflection of spatial patterns in prey availability. For example, direct comparison of diet composition of snow crabs (*Chionoecetes opilio*) to prey populations across the Beaufort and Chukchi seas indicated a lack of prey selection, and, therefore, crab diet was driven by patterns in prey distribution and availability (Divine et al. 2015). Such a comparative analysis of eelpout stomach contents to patterns in invertebrate populations was not possible for this study. Relevant prey samples were not available to make these comparisons.

Nitrogen stable isotope values for the four eelpout species indicated that *L. polaris* occupies a lower TL than the other three eelpout species, all of which fed at the same TL. Amphipoda was the dominant prey group in *L. polaris* diet (27% in 2012 and 30% in 2013/2014) based on stomach content analysis, but was also present in the three other eelpout species (ranging from 17% to 28% in 2012 and 5% to 12% in 2013/2014 for the three other eelpout species). Amphipoda is a trophically diverse group, including herbivores, carnivores, scavengers, or some combination of feeding types (Poltermann 2001; Arndt et al. 2005). The lower TL observed for *L. polaris* could be the result of consuming a higher proportion of lower TL amphipods than the other three eelpout species. However, the family Oedicerotidae observed in *L. polaris* diet is generally carnivorous (Guerra-Garcia et al. 2014). It could be that *L. polaris* is consuming additional lower TL amphipods not represented in the stomach content analysis, or which are obscured in the unidentified Amphipoda group. Cumacea also was an important prey group, having a high %MW, for *L. polaris* (19% in 2012 and 9% in 2013/2014), but not the other three eelpout species (0 – 2% in 2012 and 0 – 4% in 2013/2014). The Cumacea *Diastylis* spp. found in *L. polaris* is a benthic surface deposit feeder and is characterized by a very low TL (TL of 1.6 to 0.4, Bell et al. 2016). The presence of Cumacea in *L. polaris* diet, and the absence of Cumacea in the diet of the other three eelpout species, could be driving the observed difference in TL between *L. polaris* and the other three eelpout species. Lastly, as the stable isotope values represent diet integrated over a longer time period than stomach contents (Sakano et al. 2005; Weidel et al. 2011), the differences in diets between *L. polaris* and the other three eelpout species seem to be a persistent feature.

Average TL alone indicates that *L. adolfi*, *L. sagittarius*, and *L. seminudus* are feeding at the same TL, and therefore, these three eelpout species could be competing for similar resources. Competition for resources can occur among fish species that occupy the same habitat and TL (Parish 1975). Alternatively, the lack of significant differences in TL among the three deep-water eelpout species may be because they are consuming different prey, but prey that have similar TLs. Stomach content analysis indicated Polychaeta were the top prey item for the three deep-water eelpout species. Each eelpout species consumed different polychaete families, but *Lycodes sagittarius* consume a more diverse array of polychaete families (e.g., Lumbrineridae, Maldanidae, Nephtyidae, Opheliidae, Paraonidae, Spionidae) than *L. adolfi* or *L. seminudus* (mostly Polynoidae, Lumbrineridae, and Nephtyidae). Polychaeta is a species rich group and their ecology is diverse. Of those families observed in eelpout stomachs, Lumbrineridae, Nephtyidae, and Polynoidae are carnivores, while Maldanidae consume detritus

(Fauchald and Jumars 1979). Trophic levels of Arctic polychaetes reflect the ecological diversity of the group, with estimated TL ranges reflective of primary consumers (TL = 1) to top predators (TL = 4) (Iken et al. 2005; Bell et al. 2016). Differences in time represented by stable isotope analysis versus stomach contents may also account for the discrepancy in the results for the three deep-water eelpouts. The lack of differences in TL among the three deep-water eelpouts could indicate that over a longer time scale these three species consume similar prey, and that differences observed in diet from stomach contents are only representative of the specific sampling time. In this study, $\delta^{15}N$ and TL had a curvilinear relationship with increasing fish length, meaning eelpouts shift trophic levels with increasing length. TLs generally increase with increasing fish length (Marsh et al. 2012) due to greater gape size (Scharf et al. 2000) and expansion in foraging range. Intermediate length *L. seminudus* and *L. adolfi* exhibited lower trophic level. Decreasing TL with length has been observed for Capelin *Mallotus villosus* in the Chukchi Sea (Marsh et al. 2012), but the non-linear relationship between TL and exhibited by the two eelpout species is unusual. One possible explanation is that small eelpouts may consume small, but high TL prey (e.g., *Anonyx* sp., TL: 2.4 – 3.5, Bell 2015), shift to large but low TL prey (e.g., *Ophiocten sericeum*, TL: 2.0) at intermediate sizes, and large high trophic prey (e.g., teleost *Boreogadus saida*, TL: 2.7 – 3.8), thus driving the observed pattern. Alternatively, TL may reflect available prey community composition at different habitat requirements at different life stages. Lastly, previous community-wide analyses using nitrogen and carbon stable isotopes of the Beaufort Sea ecosystem indicated that *L. adolfi* and *L. seminudus* were top TL predators within the fish community (Bell et al. 2016), and these findings are supported by the high trophic levels found in the present study.

The high intraspecific dissimilarity in diet composition, along with the high number of different prey items found in eelpout diets, may be indicative of generalist feeding for *L. adolfi* and *L. seminudus*. Generalists feed on a broad array of prey compared with specialists that may only feed on a few prey types. *Lycodes adolfi* and *L. seminudus* had the lowest average percent intraspecific similarity of diet composition of the four eelpout species, meaning they exhibit a relatively higher degree of generalist feeding, and they had high trophic levels. This is consistent with other studies in the adjacent Canadian Beaufort Sea that classified *L. adolfi* and *L. seminudus* as mid- to high-TL generalist feeders (Giraldo et al. 2016). *Lycodes polaris* and *L. sagittarius*, though having diverse diets, show some partial diet preferences or specialization. *Lycodes polaris* has sometimes been classified both as a generalist in the Canadian Beaufort Sea (Giraldo et al. 2016), and a semi-specialist consumer, primarily of gammarid amphipods in the eastern Chukchi Sea (Whitehouse et al. 2017). My study found that amphipods, the vast majority of which were gammarid amphipods, composed 28 – 30% of *L. polaris* diet, suggesting some degree of specialization. Comparing diet over a broad geographic scale (e.g., across seas) is valuable as individuals of a species can exhibit localized specialization, while the population on a whole is generalist (Fox and Marrow 1981). Given gammarid amphipods are important for both *L. polaris* in the Chukchi Sea (Whitehouse et al. 2017) and Beaufort Sea (this study), evidence suggest *L. polaris* is a specialist. *Lycodes sagittarius* may also be a semi-specialist feeder. The presence of vomerine teeth indicates that *L. sagittarius* may specialize in crushing large, hard shelled prey (McAllister et al. 1981). Mollusca were an important prey group for *L. sagittarius* in the present study (4.8 – 12.9%), and with the relatively high within-group similarity, may suggest specialization. Other Arctic demersal fishes like sculpins and flatfishes have also been designated as generalists (Gray et al. 2017; Whitehouse et al. 2017). A generalist approach to feeding may be advantageous in a dynamic and ever-changing ecosystem like the Arctic (Chambers and Dick 2005) because it likely allows switching to prey sources that may become more abundant.

Across- and along-shelf influences

Across-shelf changes (i.e., depth) were significant predictors of all eelpout species' diet composition. Depth is a proxy for changes in water masses and food supply conditions, which drive patterns of epifauna and infauna community composition in the Beaufort Sea (Nephin et al. 2014; Ravelo et al. 2015; Roy et al. 2015). Depth coincides with changes in benthic invertebrate community composition and abundance, with greatest abundance observed at the shelf break from 50 to 100 m (Iken et al. 2016). Patterns in availability of potential eelpout prey with depth could be contributing to the observed differences in diet composition for eelpouts.

Carbon stable isotope signature is indicative of basal carbon source of a food chain and, in this particular system, also of across-shelf distance based on influence of terrestrial vs. marine derived carbon sources (Romanuk et al. 2011; Dunton et al. 2012; Bell et al. 2016). Though no differences in average $\delta^{13}C$ existed among the four eelpout species, $\delta^{13}C$ did change with increasing fish length (i.e., curvilinear relationship). While average carbon isotope values for all four eelpout species were similar, ranging from -22.84‰ for *L. polaris* to -22.03‰ for *L. adolfi*. Using cornerstone values of -24.0 ± 0.4‰ for particulate organic matter (POM) from marine phytoplankton, -21.6 ± 0.5‰ for ice associated production, and -28.8 ±3.2‰ for terrestrial matter (Dunton et al. 2012, Bell et al. 2016), the curvilinear relationship may indicate that differently sized eelpouts are a member of energy paths that build on different basal carbon sources. Eelpout length is influenced by depth, with larger fishes occupying greater depths, and, therefore, the observed increase in $\delta^{13}C$ values with length may be due to increasing distance offshore of larger fish, meaning their diet is more based on a marine carbon source. High $\delta^{13}C$ observed for the smallest *L. adolfi* sampled may indicate marine carbon sourced prey, and midsized *L. adolfi* is based more heavily on terrestrial sourced carbon than smaller or larger eelpouts.

Along-shelf changes (i.e., longitude) in diet composition were significant or not depending on region sampled. Along-shelf was not significant for eastern Beaufort Sea (2013 and 2014) fishes, but was significant for central Beaufort Sea (2012) fishes based on PERMANOVA. The differences in significance of longitude and eelpout diet are reflective of larger scale patterns in benthic invertebrate communities. Longitudinal patterns occur in benthic invertebrate communities in the western and central Beaufort Sea (Ravelo et al. 2015). These same along-shelf invertebrate community patterns could be reflected in eelpout diet across the central Beaufort Sea sampling area. The eastern Beaufort Sea is heavily influenced by organic matter input from the Mackenzie River (Bell et al. 2016). The vast influence of the Makenzie River plume may result in a more homogeneous benthic invertebrate population, and benthic invertebrate biomass and abundance do not have strong longitudinal trends in the eastern Beaufort Sea (Iken et al. 2016). The lack of strong along-shelf changes in invertebrate patterns is reflected in eelpout diet for the 2013 and 2014 sampling area. The lack of along-shelf diet differences was reflected in carbon isotope values in this study. Carbon isotope signatures indicate basal carbon source of an organism's diet (i.e., terrestrial vs. pelagic or sea ice associated production) (Iken et al. 2005; Gradinger 2009; Bell et al. 2016). Enrichment of stable carbon isotope signature with increasing TL is minimal, conserving basal carbon source signatures in higher TL consumers (Romanuk et al. 2011). The absence of a significant difference in carbon stable isotope values among eelpouts further supports that, at least in the eastern Beaufort Sea, there are no along-shelf differences in diet. Elsewhere, spatial differences in prey species distribution and composition drive diet composition of predatory fish (Hovde et al. 2002; Jaworski and Ragnarsson 2006). In the Arctic, along-shelf spatial variation in fish diet has been observed for Arctic Cod *Boreogadus* saida (Gray et al. 2017), and the invertebrate predator snow crab *Chionoecetes opilio* (Divine et al. 2015). For those eelpout species that exhibit generalist patterns in feeding, like *L. adolfi* and *L. seminudus*, eelpout diet is reflective of along-shelf homogeneous patterns in prey composition for the eastern Beaufort Sea.

Eelpout Morphology

Individual fish length was an important factor in determining composition of eelpout diets, and may contribute to limiting resource competition. Length is a factor in diet for other Arctic fish species like Arctic Cod *Boreogadus saida* (Gray et al. 2016) and sculpins in the Beaufort Sea (Gray et al. 2017), and a possible mechanism for avoidance of competition. In the present study, length was particularly important for determining diet composition for *L. adolfi* and *L. sagittarius*. For large eelpouts like *L. sagittarius*, larger total size increases mobility (Scharf et al. 2000), which is advantageous in deep habitats where prey can be scarce. Biomass and abundance of epibenthic biomass decrease with increasing depth in the eastern Beaufort Sea (Iken et al. 2016). *Lycodes adolfi* do not have the advantage of large size, and may use other means, like targeting different prey types, to thrive on the slope. *Lycodes adolfi* and *L. sagittarius* could compete for resources due to their overlapping distributions, but *L. adolfi* may exploit different sized prey than the larger *L. seminudus*. *Lycodes polaris* and *L. adolfi* exhibit similar size ranges, but *L. polaris* is on the shelf and *L. adolfi* is on the slope; potential interspecies competition is likely avoided by minimizing overlap in species distributions.

Fish length is positively related to fish gape size (Scharf et al. 2000), and as expected, this pattern was observed for the four eelpout species in this study. Though gape height and fish length were linearly related for all species, eelpout species had different gape sizes at the same length. *Lycodes seminudus* had the largest average gape size at a given length, followed by *L. sagittarius*, *L. adolfi*, and *L. polaris*. This has important ecological implications, because as gape height increases the size range of prey that can be consumed increases (Scharf et al. 2000). If this holds true for eelpouts, then a 300 mm *L. seminudus* should be able to consume larger size range of prey than a 300 mm *L. sagittarius*. Likewise, *L. adolfi* and *L. polaris* only reach maximum sizes of approximately 200 mm in length and, therefore, would not be capable of consuming the largest potential prey of 400 mm *L. sagittarius* or *L. seminudus* due to their relative smaller length and corresponding gape size. Though the size range of prey did increase with increasing fish length, multiple prey that appeared to be larger than maximum gape height were consumed. It should be noted that in this study prey length was measured, and not prey width, resulting in long prey like polychaetes having a disproportionate influence on the relationship between predator length and gape width. Not only does size of prey differ with increasing fish length, composition of prey also changed with increasing fish length. In this study, prey groups associated with greater fish length were polychaetes, brittle stars, and isopods. These were some of the largest sized prey observed. Large (> 240 mm) *L. seminudus* consumed large fish (total length; all ≥58 mm). In contrast, smaller eelpouts of all four species consumed small prey such as harpacticoid copepods, small cumaceans, and tanaids. Significant difference in diet composition between large (≥151 mm) and small (≤150 mm) *L. sagittarius* was supported from the cluster analysis. The difference in the type and size of prey consumed between large and small fish indicates an ontogenetic shift in diet. Intraspecific competition for resources is potentially minimized by smaller eelpouts consuming different types and sizes of prey than larger eelpouts in part because of differences in gape size at length. Likewise, interspecific competition is minimized by eelpouts of similar sizes, but different species, having differing gape sizes and therefore utilizing different prey.

Stomachs of all *Lycodes* species often contained highly digested prey items or were empty. This was observed in both small and large eelpouts. This may be due to small gape size and less mobility in small eelpouts, low metabolic needs associated with slow growth and cold temperatures, which reduce metabolic needs for larger eelpouts. Low growth rates, even when compared with other zoarcids, have been observed for Arctic *Lycodes* spp. (Hildebrandt et al. 2011). Long periods between feeding likely result in more stomachs with unidentifiable, heavily digested prey contents or empty stomachs. High numbers of empty stomachs have hindered previous attempts at characterizing diets of *L. seminudus* and other Arctic *Lycodes* in the eastern Norwegian Sea, including *L. frigidus, L. pallidus, L. eudipleurostictus*, and *L. esmarki* (Bjelland et al. 2000). Approximately 21% of *Lycodes* stomachs were excluded from the present study because they were empty or only contained parasites. Though empty stomachs provide information on the proportion of empty and full stomachs, they do not provide information on fish diet composition in studies that use only stomach contents. Using biomarkers like stable isotope or fatty acid signatures in conjunction with stomach content analyses, as in this study, should be considered when studying diet of this genus, as they are not reliant on having full stomachs.

Conclusions

Eelpout diet composition is diverse and composed primarily of benthic prey. Competition for resources among eelpouts is reduced by fishes of different species and lengths inhabiting different depths, and different eelpout species consuming different amounts of certain prey types due at least in part to differences in gape size. Stomach contents and stable isotope analyses used in this study provide information on diet and trophic ecology over different time scales. Using both methods provides an in-depth examination of eelpout diet ecology over a portion of the Beaufort Sea. *Lycodes* spp. are one part of the Arctic food web at trophic levels 3.9 – 4.4, and, like other fish species in the region, connect lower and upper trophic levels. They are consumed by other animals such as Greenland shark, bearded seals, and various seabirds (Finley and Evans 1983; Antonelis et al. 1994) and by Greenland shark in the north Atlantic (Yano et al. 2007). They may also serve as potential competitors with other fish species for prey resources and space. For example, *L. polaris* diet overlaps with Arctic Staghorn Sculpin *Gymnocanthus tricuspis* (Giraldo et al. 2016). These two species have similar spatial distributions in the central and western Beaufort Sea (Mecklenburg et al. 2011; Norcross et al. 2015), and, therefore, likely compete for prey. Understanding trophic ecology of Arctic marine species like eelpouts is becoming more important as managers and major agencies are moving towards ecosystem-based management practices that require an in-depth knowledge of all abundant species, not just those with commercial or cultural importance (Chambers and Dick 2005; Källgren et al. 2015). Additionally, climate change is expected to shift the main energy pathways from the benthos to the pelagic zone (Grebmeier et al. 2006). Eelpouts feed heavily on benthic organisms and could be disproportionately affected by a shift from a benthic to a more pelagic dominated food web.

References

Anderson, E.M. 1988. Studies on the Zoarcidae (Teleostei: Perciformes) of the Southern Hemisphere I. The Antarctic and Subantarctic regions. Biology of the Antarctic Seas XIX, Antarctic Research Series 47: 59–113.

Anderson, E.M. 1994. Systematic and osteology of the Zoarcidae (Teleostei: Perciformes). Ichthyological Bulletin, J.L.B. Smith Institute of Ichthyology, Grahamstown, South Africa, No. 60, 120 pg.

Anderson, E.M. and V.V. Fedorov. 2004. Family Zoarcidae Swainson 1893 – eelpouts. California Academy of Sciences Annotated Checklist of Fishes 34: 1-58.

Antonelis, G.A., S.R. Melin, Y. Bukhtiyarov. 1994. Early spring feeding habits of bearded seals (*Erignathus barbatus*) in the central Bering Sea. Arctic 47(1): 74–79.

Arndt, C.E., J. Berge , A. Brandt. 2005. Mouthpart-atlas of Arctic sympagic amphipods – Trophic niche separation based on mouthpart morphology and feeding ecology. Journal of Crustacean Biology 25(3): 401–412.

Atwell, L., K.A. Hobson, H.E. Welch. 1998. Biomagnification and bioaccumulation of mercury in an arctic marine food web: insights from stable nitrogen isotope analysis. Canadian Journal of Aquatic and Fisheries Sciences 55: 1114-1121.

Baker, R., A. Buckland, M. Sheaves. 2014. Fish gut content analysis: robust measures of diet composition. Fish and Fisheries 15(1): 170–177.

Balanov, A.A., O.Z. Badaev, V.V. Napazakov, V.I. Chuchukalo. 2006. Distribution and some biological features of *Lycodes raridens* (Zoarcidae) in the western part of the Bering Sea. Journal of Ichthyology 46(2): 148–155.

Balanov, A.A. and A.D. Kukhlevskii. 2011. Variation of coloration in *Lycodes yamatoi* Toyoshima, 1985 (Pisces: Zoarcidae) in the Northern Sea of Japan. Russian Journal of Marine Biology 37(6): 464–471.

Bell, L.E., B.A. Bluhm, K. Iken K. 2016. The influence of terrestrial organic matter in marine food webs of the Beaufort Sea shelf and slope. Marine Ecology Progress Series 550: 1–24.

Bjelland, O., O.A. Bergstad, J.E. Skjæraasen, K. Meland. 2000. Trophic ecology of deep-water fishes associated with the continental slope of the eastern Norwegian Sea. Sarsia 85: 101–117.

Blanchard, A.L., C.L. Parris, A.L. Knowlton, N.R. Wade. 2013. Benthic ecology of the northeastern Chukchi Sea. Part I. Environmental characteristics and macrofaunal community structure, 2008-2010. Continental Shelf Research 67: 52–66.

Bluhm, B.A. and R. Gradinger. 2008. Regional variability in food availability for arctic marine mammals. Ecological Applications 18(sp2): S77–S96.

Borgå, K., A.T. Fisk, P.F. Hoekstra, D.C.G. Muir. 2004. Biological and chemical factors of importance in the bioaccumulation and trophic transfer of persistent organochlorine contaminants in arctic marine food webs. Environmental Toxicology and Chemistry 23(10): 2367–2385.

Buchheister, A. and R.J. Latour. 2010. Turnover and fractionation of carbon and nitrogen stable isotopes in tissues of a migratory coastal predator, summer flounder (*Paralichthys dentatus*). Canadian Journal of Fisheries and Aquatic Sciences 67(3): 445–461.

Byrkjedal, I., G. Langhelle, T.L. Wenneck, R. Wienerroither. 2011. *Lycodes adolfi* Nielsen and Fossa, 1993 (Teleostei: Zoarcidae) found in the Arctic Ocean. Polar Biology 34: 465–467.

Carmack, E.C. and R.W. Macdonald. 2002. Oceanography of the Canadian shelf of the Beaufort Sea: a setting for marine life. Arctic 55(1): 29–45.

Chambers, C. and T.A. Dick. 2005. Trophic structure of one deep-sea benthic fish community in the eastern Canadian Arctic: application of food, parasites and multivariate analysis. Environmental Biology of Fishes 74: 365–378.

Chipps, S.R., J.E. Garvey. 2007. Assessment of diets and feeding patterns. *Analysis and interpretation of freshwater fisheries data*. Edited by CS Guy and Brown LM. Bethesda, Maryland: American Fisheries Society. 473–514 p.

Coad, B.W. and J.D. Reist. 2004. Annotated list of the Arctic Marine Fishes of Canada. Canadian manuscript report of Fisheries and Aquatic Sciences 2674: iv + 112 p.

Craig, P.C. 1984. Fish use of coastal waters of the Alaskan Beaufort Sea: a review. Transactions of the American Fisheries Society 113(3): 265–282.

Davis, M.B., R.G. Shaw, J.R. Etterson. 2005. Evolutionary responses to changing climate. Ecological Society of America 86(7): 1704–1714.

Dissen, J. 2015. Fatty acid profiles of Alaskan Arctic forage fishes: Evidence of regional and temporal variation. MS Thesis, School of Fisheries and Ocean Sciences, University of Alaska Fairbanks.

Divine, L.M., K. Iken, B.A. Bluhm. 2015. Regional benthic food web structure on the Alaska Beaufort Sea Shelf. Marine Ecology Progress Series 531: 15–32.

Dunn, M.R., A. Szabo, M.S. McVeagh, P.J. Smith. 2010. The diet of deep-water sharks and the benefits of using DNA identification of prey. Deep Sea Research Part I: Oceanographic Research Papers 57(7): 923–930.

Dunton, K.H., T. Weingartner, E.C. Carmack. 2006. The nearshore western Beaufort Sea ecosystem: circulation and importance of terrestrial carbon in arctic coastal food webs. Progress in Oceanography 71(2): 362–378.

Dunton, K.H. and S.V. Schonberg. 2012. Food web structure of the Alaska nearshore shelf and estuarine lagoons of the Beaufort Sea. Estuaries and Coast 35: 416–435.

Fahrig, L., G.R. Lilly, D.S. Miller. 1993. Predator stomachs as sampling tools for prey distribution: Atlantic Cod (*Gadus morhua*) and Capelin (*Mallotus villosus*). Canadian Journal of Fisheries and Aquatic Sciences 50(7): 1541–1547.

Fauchald, K., P.A. Jumars. 1979. The diet of worms: a study of polychaete feeding guilds. Oceanography and Marine Biology an Annual Review 17: 193–284.

Finley, K.J. and C.R Evans CR. 1983. Summer diet of the Bearded Seal (*Eriganthus barbatus*) in the Canadian High Arctic. Arctic 36(1): 82–89.

Fox, L.R. and P. A. Marrow. 1981. Specialization: species property or local phenomenon? Science 22(4,485): 887-893.

Frothingham, A.L. In progress. Age composition and growth rates of Arctic Cod (*Boreogadus saida*) from the Beaufort and Chukchi seas. M.S. thesis, University of Alaska Fairbanks, Fairbanks, AK.

Gillispie, J.G., R.L. Smith, E. Barbour, W.E. Barber. 1997. Distribution, abundance, and growth of Arctic Cod in the northeastern Chukchi Sea. American Fisheries Society Symposium 19: 81–89.

Giraldo, C., A. Stasko, E.S. Choy, B. Rosenberg, A. Majewski, M. Power, H. Swanson, L. Loseto, J.D. Reist. 2016. Trophic variability of Arctic fishes in the Canadian Beaufort Sea: a fatty acids and stable isotopes approach. Polar Biology 37(7): 1267–1282.

Gradinger, R. 2009. Sea-ice algae: Major contributors to primary production and algal biomass in the Chukchi and Beaufort seas during May/June 2002. Deep Sea Research Part II: Topical Studies in Oceanography 56(17): 1201–121.

Gray, B.P., B.L. Norcross, A.H. Beaudreau, A.L. Blanchard, A.C. Seitz. 2017. Food habits of Arctic staghorn sculpin (*Gymnocanthus tricuspis*) and shorthorn sculpin (*Myoxocephalus scorpius*) in the northeastern Chukchi and western Beaufort Sea. Deep-Sea Research II, http://dx.doi.org/10.1016/j.dsr2.2016.05.013i .

Gray, B.P., B.L. Norcross, A.L. Blanchard, A.H. Beaudreau, A.C. Seitz. 2016. Variability in the summer diets of juvenile polar cod (*Boreogadus saida*) in the northeastern Chukchi and western Beaufort Seas. Polar Research 39: 1069 -1080, doi: 10.1007/s00300-015-1796-7.

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLaughlin, and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. Science 311(5766): 1461–1464.

Grebmeier, J.M. 2012. Shifting patterns of life in the Pacific Arctic and sub-Arctic seas. Annual review of Marine Science 4: 63–78.

Guerra-Garcia, J.M., J.M. Tierno de Figueroa, C. Navarro-Barranco, M. Ros, J.E. Sanchez-Moyano, J. Moreira. 2014. Dietary analysis of the marine Amphipoda (Crustacea: Peracardia) from the Iberian Peninsula. Journal of Sea Research 85: 508–517.

Hildebrandt, N., M. Bergmann, K. Rainer. 2011. Longevity and growth efficiency of two deep-dwelling zoarcids and comparison with eight other zoarcids from different climatic regions. Polar Biology 34: 1523–1533.

Hobson, K.A., A. Fisk, N. Karnovsky, M. Holst, J.M. Gagnon, M. Fortier. 2002. A stable isotope (δ^{13}C, δ^{15}N) model for the North Water foodweb: implications for evaluating trophodynamics and the flow of energy and contaminants. Deep Sea Research Part II 49: 5131–5150.

Hovde, S.C., O.T. Albert, E.M. Nilssen. 2002. Spatial, seasonal and ontogenetic variation in diet of northeast Arctic Greenland Halibut (*Reinhardtius hippoglossoides*). ICES Journal of Marine Science 59: 421–437.

Hyslop, E.J. 1980. Stomach contents analysis—a review of methods and their application. Journal of Fish Biology 17(4): 411–429.

Iken, K., B.A. Bluhm, R. Gradinger. 2005. Food web structure in the high Arctic Canada Basin: evidence from $\delta^{13}C$ and $\delta^{15}N$ analysis. Polar Biology 28: 2238–249.

Iken, K., B. Bluhm, L. Bell.2016. *Epibenthos*. in Norcross, B.L., S.J. Apsens, L.E. Bell, B.A. Bluhm, J.N. Dissen, L.E. Edenfield, A. Frothingham, B.P. Gray, S.M. Hardy, B.A. Holladay, R.R. Hopcroft, K.B. Iken, C.A. Smoot, K.L. Walker, E.D. Wood. June 2016. US-Canada Transboundary fish and lower trophic level communities: abundance, distribution, habitat, and community analysis. Draft Final Report for BOEM Agreement Number M12AC00011. University of Alaska Fairbanks. 435 pp + appendices

IPCC. 2014. Summary for policymakers. In: Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectorial aspects. Contribution of working group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [C.B. Field, V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, B.M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1–32.

Jarman, S.N., B.E. Deagle, N.J. Gales. 2004. Group-specific polymerase chain reaction for DNA-based analysis of species diversity and identity in dietary samples. Molecular Ecology 13: 1313–1322.

Jaworski, A. and S.A. Ragnarsson. 2006. Feeding habits of demersal fish in Icelandic waters: a multivariate approach. ICES Journal of Marine Science 63: 1682–1694.

Källgren, E., T. Pedersen, E. Nilssen. 2015. Food resource partitioning between three sympatric fish species in Porsangerfjord, Norway. Polar Biology 38: 583–589.

Kelly, J.F. 2000. Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. Canadian Journal of Zoology 78(1): 1–27.

Linden, O. 2016. Impacts and effects of ocean warming on Arctic ecosystems and species. In: Laffoley D, and Baxter JM (editors). 2016. Explaining ocean warming: Causes, scale, effects and consequences. Full report. Gland, Switzerland: IUCN. pp. 321–335.

Love, M.S. 2011. *Certainly More Than You Would Want to Know About the Fishes of the Pacific Coast: A Postmodern Experience.* Santa Barbra, CA: Really Big Press.

Lowry, L.F. and K.L. Frost. 1981. Distribution, growth, and foods of Arctic Cod (*Boreogadus saida*) in the Bering, Chukchi, and Beaufort seas. Canadian Field-Naturalist 95: 186–191.

Lowry, L.F., K.J. Frost, J.J Burns. 1980. Feeding of bearded seals in the Bering and Chukchi Seas and trophic interaction with pacific walruses. Arctic 33(2): 330–342.

MacDonald, J.S., R.H. Green. 1983. Redundancy of variables used to describe importance of prey species in fish diets. Canadian Journal of Fisheries and Aquatic Sciences 40(5): 635–637.

Marsh, J.M., N. Hillgruber, R.J. Foy. 2012. Temporal and ontogenetic variability in trophic role of four groundfish species – Walleye Pollock, Pacific Cod, Arrowtooth Flounder, and Pacific Halibut – around Kodiak Island in the Gulf of Alaska. Transactions of the American Fisheries Society 141(2): 468-486.

McAllister, D.E., M.E. Anderson, J.G. Hunter. 1981. Deep-water eelpouts, Zoarcidae, from Arctic Canada and Alaska. Canadian Journal of Fisheries and Aquatic Science 38: 821–839.

Mecklenburg, C.W., T.A. Mecklenburg, L.K. Thorsteinson. 2002. *Fishes of Alaska.* Bethesda, MD: American Fisheries Society.

Mecklenburg, C.W., P.R. Møller, D. Steinke. 2011. Biodiversity of arctic marine fishes: taxonomy and zoogeography. Marine Biodiversity 41(1): 109–140.

Mecklenburg, C.W., I. Byrkjedal, O.V. Karamushko, P.R. Møller. 2014. Atlantic fishes in the Chukchi Borderland. Marine Biodiversity 44(1): 127–150.

Møller, P.R. and P. Gravlund. 2003. Phylogeny of the eelpout genus *Lycodes* (Pisces, Zoarcidae) as inferred from mitochondrial cytochrome b and 12S rDNA. Molecular Phylogenetics and Evolution 26(3): 369–388.

Møller, P.R. and O.A. Jørgensen. 2000. Distribution and abundance of eelpouts (Pisces, Zoaridae) off west Greenland. Sarsia 85: 23–48.

Nephin, J., S.K. Juniper, P. Archambault. 2014. Diversity, abundance and community structure of benthic macro- and megafauna on the Beaufort shelf and slope. PLoS ONE 9(7): e101556.

Norcross, B.L., S.J. Apsens, L.E. Bell, B.A. Bluhm, J.N. Dissen, L.E. Edenfield, A. Frothingham, B.P. Gray, S.M. Hardy, B.A. Holladay, R.R. Hopcroft, K.B. Iken, C.A. Smoot, K.L. Walker, E.D. Wood. June 2016. US-Canada Transboundary fish and lower trophic level communities: abundance, distribution, habitat, and community analysis. Draft Final Report for BOEM Agreement Number M12AC00011. University of Alaska Fairbanks. 435 pp + appendices.

Norcross, B.L., L. Horstmann-Dehn, B.A. Holladay, L.E. Edenfield, S.S. Carroll. 2015. Trophic Links: Forage fish, their prey, and ice seals in the northeast Chukchi Sea. University of Alaska Fairbanks, Institute of Marine Science, Coastal Marine Institute. Final Report 159 p. OCS Study BOEM 2013–00118.

NPFMC. 2009. Fisheries Management Plan for Fish Resources of the Arctic Management Area. North Pacific Fishery Management Council. 605 West 4th Ave, Suite 306, Anchorage, AK.

Obbard, R.W., S. Sadri, Y.Q. Wong, A.A. Khitun, I. Baker, R.C. Thompson. 2014. Global warming releases microplastic legacy frozen in Arctic sea ice. Earths Future 2(6): 3150–320.

Paredes, R., R.A. Obren, R.M. Suryan, D.B. Irons, D.D. Roby, A.M.A. Harding, R.C. Young, K. Benoit-Bird, C. Ladd, H. Renner, S. Heppell, R.A. Phillips, A. Kitaysky. 2014. Foraging responses of Black-Legged kittiwakes to prolonged food-shortages around colonies on the Bering Sea shelf. PLoS ONE 9(3): e92520.

Parish, J.D. 1975. Marine trophic interactions by dynamic simulation of fish species. Fish Bulletin 73(4): 695–716.

Phillips, R.A., M.K. Petersen, K. Lilliendahl, J. Solmundsson, K.C. Hamer, C.J. Camphuysen, B. Zonfrillo. 1999. Diet of northern fulmar *Fulmarus glacialis*: reliance on commercial fisheries? Marine Biology 135: 159–170.

Pickart, R.S., M.A. Spall, G.W.K. Moore, T.J. Weingartner, R.A. Woodgate, K. Aagaard, K. Shimada K. 2011. Upwelling in the Alaskan Beaufort Sea: Atmospheric forcing and local versus non-local response. Progress in Oceanography 88(1-4): 78–100.

Pinkas, L., M.S. Oliphant, I.L. Iverson. 1971. Food habits of albacore, bluefin tuna, and bonito in California waters: State of California. Vol. 152. United States: State of California, Department of Fish and Game.

Pinnegar, J.K. and N.V.C. Polunin. 1999. Differential fractionation of δ13C and δ15N among fish tissues: implications for the study of trophic interactions. Functional Ecology 13(2): 225–231.

Poltermann, M. 2001. Arctic sea ice as feeding grounds for amphipods – food sources and strategies. Polar Biology 24(2): 89–96.

Quakenbush, L.T., R.S. Suydam, A.L. Bryan, L.F. Lowry, K.J. Frost, B.A. Mahoney. 2015. Diet of beluga whales, Delphinapterus leucas, in Alaska from stomach contents, March – November. Marine Fisheries Review 77: 70–84.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Australia. https://www.R-project.org/

Rand, K.M. and E.A. Logerwell. 2011. The first demersal trawl survey of benthic fish and invertebrates in the Beaufort Sea since the late 1970’s. Polar Biology 34(4): 475–488.

Ravelo, A.M., B. Konar, B.A. Bluhm. 2015. Spatial variability of epibenthic communities on the Alaska Beaufort shelf. Polar Biology 38(11): 1783–1804.

Rochman, C.M., E. Hoh, T. Kurobe, S.J. Teh. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. Scientific Reports 3: 3263.

Romanuk, T.N., A. Hayward, J.A. Hutchings. 2011. Trophic level scales positively with body size in fishes. Global Ecology and Biogeography 20(2): 231–240.

Roy, V., K. Iken,P. Archambault. 2015. Regional Variability of Megabenthic Community Structure across the Canadian Arctic. *Arctic*, *68*(2): 180.

Sakano, H., E. Fujiwara, S. Nohara, H. Ueda. 2005. Estimation of nitrogen stable isotope turnover rate of *Oncorhynchus nerka*. Environmental Biology of Fishes 72(1): 13–18.

Scharf, F.S., F. Juanes, R.A. Rountree. 2000. Predator size-prey size relationships of marine fish predators: interspecific variation and effects of ontogeny and body size on trophic-niche breadth. Marine Ecology Progress Series 208: 229–248.

Somero, G.N. 2009. Physiology of climate change: how potentials for acclimatization and genetic adaptation will determine ‘winners’ and ‘loosers’. Experimental Biology 213: 912–920.

Tieszen, L.L., T.W. Boutton, K.G. Tesdahl, N.A. Slade. 1983. Fractionation and turnover of stable carbon isotopes in animal tissues: Implications for delta ^{13}C analysis of diet. Oecologia 57(1–2): 32–37.

Turanov, S.V., Y.P. Kartavtsev, Y.H. Lee, D. Jeong. 2016. Molecular phylogenetic reconstruction and taxonomic investigation of eelpouts (Cottoidei: Zoarcles) based on Co-1 and Cyt-b mitochondrial genes. Mitochondrial DNA part A DOI: 10.3109/24701394.2016.1155117

Vander Zanden, M.J. and J.B. Rasmussen. 1999. Primary consumer δ^{15}N and δ^{13}C and the trophic position of aquatic consumers. Ecology 80: 1395–1401.

Ward, R.D., R. Hanner, P.D.N. Hebert. 2009. The campaign to DNA barcode all fishes, FISH-BOL. Review Paper, Journal of Fish Biology 74: 329–356.

Ward, R.D., T.S. Zemlak, B.H. Innes, P.R. Last, P.D.N. Hebert. 2005. DNA barcoding Australia's fish species. Philosophical Transactions of the Royal Society B 360: 1847–1857.

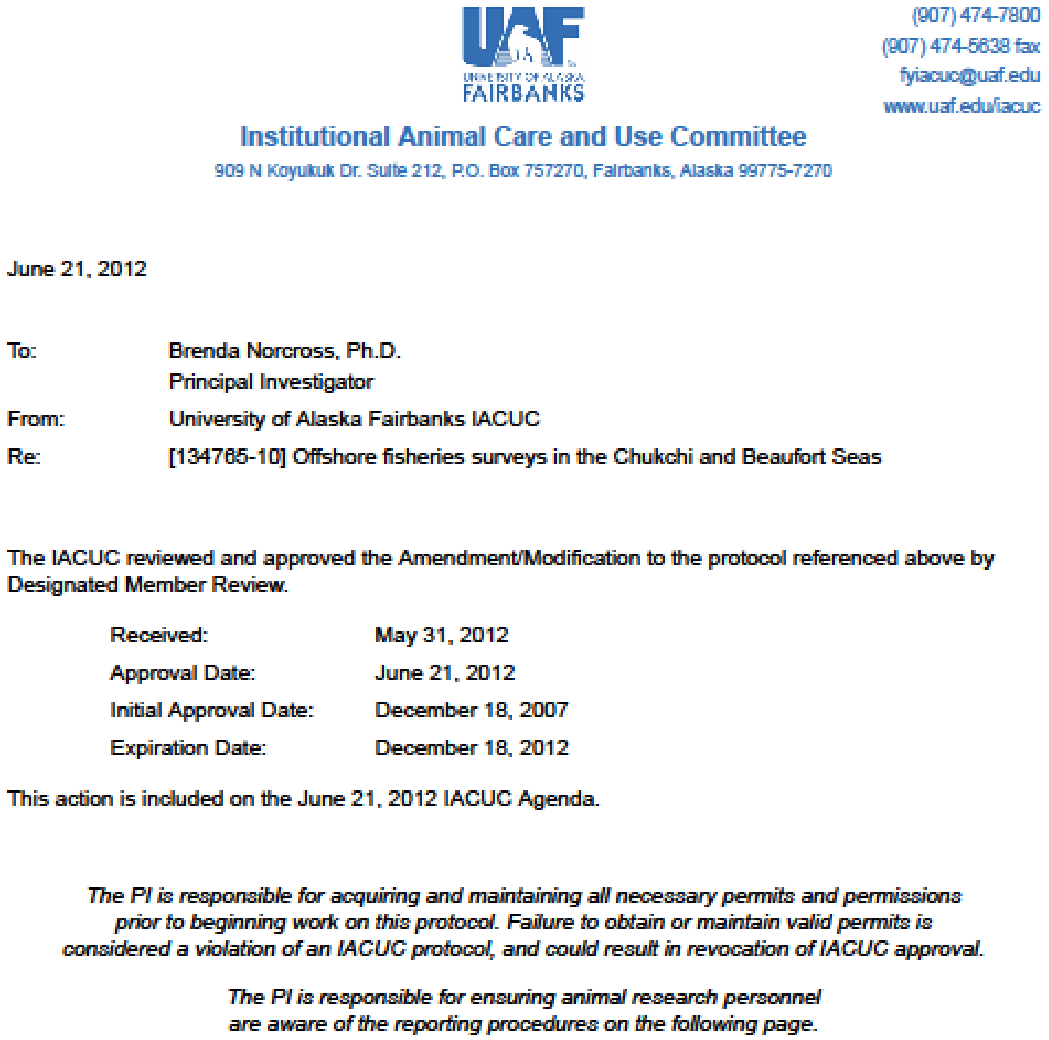
Weidel, B.C., S.R. Carpenter, J.F. Kitchell, M.J. Vander Zanden. 2011. Rates and components of carbon turnover in fish muscle: insights from bioenergetics models and a whole-lake ^{13}C addition. Canadian Journal of Fisheries and Aquatic Sciences 68: 387–399.

Weidner, T.A., A.C. Hirons, A. Leavitt, D.W. Kerstetter. 2017. Combined gut-content and stable isotope trophic analysis of the pelagic stingray *Pteroplaytrygon violacea* (Bonaparte, 1832) diet from the western North Atlantic Ocean. Journal of Applied Ichthyology. 33: 386–394.

Whitehouse, G.A., T.W. Buckley, S.L. Danielson. 2017. Diet compositions and trophic guild structure of the eastern Chukchi Sea demersal fish community. Deep-Sea Research Part II: Topical Studies in Oceanography 135: 95–1110.

Yano, K., J.D. Stevens, L.J.V. Compagno. 2007. Distribution, reproduction and feeding of the Greenland shark *Somniosus* (*Somniosus*) *microcephalus*, with notes on two other sleeper sharks, *Somniosus* (*Somniosus*) *pacificus* and *Somniosus* (*Somniosus*) *antarcticus*. Journal of Fish Biology 70: 374–390.

Appendix A
2013 IACUC #134765-12 Approval



UNIVERSITY OF ALASKA
FAIRBANKS

(907) 474-7800
(907) 474-5638 fax
fyiacuc@uaf.edu
www.uaf.edu/iacuc

Institutional Animal Care and Use Committee
909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

June 21, 2012

To:	Brenda Norcross, Ph.D. Principal Investigator
From:	University of Alaska Fairbanks IACUC
Re:	[134765-10] Offshore fisheries surveys in the Chukchi and Beaufort Seas

The IACUC reviewed and approved the Amendment/Modification to the protocol referenced above by Designated Member Review.

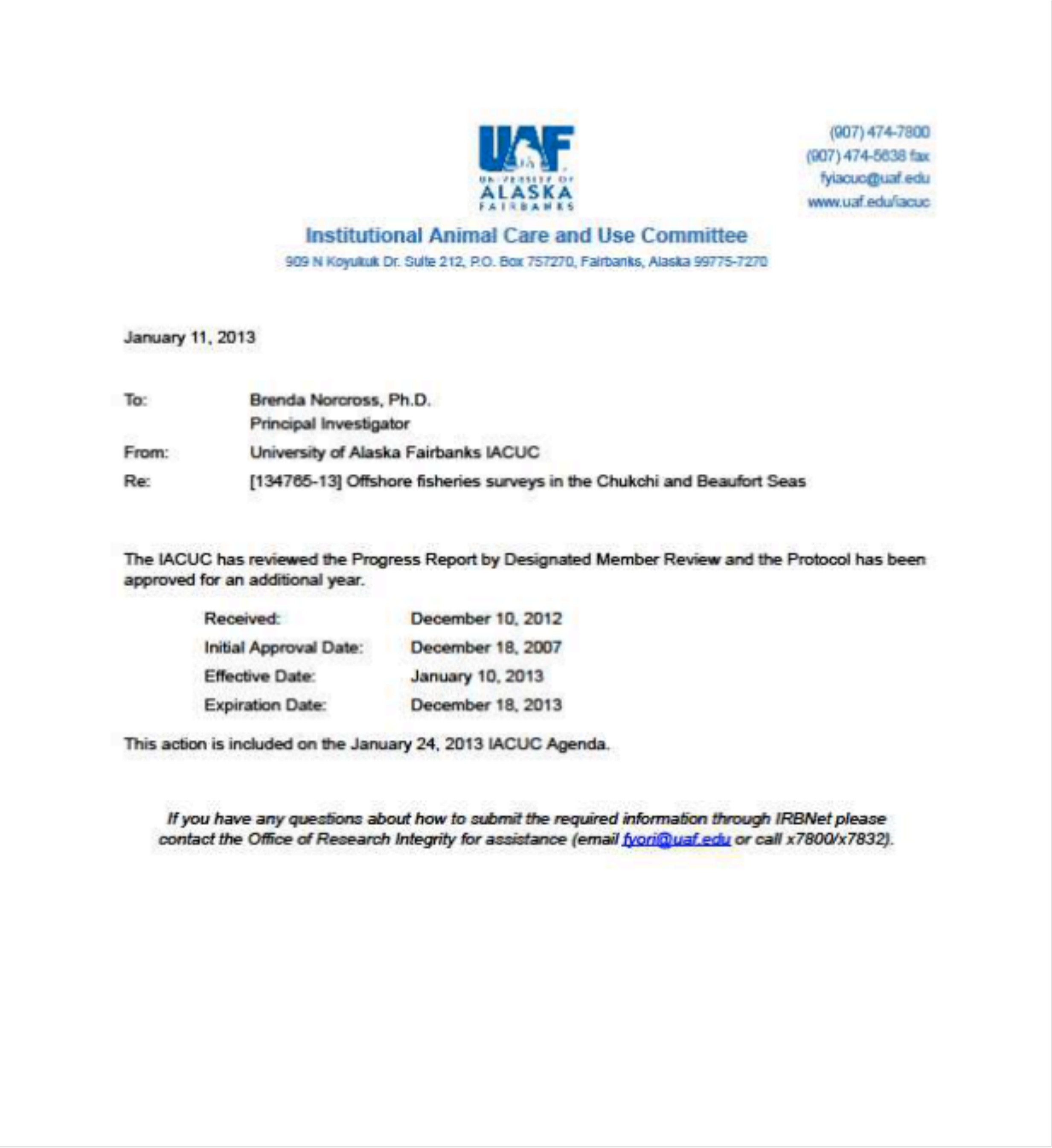
Received:	May 31, 2012
Approval Date:	June 21, 2012
Initial Approval Date:	December 18, 2007
Expiration Date:	December 18, 2012

This action is included on the June 21, 2012 IACUC Agenda.

The PI is responsible for acquiring and maintaining all necessary permits and permissions prior to beginning work on this protocol. Failure to obtain or maintain valid permits is considered a violation of an IACUC protocol, and could result in revocation of IACUC approval.

The PI is responsible for ensuring animal research personnel are aware of the reporting procedures on the following page.

Appendix B
2014 IACUC #134765-13
Approval



UAF
UNIVERSITY OF ALASKA FAIRBANKS

(907) 474-7800
(907) 474-5638 fax
fyiacuc@uaf.edu
www.uaf.edu/iacuc

Institutional Animal Care and Use Committee
909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

January 11, 2013

To:	Brenda Norcross, Ph.D. Principal Investigator
From:	University of Alaska Fairbanks IACUC
Re:	[134765-13] Offshore fisheries surveys in the Chukchi and Beaufort Seas

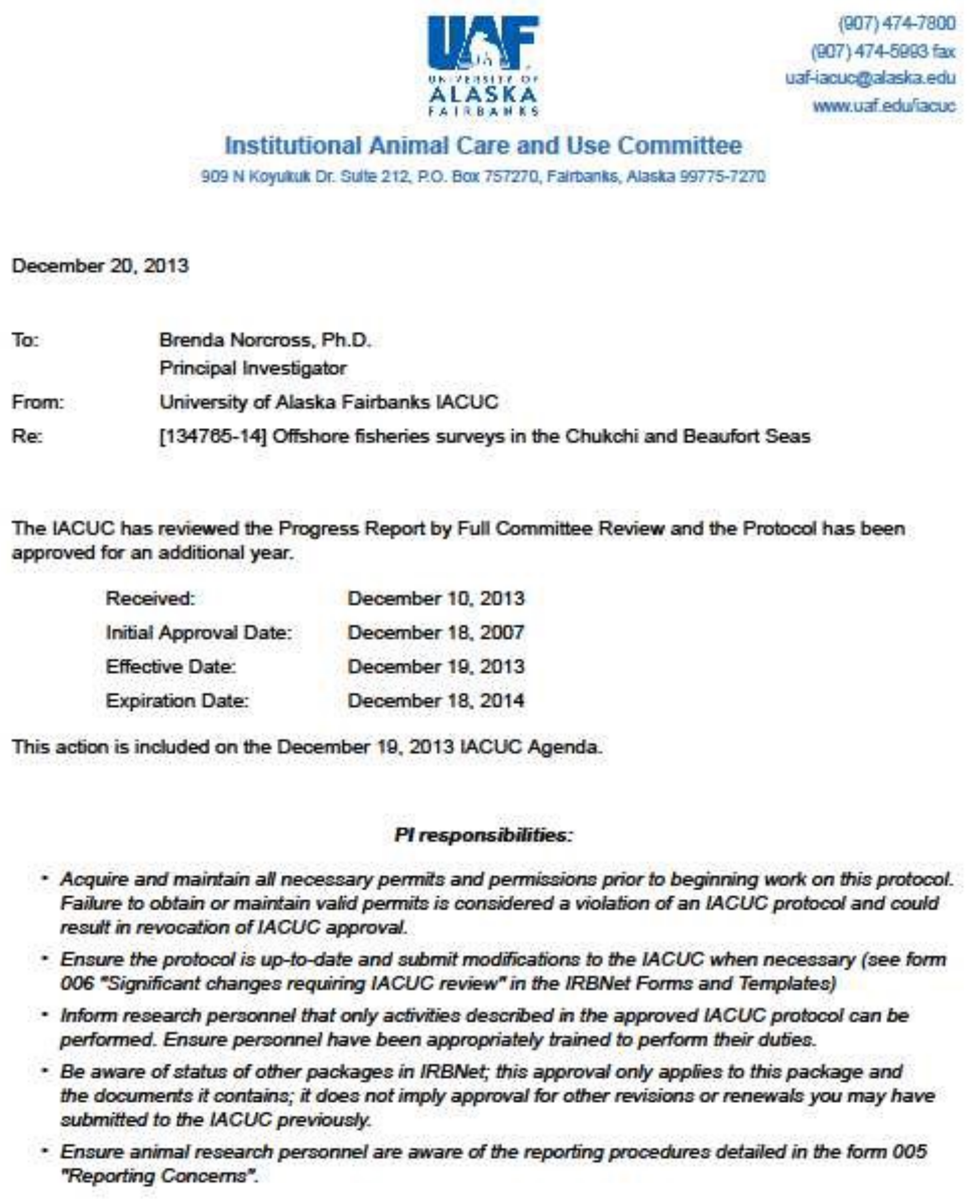
The IACUC has reviewed the Progress Report by Designated Member Review and the Protocol has been approved for an additional year.

Received:	December 10, 2012
Initial Approval Date:	December 18, 2007
Effective Date:	January 10, 2013
Expiration Date:	December 18, 2013

This action is included on the January 24, 2013 IACUC Agenda.

If you have any questions about how to submit the required information through IRBNet please contact the Office of Research Integrity for assistance (email fyori@uaf.edu or call x7800/x7832).

Appendix C
2015 IACUC #134765-14 approval



UAF
UNIVERSITY OF ALASKA FAIRBANKS

(907) 474-7800
(907) 474-5993 fax
uaf-iacuc@alaska.edu
www.uaf.edu/iacuc

Institutional Animal Care and Use Committee
909 N Koyukuk Dr. Suite 212, P.O. Box 757270, Fairbanks, Alaska 99775-7270

December 20, 2013

To: Brenda Norcross, Ph.D.
Principal Investigator
From: University of Alaska Fairbanks IACUC
Re: [134765-14] Offshore fisheries surveys in the Chukchi and Beaufort Seas

The IACUC has reviewed the Progress Report by Full Committee Review and the Protocol has been approved for an additional year.

Received:	December 10, 2013
Initial Approval Date:	December 18, 2007
Effective Date:	December 19, 2013
Expiration Date:	December 18, 2014

This action is included on the December 19, 2013 IACUC Agenda.

PI responsibilities:

- *Acquire and maintain all necessary permits and permissions prior to beginning work on this protocol. Failure to obtain or maintain valid permits is considered a violation of an IACUC protocol and could result in revocation of IACUC approval.*
- *Ensure the protocol is up-to-date and submit modifications to the IACUC when necessary (see form 006 "Significant changes requiring IACUC review" in the IRBNet Forms and Templates)*
- *Inform research personnel that only activities described in the approved IACUC protocol can be performed. Ensure personnel have been appropriately trained to perform their duties.*
- *Be aware of status of other packages in IRBNet; this approval only applies to this package and the documents it contains; it does not imply approval for other revisions or renewals you may have submitted to the IACUC previously.*
- *Ensure animal research personnel are aware of the reporting procedures detailed in the form 005 "Reporting Concerns".*

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix I

Food Web Tables

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

Appendix I Table 1. Station locations and types of isotope samples collected for this study. Stations associated with this project were arranged in transects perpendicular to shore, and have been listed as such here, but transects were pooled for analysis as follows: Colville Plume [CP] region (2012), Camden Bay [CB], Outer Mackenzie Plume [OMP], and Inner Mackenzie Plume [IMP] regions (all 2013). The CB and part of OMP regions (A1 and TBS) were resampled in 2014. Additional sPOM samples were collected during the 2013 Canada BREA program (indicated with *), and ice POM samples were collected from sea ice cores outside of Barrow in 2014. Depths listed were target depths, actual sampling depth for bottom trawls was 8.7% less than target depth on average.

Station information							Isotope samples collected				
Year	Region	Transect	Depth (m)	Latitude °N	Longitude °W	Date sampled	Water	pPOM	sPOM	Ice POM	Fauna
2012	**CP**	B2	20	71.0732	-151.1000	28-Sep		x			x
			50	71.1708	-151.1000	28-Sep		x	x		x
			100	71.3261	-151.1000	28-Sep		x			x
			200	71.3502	-151.1000	28-Sep		x			x
			350	71.4167	-151.1000	27-Sep		x			x
			500	71.4297	-151.1000	26-Sep		x			x
			1000	71.4574	-151.1000	26-Sep		x			x
		BX	200	71.2888	-150.6500	29-Sep		x			x
			350	71.3044	-150.6500	29-Sep		x			x
			500	71.3232	-150.6500	29-Sep		x			x
			1000	71.3737	-150.6500	30-Sep		x			x
		B1	20	70.7424	-150.1000	21-Sep		x	x		x
			50	71.0282	-150.1000	21-Sep		x	x		x
			100	71.2167	-150.1000	22-Sep		x			x
			200	71.2301	-150.1000	22-Sep		x	x		x
			350	71.2442	-150.1000	23-Sep			x		x
			500	71.2526	-150.1000	24-Sep		x	x		x
			1000	71.3058	-150.1000	25-Sep		x	x		x
2013	**CB**	A6	20	70.4259	-146.1083	13-Aug	x	x	x		x
			37	70.5500	-146.1006	13-Aug	x	x	x		x
			50	70.6755	-146.0956	13-Aug	x	x	x		x
			100	70.8170	-146.0614	14-Aug	x	x	x		x
			200	70.8902	-146.0812	14-Aug	x	x	x		x
			350	70.9297	-146.0694	15-Aug	x	x			x
			500	70.9704	-146.1313	15-Aug	x	x			x
			750	70.9717	-146.0272	16-Aug	x	x			x
			1000	71.0179	-146.1322	17-Aug	x	x			x
	OMP	A2	10	69.9246	-142.2309	20-Aug	x	x	x		
			40	70.1218	-142.2571	20-Aug	x	x	x		
			100	70.4857	-141.9412	19-Aug			x		
			200	70.4998	-141.9109	19-Aug	x	x	x		
			500	70.5617	-141.9846	19-Aug	x	x			
			750	70.6213	-141.9464	18-Aug	x	x			
			1000	70.6314	-142.0687	18-Aug	x	x			

Appendix I Table 1 continued.

Station information							Isotope samples collected				
Year	**Region**	**Transect**	**Depth (m)**	**Latitude °N**	**Longitude °W**	**Date sampled**	**Water**	**pPOM**	**sPOM**	**Ice POM**	**Fauna**
2013	**OMP cont.**	A1	20	69.7200	-141.1412	20-Aug	x	x	x		x
			50	70.0398	-141.0787	20-Aug	x	x	x		x
			100	70.3379	-141.1176	22-Aug	x	x	x		x
			200	70.3690	-141.1852	22-Aug					x
			350	70.4076	-141.0504	22-Aug	x	x			x
			350	70.4112	-141.0610	5-Sep			x		x
			500	70.4707	-141.0151	22-Aug	x	x			x
			750	70.5321	-141.0347	23-Aug	x	x			x
			750	70.5382	-141.0275	6-Sep			x		x
			1000	70.6027	-141.0407	23-Aug	x	x			x
		TBS	50	70.1562	-140.3967	26-Aug	x	x	x		x
			100	70.2414	-140.2628	25-Aug	x	x	x		x
			200	70.2685	-140.2974	25-Aug	x	x	x		x
			350	70.3449	-140.3903	25-Aug	x	x			x
			500	70.4151	-140.3560	24-Aug	x	x			x
			750	70.5632	-140.4501	24-Aug	x	x			x
			1000	70.5983	-140.3735	24-Aug	x	x			x
	IMP	MAC	50	69.4646	-137.6565	27-Aug	x	x	x		x
			100	69.6281	-137.9703	27-Aug	x	x	x		x
			200	69.8306	-138.4046	26-Aug	x	x	x		x
			500	70.2976	-139.2596	31-Aug	x	x			x
			750	70.4403	-139.5208	31-Aug	x				
			1000	70.5920	-139.7815	30-Aug	x	x			x
		GRY	20	69.7014	-136.6746	27-Aug	x	x	x		x
			50	69.8775	-137.2199	27-Aug	x	x	x		x
			100	70.0920	-137.7705	28-Aug	x	x			x
			200	70.1427	-137.9840	28-Aug	x	x	x		x
			350	70.2532	-138.3628	28-Aug	x	x			x
			350	70.2594	-138.3823	29-Aug			x		x
			500	70.2983	-138.4929	29-Aug	x	x			x
			750	70.4404	-138.9493	29-Aug	x	x			x
			750	70.4409	-138.9866	30-Aug			x		x
			1000	70.5241	-139.2267	30-Aug	x	x			x
		-	1200	70.5980	-138.3180	9-Sep			x		
2014		-	sea ice	71.3815	-156.5243	8-Apr				x	

Appendix I Table 2. Mean $\delta^{13}C$ and $\delta^{15}N$ values (‰) of pPOM, sPOM, and sampled taxa by region and depth group (shelf or slope). Trophic positions (TP) were calculated using the primary consumer baseline. Definitions of feeding guild abbreviations described in methods, and references for each taxon are superscripted and listed below as a footnote. N represents number of samples analyzed in each category Data are from 2012 and 2013.

	Region	**CP**								**CB**							
		Shelf				**Slope**				**Shelf**				**Slope**			
Species/taxon	**Feeding guild**	**$\delta^{13}C \pm$ sd**	**$\delta^{15}N \pm$ sd**	**N**	**TP**	**$\delta^{13}C \pm$ sd**	**$\delta^{15}N \pm$ sd**	**N**	**TP**	**$\delta^{13}C \pm$ sd**	**$\delta^{15}N \pm$ sd**	**N**	**TP**	**$\delta^{13}C \pm$ sd**	**$\delta^{15}N \pm$ sd**	**N**	**TP**
pPOM		-25.2 ± 0.5	6.1 ± 1.7	18		-25.6 ± 0.5	6.3 ± 1.3	33		-26.3 ± 1.0	5.8 ± 1.9	12		-26.9 ± 0.9	4.7 ± 1.0	15	
sPOM		-25.4 ± 0.6	4.9 ± 1.6	4		-24.3 ± 0.5	5.4 ± 0.7	7		-21.6 ± 3.9	4.7 ± 1.5	5		-24.5	4.0	1	
ANNELIDA																	
Clitellata																	
Hirudinea	Pred[1]																
Echiura																	
Hamingia arctica	SSDF[2]					-16.7 ± 0.9	14.1 ± 0.9	13	**2.0**								
Polychaeta																	
Nephtys sp.	Pred[1]	-18.9 ± 0.5	13.3 ± 1.6	10	**2.1**	-17.9 ± 0.9	15.3 ± 1.2	6	**2.4**	-20.4 ± 0.4	14.8 ± 1.1	6	**4.3**	-19.6 ± 0.4	16.6 ± 0.8	11	**3.8**
Polynoidae spp.	Pred[1]	-19.2 ± 0.5	13.4 ± 1.2	10	**2.1**	-18.7 ± 0.7	16.0 ± 1.4	14	**2.6**	-20.6 ± 1.0	14.6 ± 1.5	9	**4.3**	-20.5 ± 0.5	16.8 ± 1.1	10	**3.8**
ARTHROPODA																	
Amphipoda																	
Anonyx sp.	Pred[1]	-20.3 ± 0.6	15.0 ± 1.2	16	**2.5**	-20.4 ± 0.8	16.4 ± 1.0	7	**2.7**	-21.0 ± 0.4	13.1 ± 1.9	9	**3.8**	-20.6 ± 0.4	15.7 ± 2.7	10	**3.5**
Themisto libellula	pPred[3]	-22.3 ± 0.7	12.2 ± 0.6	12	**1.7**	-22.1 ± 1.1	12.2 ± 0.7	28	**1.5**	-25.1 ± 0.8	10.0 ± 1.0	9	**2.9**	-24.6 ± 0.9	11.1 ± 1.4	12	**2.2**
Calanoida																	
Calanus glacialis	pFilt[4]	-22.4 ± 0.6	11.2 ± 0.6	15	**1.4**	-21.4 ± 0.7	11.5 ± 0.6	21	**1.3**								
Calanus hyperboreus	pFilt[4]									-23.6 ± 0.8	9.4 ± 1.4	7	**2.7**	-23.7 ± 0.6	10.0 ± 0.8	9	**1.8**
Neocalanus cristatus	pFilt[4]					-22.5 ± 0.4	8.6 ± 0.9	12	**0.4**								
Cumacea																	
Diastylis sp.	SDF[1,2]	-23.1 ± 0.8	8.1 ± 1.0	11	**0.5**	-22.4	8.6	1	**0.4**	-23.6 ± 0.7	5.6 ± 0.9	10	**1.6**	-24.0 ± 0.7	6.2 ± 2.0	4	**0.7**
Decapoda																	
Chionoecetes opilio	Pred[1]					-19.1 ± 0.5	15.7 ± 0.6	14	**2.5**					-18.1	14.6	1	**3.2**
Eualus gaimardii	Pred[1]	-19.7 ± 0.9	14.3 ± 0.7	15	**2.3**	-18.3 ± 1.2	16.0 ± 1.1	23	**2.6**	-19.6 ± 0.5	12.7 ± 0.7	8	**3.7**	-17.7 ± 1.6	15.3 ± 1.2	10	**3.4**
Sabinea septemcarinata	Pred[5]									-18.8 ± 0.5	14.7 ± 0.6	12	**4.3**	-18.4 ± 0.5	15.8 ± 0.8	6	**3.5**
Isopoda																	
Saduria sabini	Pred[6]	-20.2 ± 0.3	13.6 ± 0.1	3	**2.1**	-19.5 ± 0.3	16.9 ± 0.8	9	**2.8**	-22.0 ± 0.4	9.9 ± 1.7	3	**2.9**	-20.5 ± 0.9	13.0 ± 3.1	9	**2.7**
Pycnogonida																	
Pycnogonida	Pred[1]													-21.3 ± 0.2	14.9 ± 0.6	3	**3.3**
CHAETOGNATHA																	
Parasagitta elegans	pPred[7]	-20.0 ± 0.8	15.4 ± 0.6	9	**2.7**	-20.3 ± 0.9	14.9 ± 0.5	31	**2.3**								
CHORDATA																	
Anisarchus medius	Pred[8]																
Aspidophoroides olrikii	Pred[8]	-20.2 ± 0.6	15.6 ± 1.1	9	**2.7**	-19.4 ± 0.6	16.8 ± 0.7	6	**2.8**								
Boreogadus saida	Pred[8]	-21.4 ± 0.4	13.6 ± 0.7	18	**2.1**	-21.4 ± 0.6	13.7 ± 1.2	36	**1.9**	-24.2 ± 0.6	10.4 ± 0.5	3	**3.0**	-22.1 ± 0.7	14.4 ± 1.0	9	**3.1**
Icelus spatula	Pred[8]	-20.3 ± 0.6	15.1 ± 1.3	8	**2.6**					-20.6 ± 0.4	15.1 ± 1.1	3	**4.4**				
Lycodes adolfi	Pred[8]					-19.3 ± 0.4	18.9 ± 0.7	6	**3.4**								
Lycodes seminudus	Pred[8]					-19.0 ± 0.6	18.4 ± 1.0	18	**3.3**								
Triglops pingelii	Pred[8]	-20.0 ± 0.3	14.6 ± 0.6	9	**2.4**	-20.7 ± 1.0	14.5 ± 1.2	4	**2.1**								

Appendix I Table 2 continued.

		Shelf				Slope				Shelf				Slope			
Species/taxon	**Feeding guild**	**$\delta^{13}C$ ± sd**	**$\delta^{15}N$ ± sd**	**N**	**TP**	**$\delta^{13}C$ ± sd**	**$\delta^{15}N$ ± sd**	**N**	**TP**	**$\delta^{13}C$ ± sd**	**$\delta^{15}N$ ± sd**	**N**	**TP**	**$\delta^{13}C$ ± sd**	**$\delta^{15}N$ ± sd**	**N**	**TP**
CNIDARIA																	
Allantactis parasitica	Sus[9]													-18.4 ± 0.5	16.8 ± 0.8	6	**3.9**
Gersemia sp.	Sus[2]									-21.9 ± 0.1	12.0 ± 0.3	3	**3.5**	-21.8 ± 0.1	15.7 ± 1.0	3	**3.5**
Stomphia sp.	Sus[10]	-17.7 ± 0.6	17.3 ± 0.2	3	**3.2**	-17.9 ± 1.4	18.3 ± 1.2	9	**3.2**								
ECHINODERMATA																	
Asteroidea																	
Ctenodiscus crispatus	SDF[1]	-19.9	15.2	1	**2.6**	-17.7 ± 0.7	17.5 ± 0.7	27	**3.0**	-19.6 ± 0.9	16.0 ± 0.9	3	**4.7**	-19.3 ± 0.5	16.0 ± 1.1	9	**3.6**
Icasterias panopla	Pred[11]																
Pontaster tenuispinus	Pred[12]									-17.8 ± 0.8	16.5 ± 0.8	3	**4.8**	-19.1 ± 0.7	15.8 ± 1.5	13	**3.6**
Bathybiaster vexillifer	Pred[2,13]					-16.7 ± 0.4	21.6 ± 0.7	18	**4.2**								
Crossaster papposus	Pred[1]	-18.2 ± 0.8	19.3 ± 0.8	9	**3.8**	-17.2 ± 1.1	21.0 ± 1.0	20	**4.0**	-20.2 ± 0.8	15.2 ± 1.9	5	**4.5**				
Crinoidea																	
Florometra spp.	Sus[12]																
Holothuroidea																	
Molpadia borealis	SSDF[1,12]					-16.6 ± 0.8	17.5 ± 2.1	3	**3.0**					-18.9 ± 0.8	17.1 ± 2.7	6	**3.9**
Myriotrochus rinkii	SDF[12]	-20.5 ± 1.3	12.1 ± 0.8	9	**1.7**	-20.1 ± 0.4	12.8 ± 0.4	6	**1.6**								
Psolus peronii	Sus[1,12]									-21.8 ± 0.4	9.9 ± 0.5	6	**2.9**				
Ophiuroidea																	
Gorgonocephalus spp.	Pred[1,12]																
Ophiacantha bidentata	SDF[1,12]	-20.4 ± 0.7	17.0 ± 1.0	6	**3.1**	-20.0 ± 0.9	17.5 ± 1.4	6	**3.0**								
Ophiocten sericeum	SDF[1]	-20.9 ± 0.8	13.1 ± 0.3	3	**2.0**	-21.4 ± 1.1	14.1 ± 2.4	3	**2.0**	-22.7 ± 1.5	6.9 ± 3.7	15	**2.0**	-21.7 ± 1.8	10.5 ± 1.7	20	**2.0**
Ophiopleura borealis	SDF[12]					-20.2 ± 1.1	15.4 ± 0.8	8	**2.4**					-17.7 ± 1.7	14.4 ± 0.9	9	**3.1**
Ophiura sarsii	SDF[12,13]	-21.6 ± 0.4	12.4 ± 0.6	9	**1.8**	-21.2 ± 0.6	13.1 ± 0.9	26	**1.7**								
MOLLUSCA																	
Bivalvia																	
Bathyarca glacialis	Sus[2,13]									-20.0 ± 0.5	11.4 ± 0.5	3	**3.3**	-19.8 ± 0.8	12.5 ± 1.7	9	**2.6**
Similipecten greenlandicus	Sus[14]									-19.5 ± 1.7	9.5 ± 1.3	12	**2.8**	-19.0 ± 0.2	13.3 ± 0.3	3	**2.8**
Yoldia hyperborea	SSDF[1]	-21.3 ± 0.2	8.5 ± 0.4	3	**0.6**	-19.5 ± 0.6	8.8 ± 1.8	14	**0.4**								
Cephalopoda																	
Bathypolypus arcticus	Pred	-20.6 ± 0.2	13.8 ± 0.2	3	**2.2**	-18.3 ± 0.7	17.9 ± 0.9	3	**3.1**								
Cirroteuthis sp.	Pred					-20.4	15.7	1	**2.5**								
Gastropoda																	
Buccinum scalariforme	Pred[1]	-19.7 ± 0.8	13.6 ± 0.8	3	**2.1**	-18.5 ± 0.7	15.2 ± 1.9	19	**2.3**	-19.4 ± 1.0	14.2 ± 0.9	3	**4.1**	-16.9 ± 0.4	17.3 ± 0.4	3	**4.0**
Colus sabini	Pred[1]													-18.4	15.3	1	**3.4**
Cryptonatica affinis	Pred[1]	-18.0 ± 0.8	13.5 ± 0.9	5	**2.1**	-17.9 ± 0.6	13.7 ± 1.2	22	**1.9**								
Margarites spp.	SDF[1]	-20.7 ± 0.5	11.8 ± 0.9	7	**1.6**	-20.6 ± 0.4	12.4 ± 0.5	12	**1.5**	-19.8 ± 1.8	9.2 ± 1.1	9	**2.7**				
Tachyrhynchus erosus	Pred[1]					-19.0 ± 2.9	10.5 ± 0.6	21	**0.9**								
Scaphopoda																	
Siphonodentalium sp.	SDF[15]													-17.8 ± 2.7	10.9 ± 2.8	6	**2.1**
PORIFERA																	
Polymastia sp.	Sus[1]	-20.5 ± 0.5	11.1 ± 1.3	3	**1.4**	-20.4 ± 0.7	16.8 ± 1.4	3	**2.8**								

Appendix I Table 2 continued.

Region		OMP								IMP							
		Shelf				Slope				Shelf				Slope			
Species/taxon	**Feeding guild**	**δ^{13}C ± sd**	**δ^{15}N ± sd**	**N**	**TP**	**δ^{13}C ± sd**	**δ^{15}N ± sd**	**N**	**TP**	**δ^{13}C ± sd**	**δ^{15}N ± sd**	**N**	**TP**	**δ^{13}C ± sd**	**δ^{15}N ± sd**	**N**	**TP**
pPOM		-26.1 ± 0.8	4.1 ± 2.0	21		-26.7 ± 1.1	4.5 ± 1.5	39		-26.9 ± 0.7	4.3 ± 1.4	15		-26.9 ± 1.0	5.5 ± 2.1	24	
sPOM		-24.2 ± 1.5	6.1 ± 2.6	8		-24.5 ± 0.7	6.7 ± 2.8	4		-26.0 ± 0.1	4.5 ± 2.2	4		-25.0 ± 0.5	6.7 ± 1.6	5	
ANNELIDA																	
Clitellata																	
Hirudinea	Pred[1]													-19.8	16.0 ± 1.5	2	**3.9**
Echiura																	
Hamingia arctica	SSDF[2]																
Polychaeta																	
Nephtys sp.	Pred[1]	-21.1	14.3	1	**3.9**	-20.6 ± 0.8	15.5 ± 0.9	20	**3.7**	-21.9 ± 0.6	13.3 ± 1.0	6	**3.2**	-20.9 ± 0.9	15.1 ± 1.4	11	**3.7**
Polynoidae spp.	Pred[1]	-21.2 ± 1.1	13.7 ± 1.3	12	**3.7**	-21.4 ± 0.8	15.4 ± 0.9	12	**3.7**	-21.5 ± 1.4	14.0 ± 2.1	11	**3.5**	-21.8 ± 0.7	15.2 ± 1.7	15	**3.7**
ARTHROPODA																	
Amphipoda																	
Anonyx sp.	Pred[1]	-21.4 ± 0.3	12.9 ± 1.8	14	**3.5**	-21.8 ± 0.2	11.0 ± 0.7	2	**2.4**	-21.8 ± 0.5	13.7 ± 1.2	11	**3.4**	-21.4 ± 0.7	14.3 ± 2.6	5	**3.4**
Themisto libellula	pPred[3]	-26.5 ± 0.6	10.0 ± 0.8	15	**2.6**	-26.0 ± 0.8	10.1 ± 1.2	30	**2.1**	-26.8 ± 0.7	10.5 ± 1.2	12	**2.4**	-26.3 ± 0.7	10.3 ± 0.9	24	**2.3**
Calanoida																	
Calanus glacialis	pFilt[4]																
Calanus hyperboreus	pFilt[4]	-24.5 ± 0.5	9.9 ± 0.7	15	**2.6**	-24.4 ± 0.7	9.7 ± 0.7	30	**2.0**	-24.5 ± 0.5	9.4 ± 0.8	12	**2.1**	-24.4 ± 0.5	9.8 ± 0.5	24	**2.1**
Neocalanus cristatus	pFilt[4]																
Cumacea																	
Diastylis sp.	SDF[1,2]	-23.5 ± 1.3	5.8 ± 0.7	9	**1.4**	-25.7 ± 0.9	5.6 ± 0.9	17	**0.8**	-24.5 ± 1.8	5.5 ± 1.1	12	**1.0**	-25.5 ± 0.9	5.7 ± 1.1	14	**0.9**
Decapoda																	
Chionoecetes opilio	Pred[1]																
Eualus gaimardii	Pred[1]	-19.8 ± 0.9	13.0 ± 0.6	18	**3.5**	-19.2 ± 1.3	13.9 ± 1.0	21	**3.2**	-20.9 ± 1.0	12.8 ± 1.0	8	**3.1**	-19.7 ± 1.0	13.9 ± 0.9	19	**3.3**
Sabinea septemcarinata	Pred[5]	-18.3 ± 1.2	13.9 ± 0.9	15	**3.8**	-18.0 ± 1.3	13.9 ± 0.9	7	**3.2**	-19.6 ± 0.9	14.0 ± 0.6	13	**3.5**	-19.3 ± 0.5	14.7 ± 1.0	9	**3.6**
Isopoda																	
Saduria sabini	Pred[6]					-22.6 ± 1.7	10.4 ± 2.5	17	**2.2**	-22.3 ± 0.6	10.7 ± 1.2	12	**2.5**	-22.6 ± 0.7	10.9 ± 1.3	14	**2.4**
Pycnogonida																	
Pycnogonida	Pred[1]	-22.6 ± 0.4	10.2 ± 1.2	10	**2.7**	-22.5 ± 1.1	11.5 ± 1.2	18	**2.5**	-23.0 ± 0.7	11.4 ± 1.6	7	**2.7**	-22.8 ± 0.5	12.9 ± 1.6	20	**3.0**
CHAETOGNATHA																	
Parasagitta elegans	pPred[7]																
CHORDATA																	
Anisarchus medius	Pred[8]									-21.9 ± 0.4	14.4 ± 1.0	6	**3.6**				
Aspidophoroides olrikii	Pred[8]	-21.1 ± 0.3	14.4 ± 0.5	6	**3.9**					-21.5 ± 1.0	14.8 ± 0.9	6	**3.7**				
Boreogadus saida	Pred[8]	-22.7 ± 0.4	14.0 ± 0.6	11	**3.8**	-24.1 ± 1.8	12.3 ± 2.5	30	**2.8**	-25.2 ± 1.8	11.5 ± 2.2	12	**2.7**	-24.6 ± 1.6	11.9 ± 2.2	24	**2.7**
Icelus spatula	Pred[8]	-21.3 ± 0.3	15.2 ± 0.7	12	**4.1**					-21.8 ± 0.5	15.4 ± 0.7	9	**3.9**				
Lycodes adolfi	Pred[8]					-20.8 ± 0.7	17.0 ± 0.8	9	**4.1**					-21.5 ± 0.8	15.7 ± 2.0	11	**3.8**
Lycodes seminudus	Pred[8]					-21.1 ± 0.4	16.5 ± 1.1	12	**4.0**					-21.0 ± 0.5	16.4 ± 0.7	10	**4.1**
Triglops pingelii	Pred[8]	-22.2 ± 0.4	13.6 ± 0.4	6	**3.7**	-22.6	15.2	1	**3.6**	-22.2 ± 0.7	14.2 ± 0.8	7	**3.5**	-22.2 ± 0.5	14.8 ± 0.8	5	**3.6**

Appendix I Table 2 continued.

	Region	OMP								IMP							
		Shelf				Slope				Shelf				Slope			
Species/taxon	Feeding guild	δ^{13}C ± sd	δ^{15}N ± sd	N	TP	δ^{13}C ± sd	δ^{15}N ± sd	N	TP	δ^{13}C ± sd	δ^{15}N ± sd	N	TP	δ^{13}C ± sd	δ^{15}N ± sd	N	TP
CNIDARIA																	
Allantactis parasitica	Sus[9]	-20.6 ± 0.6	12.4 ± 1.0	4	**3.3**	-18.7 ± 0.8	15.4 ± 1.3	16	**3.7**	-21.1 ± 1.0	13.1 ± 1.2	9	**3.2**	-18.6 ± 1.5	15.8 ± 1.5	17	**3.9**
Gersemia sp.	Sus[2]	-22.4 ± 0.6	10.7 ± 1.8	2	**2.8**	-22.5 ± 0.8	13.5 ± 0.7	9	**3.1**	-23.1 ± 0.9	11.6 ± 0.8	11	**2.7**	-22.5 ± 0.9	12.8 ± 0.8	9	**3.0**
Stomphia sp.	Sus[10]																
ECHINODERMATA																	
Asteroidea																	
Ctenodiscus crispatus	SDF[1]									-20.6 ± 0.8	15.0 ± 1.5	7	**3.7**	-20.1 ± 0.1	15.2 ± 1.7	2	**3.7**
Icasterias panopla	Pred[11]	-19.9 ± 0.3	16.7 ± 0.7	5	**4.6**	-18.9 ± 0.7	18.8 ± 0.6	16	**4.7**	-18.6	17.5	1	**4.5**	-18.8 ± 0.9	18.2 ± 1.3	12	**4.6**
Pontaster tenuispinus	Pred[12]	-19.8 ± 0.4	13.6 ± 0.4	6	**3.7**	-19.5 ± 1.3	15.0 ± 1.3	30	**3.6**	-20.2	15.6	1	**3.9**	-19.3 ± 1.3	14.4 ± 1.5	22	**3.5**
Bathybiaster vexillifer	Pred[2,13]																
Crossaster papposus	Pred[1]	-20.8 ± 0.5	16.0 ± 0.8	10	**4.4**												
Crinoidea																	
Florometra spp.	Sus[12]	-22.9 ± 0.4	12.5 ± 0.4	16	**3.3**												
Holothuroidea																	
Molpadia borealis	SSDF[1,12]					-20.2 ± 0.8	15.2 ± 1.8	9	**3.6**					-19.4 ± 1.0	14.6 ± 1.7	4	**3.5**
Myriotrochus rinkii	SDF[12]																
Psolus peronii	Sus[1,12]	-22.6 ± 0.5	9.9 ± 0.8	9	**2.6**												
Ophiuroidea																	
Gorgonocephalus spp.	Pred[1,12]					-20.5 ± 0.5	16.7 ± 0.3	3	**3.4**	-22.0 ± 0.5	13.9 ± 0.8	8	**4.0**				
Ophiacantha bidentata	SDF[1,12]																
Ophiocten sericeum	SDF[1]	-22.9 ± 2.0	7.9 ± 2.1	25	**2.0**	-22.2 ± 2.2	9.7 ± 0.9	22	**2.0**	-22.9 ± 0.9	9.0 ± 1.0	11	**2.0**	-23.3 ± 0.7	9.4 ± 1.0	7	**2.0**
Ophiopleura borealis	SDF[12]					-17.7 ± 1.6	13.0 ± 1.1	29	**3.0**					-18.4 ± 1.8	12.4 ± 1.6	22	**2.9**
Ophiura sarsii	SDF[12,13]																
MOLLUSCA																	
Bivalvia																	
Bathyarca glacialis	Sus[2,13]	-20.9 ± 0.4	9.9 ± 0.4	8	**2.6**	-20.8 ± 0.5	11.8 ± 1.4	11	**2.6**	-21.6 ± 0.6	9.6 ± 1.0	10	**2.2**	-21.3 ± 0.3	11.9 ± 0.7	12	**2.7**
Similipecten greenlandicus	Sus[14]	-19.7 ± 2.6	9.5 ± 1.0	13	**2.4**					-21.5 ± 1.9	9.7 ± 0.7	12	**2.2**	-22.1	9.8	1	**2.1**
Yoldia hyperborea	SSDF[1]																
Cephalopoda																	
Bathypolypus arcticus	Pred																
Cirroteuthis sp.	Pred																
Gastropoda																	
Buccinum scalariforme	Pred[1]									-20.4 ± 0.9	11.7 ± 2.2	5	**2.8**				
Colus sabini	Pred[1]	-19.8 ± 0.7	12.1 ± 1.3	6	**3.2**	-19.3 ± 1.2	13.8 ± 1.1	16	**3.2**	-20.4 ± 0.7	12.8 ± 1.2	8	**3.1**	-19.5 ± 0.8	14.6 ± 1.9	20	**3.5**
Cryptonatica affinis	Pred[1]																
Margarites spp.	SDF[1]	-21.2 ± 0.9	9.0 ± 1.4	12	**2.3**					-21.4 ± 1.1	9.5 ± 0.8	4	**2.1**	-22.3 ± 0.8	10.1 ± 0.8	6	**2.2**
Tachyrhynchus erosus	Pred[1]																
Scaphopoda																	
Siphonodentalium sp.	SDF[15]					-20.5 ± 2.7	9.9 ± 1.7	16	**2.1**					-20.7 ± 2.5	10.0 ± 0.9	17	**2.2**
PORIFERA																	
Polymastia sp.	Sus[1]	-22.5 ± 1.0	8.3 ± 2.6	3	**2.1**	-21.0 ± 0.4	10.2 ± 1.3	3	**2.1**					-20.7 ± 2.9	8.8 ± 5.2	4	**1.8**

1) Macdonald et al. 2010
2) Bergmann et al. 2009
3) Auel and Werner 2003
4) Mauchline 1998
5) Graeve et al. 1997
6) Haahtela 1990
7) Terazaki 1998
8) Mecklenburg et al. 2002
9) Mercier et al. 2011
10) Lundsten et al. 2010
11) Jangoux and Lawrence 1982
12) Mah 2014
13) Aitken and Fournier 1993
14) Pieńkowski et al. 2014
15) Reynolds 2006

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix J

Monitoring Plan Design

Author
Brenda Norcross

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX J MONITORING PLAN DESIGN

Survey Design Review

BOEM-2011 Cruise

The sample design for 2011 was based on three areas: east, central, and west US Beaufort Sea; station locations were designed to replicate sites that had been previously sampled and to maximize cover of the shelf (155.25° W to 145.09° W) in the time (21 days) allotted. Because of these varying constraints, the pattern of stations was not consistent among the three regions. The eastern portion sampled 15 sites in the same grid pattern sampled during the WWW1004 cruise in 2010 (LGL, Inc. and Norcross, unpublished). In the central area, which was previously unsampled, stations were spaced at approximately 0.5^o latitude and 0.25^o longitude; this grid pattern was used to maximize spatial coverage of the central Beaufort shelf. The layout of the stations resampled sites that were trawled in 2008 (Rand and Logerwell 2011). Avoiding sampling east of 150° W starting 25 August is critical to maintaining good relations with the local communities who engage in subsistence hunting for bowhead whales (*Balaena mysticetus*) each autumn. That further dictated that we could only sample in the west-central and western areas after 24 August 2011. Because the cruise in 2011 experienced extraordinarily good weather, extra stations were added to fill in between the 2008 sites and to create transects, i.e., ~155° W, ~154° W, ~153° W, ~152° W, ~151° W and 150.1° W. Note that all are west of 150° W.

Choosing the appropriate sampling gear is a learning process. We used two types of beam trawls to capture fish during the BOEM 2011 cruise: a plumb staff beam trawl (PSBT; Norcross et al. 1995, 1997, Gunderson and Ellis 1986) and plumb staff beam trawl that was modified (PSBT-A) based on our previous encounters with mud in the Chukchi Sea (Norcross et al. 2010, 2013) and those of Logerwell et al. (2010) in the Beaufort Sea (PSBT-A). The beam trawls had a 4.7 m headrope, 4.6 m footrope, 7 mm mesh in body, and 4 mm mesh as codend liner. A rigid 3 m pipe forward of the net held the mouth open for an effective swath of 2.26 m, allowing for accurate quantifications of trawl effort by area swept or by duration of tow. The PSBT-A was modified according to Abookire and Rose (2005) by adding rollers to the footrope to exclude boulders and rocky substrate and by securing the headrope to the beam in several places in order to prevent fish escapement. The PSBT-A was used at stations where a regular PSBT would have been impractical (i.e., dense mud or boulders).

Lessons Learned 2011

- The modified PSBT-A beam trawl is sturdier than PSBT. Use PSBT-A in future Beaufort Sea cruises.
- To get greater abundance and biomass and to catch snow crabs need to sample deeper stations. In future sample slope also, not just shelf.
- Physical oceanographic characteristics change on slope. Atlantic Water may upwell onto shelf. Sample slope in future.
- Inform Alaska Eskimo Whaling Commission of our plans and activities before, during and after cruise to avoid conflicts and promote community engagement.

TB-2012 Cruise

Using what was learned during the BOEM-2011 cruise, we designed the Transboundary cruise for 2012. In 2012, the goal was to sample up to six transects from shelf to slope from Camden Bay to the US-Canada border. However, due to an unfortunate combination of weather delays and the unrealized completion of whaling east of 150°W by our September start date, our actual sampling was in the Central Beaufort Sea rather than the Eastern US Beaufort. The crew transfer was delayed by three days until 20 September, first due to poor weather in Prudhoe Bay, and then due to conflicts with the bowhead hunt in Kaktovik and Nuiqsut. Within two days prior to the scheduled crew transfer, we were informed that the death of an elder in the village of Kaktovik had suspended the hunt for approximately a week. There was a brief period of weather that was favorable for the crew transfer during this time, so the science crew boarded the vessel on 20 September. Dr. Norcross contacted the Alaska Eskimo Whaling Commission (AEWC) to request permission to sample in the proposed Transboundary area during the suspension of the hunt. While waiting for a response from AEWC, the science crew began sampling in the area called “Central Beaufort” during the BOEM-2011 cruise, starting with a shallow site that had been previously sampled and then sampling at predetermined depths outlined in the 2012 Transboundary cruise plan. Ultimately, however, the request to transit to, and sample in, the target area during the suspension of the hunt was denied, and sampling continued in the Central Beaufort Sea. Although the goal of 2012 was to sample shallow and deep stations in the Eastern US Beaufort, we were able to work with the local communities successfully, while resampling some stations from 2011. This opportunity, although not quite what we had anticipated, allowed us some time to learn how to fish our gears under new conditions: at deeper stations with a heavier wire. We only fished the heavier, studier PSBT-A that we had shown in 2011 produced results comparable to the PSBT and was more suitable for the muddy, rocky conditions of the Beaufort Sea. Additionally, we used a Canadian beam trawl (CBT) to collect comparison data between our work in the US Beaufort Sea and the Canadians’ work in the Canadian Beaufort.

Each successive year has taught us something about sampling in the Beaufort Sea. In 2011 we learned how important it was to sample both shelf and slope communities. As a result, in 2012 we focused on a smaller spatial coverage with greater depth coverage. During that year, we not only learned how to fish at deeper stations, but we also discovered how important it is to have a voice in the local communities.

Lessons Learned 2012

- Timing of cruise is critical. Bowhead whaling season confounds sampling after 25 August. Ice-out confounds sampling before 1 August. Thus, we are constrained to work in August only. Access to a vessel that is capable of deploying all of our gear and accommodating enough scientists to work 24 hrs/day is extremely limited.
- We need to include a native communicator in our crew to act as an advocate for us with local communities. This is especially important to deal with timing issues and whaling. It is worth losing a bunk (and thus a scientist) to have a native communicator aboard; include on in 2013.
- The wire time required to actually deploy all gears at all stations was prohibitive. Revise amount of gear and replicate sampling that can be deployed at each stations.
- Do not use box core off *Norseman II*. It is too dangerous. In future cruises use single or double Van Veen grab.

- We need to have a SIMRAD depth sounder on the bottom trawl net so we know when sufficient scope has been deployed that the trawl is actually fishing on the bottom. Purchase one for 2013.
- We lost too many trawls. Spectra® (a gel-spun polyethylene non-braided line) is expensive but known to be effective (JJ Vollenweider, NOAA, pers. comm.). Purchase bridles made of Spectra line for each PSBT-A for 2013.
- Sampling on the slope caught species of fishes and invertebrates seldom or never seen on shelf. Continue to sample on slope.

TB-2013 Cruise

We designed the Transboundary cruise for 2013 by incorporating what was learned during BOEM-2011 and TB-2012-US cruises. In 2013, the first sampling priority was to sample on both sides of the US-Canada border, i.e., the Transboundary area. As in 2011, the cruise was scheduled in August so we needed work around the start of local subsistence hunts. We did this by working from the western side of our study area to the eastern Canadian portion. We were able to successfully sample all but one of our planned transects, and we were able to sample an extra transect along the Mackenzie River trough. This sampling plan was developed through many months of close work with Canadian researchers. As in 2012, this cruise used both US (PSBT-A) and CBTs.

Because we made the presence of a native communicator a priority in 2013, we were able to have direct communications with the local communities. This communication was absolutely necessary for the success of the 2013 field season; it enabled critical gear delivery through the village of Kaktovik and access to up-to-date information about whaling activities.

Perfecting fishing methods was a priority in 2013. We further refined the PSBT-A for fishing in the Beaufort Sea by using stronger materials to make a more resilient bridle. This net fished successfully and we did not lose any beam trawls; It was our first Arctic cruise where no beam trawl was lost. Unfortunately, 2013 was the first time we lost an otter trawl (OT), for which we did not have a backup. We discovered how critical it is to use real-time readouts of net depth and height (SIMRAD) above the bottom while fishing all gears. Without this technology, we are essentially fishing “blind.” With this technology, we have a greater degree of control over our gears and confidence in the quality of our samples. Unfortunately, our pre-cruise belief that the SIMRAD could not be lost because it was attached directly to the tow cable was untrue. The only SIMRAD rated to 1000 m was lost and had to be replaced during the cruise. Always attach a time-depth recorder (TDR) as a post-deployment backup to provide a pattern of contact time on bottom and depth fished. Unfortunately, without previously having had a real-time readout of bottom contact, we did not recognize the importance of a TDR.

Lessons Learned 2013

- The SIMRAD is really important. A more secure manner for attaching the SIMRAD to the tow cable must be devised. Losing a SIMRAD causes delays and gaps in data. Always bring back-up SIMRADs, i.e., at least two for shallow and two for deep.
- SIMRAD works for real-time fishing adjustments whereas a TDR should be used to determine actual time (converted to distance) of bottom contact and actual fishing. We learned too late that we should have placed more importance on this; in 2012 many TDRs malfunctioned, were lost, or were never put on nets. Actual amount of trawl bottom contact (distance used in calculating CPUE) cannot be calculated for TB-2012.

- Spectra bridles work great. No PBST-A was lost. One OT was lost and we have never lost one before. For the future, consider purchasing spectra bridles for OT and bring back-up OT.
- Having a native communicator onboard is invaluable. Our native communicator facilitated local assistance in Kaktovik to bring our replacement SIMRAD from the airport to the beach. The expense, monetary and loss of a scientific bunk, to have a native communicator onboard is a good investment.
- Timing of the cruise is important and negotiations must be made with the AEWC. Generally, be at least 50 nmi (nautical mile) from Kaktovik by 25 August. We can sample in Canadian waters starting 25 August. Always go offshore and eastward starting 25 August so as not to spook whales that are moving nearshore from east to west.
- The physical signature of the Mackenzie River Plume is obvious in CTD. Continue to sample the US-Canada Transboundary area to assess the influence of the Mackenzie River.

TB-2014 Cruise

Again we used previous cruises to inform our sampling design for the 2014 Transboundary cruise. As in 2013, we worked around the start of local subsistence hunts by starting sampling on the western side of our study area and proceeding eastward toward Canada. It was critical that we be offshore and at least 50 nmi from the village of Kaktovik by 25 August 2014. In 2014 our focus was (1) to sample stations that had been sampled previously to enable interannual comparisons, (2) to sample more stations in Camden Bay, and (3) to conduct replicate hauls with bottom trawls at the same stations, i.e., location and depth. To accomplish these goals, the progression of stations sampled was different than in previous years. Nearshore stations at all transects were sampled on the transit eastward. Offshore stations (>50 nmi from Kaktovik) were sampled on the westward transit.

The three goals were achieved on this cruise. The first goal of maximizing stations for interannual comparison was accomplished. Each transect had stations at predetermined depths (20, 50, 75, 100, 200, 350, 500, 750, and 1000 m) plus zooplankton and oceanographic stations at regular intervals on the shelf. While most stations were at pre-determined depth contours, three stations occurred at unexpected depths. A 10 m station and a 40 m station were added to transect A2, as the depths sampled in 2013 were found to be incorrectly labeled due to an error in the ship's fathometer during that portion of the 2013 cruise. To provide maximum opportunities for interannual comparison, the historical station locations were sampled again, and the actual depth contours were sampled as well. The second goal of sampling in Camden Bay was fulfilled. This was the first year that we sampled transects A5 and A4. To balance the goal with the first one, we only sampled on the shelf (20–200 m) on these transects because deeper slope stations take much longer and would not be replicates. The third goal of repeatability of bottom hauls was achieved as three replicate PSBT-A hauls were made at each station on A1 to assess within-station variability of fishes. A1 was the ideal transect for these hauls because it is within Alaska waters and outside of 50 nmi buffer zone around Kaktovik. Therefore, these replicate samplings were reserved for near the end of the cruise when we were reasonably certain there was enough time to conduct this bottom-haul experiment. Fishes were collected using a demersal PSBT-A because it had been the most successful in previous years and was comparable to the small beam trawl that the Canadians use in the Beaufort Sea.

When available, we attached SIMRAD depth and height sensors to each net; unfortunately, we had difficulties with these devices. These depth and height sensors provided real-time feedback on the behavior of the nets. In 2013, we found a SIMRAD to be a valuable tool to help determine that towed nets had settled on the bottom and were fishing and to determine height above the bottom for the net bridles. However, in 2014, the SIMRAD sensors were not functioning for much of the sampling, despite the fact that we brought new and recently recalibrated instruments. Regrettably, many of our bottom hauls did not have SIMRAD sensors attached and were fished based on wire scope alone. A Star-Oddi TDR was attached to all nets to provide temperature and depth for the duration of the trawls.

Because, in previous years, the Isaacs-Kidd midwater trawl (IKMT) caught mainly cods and sculpins <50 mm, we chose to forgo that gear in favor of using an Aluette midwater trawl (AMT). The goal was to capture larger Arctic Cod, *Boreogadus saida,* in deeper waters at the 200 m, 350 m, and 500 m stations as well as opportunistically whenever the ship's fathometer showed signs of fish aggregations. This net has successfully captured fish to 150 mm in the Bering Sea (K. Miller, pers. comm.) and the Gulf of Mexico (G. Faulkner, pers. comm.). The ship we used did not have a 38 kHz fisheries acoustic system, and the depth sounder was not able to reliably detect fish sign. The catch success rate of the AMT was low, suggesting that more test fishing and troubleshooting is needed. Furthermore, a calibrated scientific-quality hydroacoustic system (beyond the ship's depth sounder) is needed to target schools of fish. In addition, a SIMRAD is too large to attach to the AMT; it will change the towing characteristics. Ideally a pinger would be on the net and a hydrophone would be towed at the surface. Deploying a hydrophone and having someone monitor it requires more time than we elected to expend on this cruise. At minimum a TDR should be attached to the AMT for later recovery of depth-fished data.

Prior to the cruise, we acknowledged that there would not be enough time to sample all of the fishing gear used in the previous years as well as to conduct a replicate-haul experiment. Time is always a limiting factor. For 2014, we chose to ensure that we met all three goals for bottom trawling. Choosing which gear and which stations to sample will always depend on the specific objectives.

Lessons Learned 2014

- There will always be tradeoffs between what accomplishments are desirable and what are possible, e.g., repeat stations for interannual variability vs. sample new locations for breadth, replicate samples vs. additional gear.
- Decisions about specific goals of each sampling cruise need to be made in advance so tradeoffs can be evaluated.
- Time should be allotted to test new gear and to compare with that previously used, even if they do not target the same size of fish, e.g., AMT and IKMT.
- A hydroacoustic system is essential to efficiently sample with an Aluette or other midwater net.
- While at sea, always check station position and depth against that from previous years. Discrepancies, such as incorrect readings on a depth sounder, can be corrected while at sea.
- A larger CTD with more bottles on all cruises would have allowed for better resolution of deep nutrient pools.
- Size fractionated chlorophyll-*a* should be collected on all cruises

- A real-time Multinet control/data coupled with SIMRAD altimeter on zooplankton Multinet would have been beneficial to monitor the distance to the seafloor. This would have avoided several recasts due to missing the target programmed trigger depth. It also would not have required us to build in as large of a depth buffer that added time to each cast.
- It would be beneficial to perform a five-minute 150-µm tow zooplankton tow in the freshwater upper mixed layer to resolve community differences between the freshwater lens and the rest of the Polar Mixed Layer.
- The gap within the study area for transects A3 and A4 (and A2 in 2013) was not ideal and made elucidating east-west patterns challenging.
- Given the issues of working around whaling dates for the end of the cruise, an earlier start to cruise is needed.
- Even backups fail. We prepared by having backup SIMRADs, but there were software problems which we could not have detected until we were at sea.
- In-lab verification of species IDs is critical for fish; thus preliminary field identifications should only be used with caution.
- Processing samples in the laboratory will take longer than expected.

Cumulative Experience

For meaningful monitoring of an ecosystem to support environmentally sound offshore development, a time series of collections is necessary. Therefore, it is necessary to build upon what exists. Minimal historical data exist for offshore marine fish populations in the US Beaufort Sea. The data that do exist come from OCS/MMS/BOEM fish surveys on the shelf, which were conducted sporadically in 1977 aboard the USCGC *Glacier*, (Frost and Lowry 1983), 1990 (nearshore survey, Thorsteinson et al. 1991), and 2008 (Logerwell et al. 2010, Logerwell et al. 2011). The area sampled has ranged from Barrow to the Alaska-Canada border, though there were no sites sampled in multiple years. Contemporary data were absent east of 145° W to the border prior to the BOEM-funded Transboundary cruise in 2013 (TB-2013-US). As offshore oil exploration interest expands, more information about the sparsely documented fish and invertebrate species inhabiting the US Beaufort Sea is required.

In addition to examining previous work, we used an iterative planning process to design a fish monitoring survey to assess interannual variation (Appendix J Table 1). We used the results from BOEM-2011 cruise (BOEM 2017-33) to formulate a sample plan for the 2012-US cruise. In turn, we used the results from sampling in 2012 (US-Canada Transboundary BOEM 2017-34) to structure the sampling plan for 2013. We learned more on the 2013-US cruise to refine the sampling for 2014 (Appendix J Table 2). Though history showed that the whaling season in Kaktovik usually took place over Labor Day weekend, this was not the case in 2012, despite a 3-day start delay due to weather. We were forced to sample west of 150 ºW to accommodate the whaling and learned that to avoid this conflict; future sampling should be conducted in August. However, we did gain valuable experience about deep water sampling in 2012. In 2013, we were able to approximate how many stations could be sampled in 21 days when sampling the shelf and slope (59) as opposed to only sampling the shelf (81) as in 2011. From 2011 through 2013 only a half day was lost to weather, so a large number of stations could be sampled. However, in 2014 that good luck was reversed and the cruise start was delayed 10 days because of an extended bout of bad weather in the Beaufort Sea. Once the cruise started, only a half day at sea was lost due to weather. However, the cruise had to be shortened by four days (from 21 to 17) because the vessel was booked for another cruise following ours. In 2014 we also were reminded not to discount delays in start time due to the presence of ice. Ideally, to complete all our desired sample locations before the bowhead whaling season, the cruise should start earlier, but nearshore ice in the Chukchi and Beaufort Seas often prevents ships from transiting into the Beaufort Sea. Furthermore, it was not financially possible for us to hire a vessel for the entire ice-out season to ensure total access to a ship. However Fisheries and Oceans Canada (DFO) did exactly that; they chartered a vessel round trip from Vancouver, Canada to Amundsen Sound in the eastern Beaufort Sea for the Beaufort Regional Environmental Assessment (BREA) project sampling in 2012, 2013, and 2014. Thus, it is possible to charter a vessel for the entire open water season, but it is not usually financially feasible.

Not only did we learn about logistics and scientific sample design by our iterative approach (Appendix J Table 2), but also we learned about scientific compromise to accomplish our goals. For example, there were a finite number of bunks available on the ship (R/V *Norseman II*) that was used 2011 through 2014. Each year tradeoffs were made in balancing scientists and support crew (Appendix J Table 2). In 2011, we discovered it is not safe or equitable to operate 24 hrs/day without a night cook and a night deck boss. In 2012, the fish crew gave up two bunks (from 6 to 4) to accommodate those two additional crew members. We also learned that we needed an additional bunk for an infauna scientist more than we needed a researcher to collect opportunistic seabird observations as accommodated in 2011; there was a bunk for a second infauna scientist in 2012 because a BOEM project officer was not at sea. In 2012, we learned that a box corer could not be safely used off the R/V *Norseman II*, thus, in 2013 there was no infauna sampling. The two infauna researcher bunks were reallocated to a third zooplankton person and a BOEM project officer in 2013. We did not have a native communicator in either 2011 or 2012; however, in 2013 we were able to secure a native communicator who was willing to share a room with the medic. The native communicator was invaluable; as a native from the North Slope, he was able to contact a friend in Kaktovik (who happened to be the AEWC commissioner) for help to get our replacement parts from the airport to the skiff. Simultaneously, in 2013 we realized that the medic did not have enough work to do and that the crew was very safety conscious; therefore, that bunk could be better utilized. We also realize that a fourth (increase to two each shift) zooplankton/ CTD person was needed. To have a comprehensive environmental assessment, we determined that infauna collections should be made on the shelf, which requires two scientists, one on each 12-hr shift. Thus, when planning for the 2014 cruise, compromises again had to be made regarding bunk space. The fish crew gave up one more bunk (to an untenable total number of 3) and the ship crew compromised by doubling up on another bunk space (Appendix J Table 2).

Because of the paucity of non-nearshore (i.e., outer continental shelf) information, it would not have been possible to design a survey to assess interannual variation in regional distribution, diversity, abundance and biomass of fishes in the Beaufort Sea without the additional knowledge gained from multiple years of sampling.

Appendix J Table 1. Sample collections in the Beaufort Sea by year and longitude.

	Year Sampled:		**2010**	**2011**	**2012**	**2013**	**2014**
	Max depth sampled (m):		100	223	1000	1000	1000
Area	**Longitude**	**Transect**					(1x1500 m)
Western Beaufort				X			
Central Beaufort				X			
	151	B2		X	X		
	150.6	BX		X	X		
	150	B1		X	X		
Camden Bay/Eastern Beaufort			X	X			
	146	A6	X	X		X	X
	145	A5	X	X			X
US-Canada Transboundary Area							
	144	A4					X
	142	A2				X	X
	141	A1				X	X
	140	TBS				X	X
	139	MAC				X	
	138	GRY				X	

Appendix J Table 2. Parameters for cruises. PSBT: plumb staff beam trawl, PSBT-A: modified PSBT, IKMT: Isaacs-Kidd midwater trawl.

	Year	2011	2012	2013	2014
	Cruise	Beaufish	TB-2012	TB-2013	TB-2014
	Vessel	Norseman II	Norseman II	Norseman II	Norseman II
	Total # science bunks	**15**	**13**	**13**	**15**
Scientific Disciplines Number of Scientists	Chief Scientist	1	1	1	1
	BOEM Project Officer	1	0	1	1
	Fish	6	4	4	3
	Epibenthos	4	4	4	4
	Sediment/water chemistry	1	0	0	0
	Zooplankton/CTD/water	1	2	3	4
	Infauna/sediment	0	2	0	2
	Seabirds	1	0	0	0
	Total # support and crew	**10**	**12**	**13**	**12**
Support	Medic	1	1	1	0
	Native communicator	0	0	1	1
	vessel crew	9	11	11	11
Details	°W Longitude	155.25–145.09	151.1–150.1	146.13–137.22	146.13-140.30
	°N Latitude	71.85–70.33	71.45–70.74	71.02–69.46	71.09-69.71
	Start date	15-Aug-11	20-Sep-12	13-Aug-13	18-Aug-14
	End Date	4-Sep-11	28-Sep-11	30-Aug-13	2-Sep-14
	Weather delayed start (days)	0	3	0	10
	Days at sea	21	10	21	16
	Days lost to weather	0	0	0.5	1.5
	# Stations	81	18	59	53
	Depth range (m)	135–184	20–1005	17–1000	10-1500
Gear	PSBT	x	--	--	--
	PSBTA	x	x	x	x
	CBT	--	x	x	x
	Otter trawl	x	x	x	x
	IKMT	x	x	x	--
	Aluette pelagic trawl	--	--	--	x
	Multinet	--	x	x	x
	Bongo nets	x	x	x	x
	Vertical net	--	x	x	x
	Van Veen grab	x	--	x	x
	Box core	--	x	--	--
	CTD	x	x	x	x
	Niskin bottles	x	x	x	x

Cruise Logistics

Very few vessels exist that can work under the conditions and time constraints required for conducting this type of research in the western Arctic (Appendix J Table 2). An excellent safety record is the first consideration. As the ship is the most expensive part of collecting samples, it is desirable to work 24 hrs/day. The additional cost in vessel and scientific crew is minimal compared to the logistical costs of getting the vessel to the Arctic and its daily operations. A smaller ship means more days are lost to weather than with a larger ship. However, getting one vessel that can house enough scientists from necessary disciplines is difficult. Excellent vessels are in high demand, thus compromises must be made for timing of the cruise. Further constraints on ideal timing for sampling are interconnected with the vessel. A non-ice-strengthened hull delays the time when the ship can get around Pt. Barrow, which in turn can push the cruise against the whaling closure date of 25 August. At the time of this study, the only vessel that met the needs of providing baseline ecosystem information to BOEM was the *Norseman II*, which is why we used her for four years. This vessel is not ideal, but it was the best available. Deploying out of Prudhoe Bay, as we did in 2011, 2012, 2013, and 2014, saves a lot of time when working in the Beaufort Sea. Scientists do not have to board in Nome, and it saves on time and expense of transiting scientists to the eastern Beaufort Sea. However, this requires connections with oil companies to allow university personnel access to restricted areas. That connection was provided by the logistics company from whom we leased the vessel. As is known in fisheries research, sampling from the same vessel each year is desirable. It reduces catchability variability and is efficient as there is less time spent learning the vessel and gear deployment capabilities. It is important to have as many of the same people onboard each year, especially the Captain and the Chief Scientist. Having a consistent decision-making process year to year is more efficient. It is critical to have at least one person in each discipline on each shift that has experience with the gear and procedures for sampling that day. As of summer 2015, the R/V *Sikuliaq* is available. She has an ice-strengthened hold and can support 24 scientists. In April 2015 the midwater nets that we deployed from the *Norseman II* were tested off the *Sikuliaq*. Unfortunately not all her winches were operating and bottom trawls could not be deployed. The *Sikuliaq* is twice the size of the *Norseman II* and rental costs will likely be higher.

Cruise plans made in an office months ahead of time are logistically complicated and compromises are made. Appendix J Table 2 is useful for cruise planning purposes, but it is only two dimensional. In actuality, decisions about sampling involve the many dimensions that I have attempted to discuss. Though pre-cruise contingencies are discussed, there are even more complications at sea and problems arise. Thorough cruise plans attempt to have alternatives considered before amendments must be made. Determination of priority of gear for sampling fish, physical and lower trophic levels should be decided based on a combination of gear efficiency, weather conditions, and project needs. For example, the benthic beam trawls and the CTD provide samples and data for multiple disciplines, whereas the vertical net might only provide information for one discipline. That consideration must be balanced with the wire time required for deployment and retrieval of each gear. In this example, the vertical net uses less wire time than the benthic net. Further, if the weather conditions are marginal, the least rugged of the gears must be cut from the sampling program before the more rugged gears. A general rule of thumb is that a sediment grab will not function in weather in which a CTD can be safely deployed. A CTD is more expensive and fragile than vertically hauled nets which can be fished in rougher weather. Trawls are the sturdiest and can be fished in the roughest weather; thus there may be data gaps as some stations will only have fish and epibenthos data. Generally, the vertically hauled gears are the most sensitive to rough weather but require less wire time, while the towed gears are more robust to weather conditions but require more wire time.

US-Canada Transboundary Fish and Lower Trophic Communities

Abundance, Distribution, Habitat and Community Analysis

BOEM Agreement Number M12AC00011

BOEM 2017-034 Appendix K

Database Description

Institute of Marine Science
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
PO Box 757220
Fairbanks AK 99775

FINAL REPORT
December 2017

OVERVIEW

The database for the US-Canada Transboundary Fish and Lower Trophic Communities project consists of 24 data tables in Microsoft Excel format. Tables report station collection and environmental data, catch data for pelagic and demersal fishes, zooplankton, benthic infauna and epifauna, and data about individual specimens of fishes and invertebrates. Data about subsets of fish specimens include length, weight, age, fatty acid content, stable isotope ratios in muscle tissues, and diet. Environmental data include conductivity, temperature, density vertical profiles and sediment grain size data. Data are provided as Microsoft Excel files, with each file having one worksheet of data and one worksheet of metadata that describe the data fields.

This project was funded by the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM), Alaska Outer Continental Shelf Region, Anchorage Alaska, through Cooperative Agreement Award No. M12AC00011 between BOEM and the University of Alaska Fairbanks, as part of the MMS Alaska Environmental Studies Program.

Please contact Brenda Holladay with comments or questions:

Brenda Holladay
Research Scientist/Database Manager
Fisheries Oceanography Laboratory
College of Fisheries and Ocean Sciences
University of Alaska Fairbanks
P.O. Box 757220, Fairbanks, AK 99775-7220
Voice - 907-474-5428; Fax - 907-474-7204
Email: bahollladay@alaska.edu

TABLE OF CONTENTS - DATABASE TABLES

COLLECTION DATA

BIOLOGICAL DATA

SPECIMEN DATA

ENVIRONMENTAL DATA

MISCELLANEOUS TABLES

COLLECTION DATA

Table 1. **tblCruise.** One row for each type of gear deployed on open-water cruises TB-2012-US, TB-2013-US, TB-2014-US and under-ice cruise TB-2014-Ice.
Each combination of Cruise and Gear is unique.

Field	**Type**	**Description**
Cruise	Text	Name that associates a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
CruiseAlt	Text	Populated only where alternate names have been used to identify Cruise. Blank indicates no data
Region	Text	E.g., U.S. Beaufort Sea, Canadian Beaufort Sea
Vessel	Text	Sampling base. E.g., name of vessel from which gear was deployed, shore-based
Year	Number	Year of cruise
DateStart	yyyy-mm-dd	Local date of start of cruise, i.e., vessel leaves dock. Where no vessel was utilized, DateStart is date of first deployment of any Gear during cruise
DateEnd	yyyy-mm-dd	Local date of end of cruise, i.e., vessel returns to dock
LatLongComment	Text	E.g., vessel Global Positioning System (GPS); celestial navigation; one position per deployment
MeshSmallest_mm	Number	Populated only for net gear. Smallest mesh size in the gear in millimeters; usually from codend or codend liner or sieve. NA indicates not applicable
DeploymentMethod	Text	Description of the typical deployment method for this gear during cruise
DurationReported	Text	Availability in database of duration of deployment: yes, no, not applicable (NA), or comment
DistanceReported	Text	Availability in database of distance of deployment: yes, no, not applicable (NA), or comment
SwathReported	Text	Availability in database of horizontal swath (width of haul track or observation): yes, no, not applicable (NA), or comment
CountReported	Text	Availability in database of count data: yes, no, not applicable (NA), or comment
WeightReported		Availability in database of weight data: yes, no, not applicable (NA), or comment
CPUEReported	Text	Availability in database of abundance (catch-per-unit-effort) data: yes, no, not applicable (NA), or comment
BiomassReported	Text	Availability in database of biomass data: yes, no, not applicable (NA), or comment
VoucherCollections	Text	Location of voucher collections, not applicable (NA), or comment
Comment	Memo	Blank cell or comment about row of data

37 rows

Table 2. **tblEvent.** Details about deployment and environmental parameters associated with each deployment of gear during open-water cruises TB-2012-US, TB-2013-US, TB-2014-US and under-ice cruise TB-2014-Ice..
Data rows are sorted by Cruise, Gear and Haul. Each Event is unique.

Field	Type	Description
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores. E.g., TB-2012-US_B1-500_IKMT_6. "x" is a placeholder for a missing gear or haul.
Region	Text	E.g., U.S. Beaufort Sea, Canadian Beaufort Sea, U.S. Chukchi Sea
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Stratum_TB	Text	The study region of TB cruises was divided into 11 geographical transects: western TB area (B2, BX, B1) eastern US TB area (A6, A5, A4, A2, A1) and Canadian TB area (TBS, MAC, GRY). The B, A, and TBS transects were placed along lines of longitude. The MAC and GRY transects radiated to the northwest from near the mouth of the Mackenzie River. Stations off-transect were assigned as not applicable (NA)
TargetStnDepth_m	Number	Depth stratum in meters or not applicable (NA)
Station	Text	Name identifying the site (location) to associate multiple deployments of gear. Transboundary station names indicate Stratum (transect) and target station depth, e.g., A1-50 indicates transect A1 and 50 m
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise; "no data" indicates deployment sequence unknown
Year	Number	Year of field collection
Date	yyyy-mm-dd	Local date of haul or "no data" indicating precise date unknown
Time	hh:mm	Time of sample collection or "no data"
Duration_min	Number	Number of minutes the gear was deployed. For bottom trawls, Duration_min is the number of minutes the gear was on the sea floor. “No data” indicates missing value and "NA" indicates not applicable
Latitude	Number	Latitude of vessel at start of Haul in decimal degrees; if only one latitude was reported for the haul that latitude is assigned in this field. xx.xxxx
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; if only one longitude was reported for the haul that longitude is assigned in this field; -xxx.xxxx

Field	Type	Description
LatitudeEnd	Number	Latitude of vessel at the end of Haul in decimal degrees; xx.xxxx. Blank indicates no data
LongitudeEnd	Number	Longitude of vessel at the end of Haul in negative decimal degrees to indicate western hemisphere; -xxx.xxxx. Blank indicates no data
DepthGearMin_m	Number	Minimum depth of Haul in meters
DepthGearMax_m	Number	Maximum depth of Haul in meters
DepthGearPredom_m	Number	Predominant depth of Haul in meters, not applicable (NA) or "no data". For bottom trawl net hauls this is equal to DepthMax_m; for pelagic net hauls that did not pause at a particular depth this is equal to average of DepthMin_m and DepthMax_m
DepthStn_m	Number	Depth of station in meters
DistanceTowed_m	Number	Distance between start and end positions of haul in meters, not applicable (NA) or "no data"
Swath	Number	Effective opening of the gear in meters (e.g., bottom trawls) or sq m (e.g., plankton nets, sediment grab); units are indicated. "No data" is assigned to nets without fixed opening and "NA" indicates not applicable
CPUE_Quality	Text	CPUE area, CPUE distance, CPUE volume, CPUE proportional, Presence or "no data". CPUE area: catch data are quantitative per unit area & can be compared with hauls of same gear. CPUE distance and CPUE volume: catch data can be compared within a gear type. CPUE proportional: area, distance and time on bottom not known: analyze by proportional catch; Presence: analysis should be limited to taxon presence (e.g., specimens collected from haul that was incompletely sorted, gear deployment unsuccessful, haul not quantitative)
Comment	Memo	Comment about row of data or blank cell

873 rows

BIOLOGICAL DATA

Table 3. **tblFish_Catch_2012-14**. Count, weight, abundance and biomass of fishes at each haul by fishing gear from cruises TB-2012-US, TB-2013-US and TB-2014-US. No fishes were caught during cruise TB-2014-Ice.
Fishing gears include pelagic nets Aluette midwater trawl (AMT) and Isaacs-Kidd midwater trawl (IKMT), and benthic nets Canadian benthic trawl (CBT), otter trawl (OT) and modified plumb staff beam trawl (PSBT-A). Where appropriate count and weight data are standardized to time (10 min), distance (1000 m), area (1000 square meters) or volume (1000 cubic m). Data rows are sorted by Cruise, Gear, Haul and taxon AnalysisLevel. Each combination of Event and NameScientific is unique.

Field	**Type**	**Description**
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores. E.g., TB-2012-US_B1-500_IKMT_6. "x" is a placeholder for a missing gear or haul.
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Stratum_TB	Text	The study region of TB cruises was divided into 11 geographical transects in 4 areas: western TB area (B2, BX, B1) eastern US TB area (A6, A5, A4, A2, A1) and Canadian TB area (TBS, MAC, GRY). The B, A, and TBS transects were placed along lines of longitude. The MAC and GRY transects radiated to the northwest from near the mouth of the Mackenzie River
TargetStnDepth_m	Number	Depth stratum in meters
Station	Text	Name identifying the site (location) to associate multiple deployments of gear. Transboundary station names indicate Stratum (transect) and target station depth, e.g., A1-50 indicates transect A1 and 50 m
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used for associating data from multiple events at station.
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Mesh_Smallest_mm	Text	Smallest mesh size in the gear; usually from codend, codend liner of net, or mesh of sieve. NA indicates not applicable
Swath	Number	Effective opening of the gear in meters (e.g., bottom trawls) or sq m (e.g., plankton nets, sediment grab); units are indicated. "No data" is assigned to nets without fixed opening and "NA" indicates not applicable
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise
Date	yyyy-mm-dd	Local date of Event
Time_StartHaul	hh:mm:ss	Local time at start of Haul or "no data". For oblique hauls by Bongo and IKMT, Time_StartHaul when net is at surface of water at beginning of deployment. For midwater hauls targeting a particular depth range, Time_StartHaul is when net arrives at target depth. For bottom trawls hauls, Time_StartHaul is when net is on the seafloor with wire fully deployed

Field	Type	Description
Duration_min	Number	Number of minutes the gear was deployed. For bottom trawls, Duration_min is the number of minutes the gear was on the sea floor. “No data” indicates missing value and "NA" indicates not applicable
GearDepthMin_m	Number	Minimum depth of the Haul in meters
GearDepthMax_m	Number	Maximum depth of the Haul in meters
GearDepthPredom_m	Number	Predominant depth of Haul in meters; for bottom trawl hauls this is equal to DepthMax_m; for pelagic hauls that did not pause at a particular depth this is equal to average of DepthMin_m and DepthMax_m
DepthStn_m	Number	Depth of station in meters; for bottom trawl hauls this is equal to DepthMax_m
Latitude	Number	Latitude of vessel at start of Haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
DistanceTowed_m	Number	Distance between start and end positions of haul in meters, not applicable (NA) or "no data"
CPUE_Quality	Text	CPUE area, CPUE distance, CPUE volume, CPUE proportional, or Exclude from analysis. CPUE area: catch data are quantitative per unit area & can be compared with hauls of same gear. CPUE distance and CPUE volume: catch data can be compared within a gear type. CPUE proportional: area, distance and time on bottom not known but deployment appeared successful: analyze by relative count or weight of taxon. Exclude from analysis: data are not appropriate for CPUE or Presence/Absence analyses; fishes or other biological samples are sometimes retained from this quality of haul; may be assigned to hauls where gear deployment was unsuccessful or haul was incompletely sorted
PercentSorted	Text	Set as a number between 0 and 100 if a portion of the haul was sorted quantitatively; 0 indicates none of haul was sorted; "NQ" indicates haul was not sorted in a quantitative fashion
Family	Text	Scientific name of family
AnalysisLevel	Text	Taxonomic level at which taxa were aggregated for some analyses; some taxa are also divided into ranges of total length, e.g., Icelus spp. ≤40 mm and Icelus spp. 41-87 mm
NameScientific	Text	Genus and species, or the most precise level of taxonomy available; set as "None captured" at hauls where no fishes were captured and CPUE_Quality is other than "NonQuant"
Presence	Number	1 indicates the taxon was present at a haul of any CPUE_Quality
Count_per_Haul	Number	Count of individuals in entire haul or "no data"; where only part of haul was sorted, count was extrapolated to 100% of the haul. Where CPUE_Quality = presence, this field is set to "no data" to discourage standardization of nonquantitative data
Wt_per_Haul_g	Number	Demersal gears only. Weight of taxon in the entire haul in grams; where only part of haul was sorted, this weight is extrapolated to 100% of the haul. Where CPUE_Quality = presence, field is set to "no data" to discourage standardization of nonquantitative data
Count_per_10_min	Number	Count of individuals standardized to 10 minute haul or "no data". (Count_per_Haul / Duration in minutes) * 10 min.

Field	Type	Description
Weight_per_10_min_g	Number	Demersal gears only. Weight of taxon standardized to 10 minute haul in grams or "no data". (Weight_per_Haul_g / Duration in minutes) * 10 min
Count_per_1000_m	Number	Count of individuals standardized to 1000 m distance or "no data". (Count_per_Haul / DistanceTowed_m) * 1000
Weight_per_1000_m_g	Number	Demersal gears only. Weight of taxon standardized to 1000 m distance or "no data". (Weight_per_Haul_g / DistanceTowed_m) * 1000
Count_per_1000_sq_m	Number	Count of individuals standardized to 1000 sq m of sea floor (benthic nets), water surface (pelagic nets), or "no data". CBT: (Count_per_Haul / (DistanceTowed_m * 3 m NetSwath_m) * 1000; PSBT-A: (Count_per_Haul / (DistanceTowed_m * 2.257 m NetSwath_m) * 1000; IKMT: (Count_per_Haul / DistanceTowed_m * 1.5 m) * 1000, where 1.5 m is horizontal swath of IKMT
Weight_per_1000_sq_m_g	Number	Demersal gears only. Weight of taxon standardized to 1000 sq m of sea floor or "no data". CBT: (Weight_per_Haul_g / (DistanceTowed_m * 3 m NetSwath_m) * 1000; PSBT-A: (Weight_per_Haul_g / (DistanceTowed_m * 2.257 m NetSwath_m) * 1000
Count_per_1000_cu_m	Number	Count of individuals standardized to 1000 cubic meters volume or "no data". IKMT: (Count_per_Haul / DistanceTowed_m * 2.137 sq m) * 1000. Mouth of IKMT is 2.137 sq m when net is fished at 45 degree angle.
Comment	Memo	Comment about row of data or blank cell

1556 rows

Table 4. **tblFish_TLength_Increment.** Count and weight of each fish taxon, by 10-mm increment of total length, at each haul by fishing gear from cruises TB-2012-US, TB-2013-US and TB-2014-US. Abundance and biomass are reported for hauls that are quantitative for area or volume fished.
Fishing gears include pelagic nets Aluette midwater trawl (AMT) and Isaacs-Kidd midwater trawl (IKMT), and benthic nets Canadian benthic trawl (CBT), otter trawl (OT) and modified plumb staff beam trawl (PSBT-A). Biomass (grams per 1000 sq m) and abundance (number individuals per 1000 sq m) are reported for quantitative CBT and PSBT-A hauls. Abundance (number individuals per 1000 cu m) is reported for quantitative IKMT hauls. Data rows are sorted by Cruise, Gear, Haul, NameScientific and Midpoint_10mm. Each combination of Event, NameScientific and Midpoint_10mm is unique.

Field	**Type**	**Description**
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores. E.g., TB-2012-US_B1-500_IKMT_6. "x" is a placeholder for a missing gear or haul.
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name identifying the site (location) to associate multiple deployments of gear. Transboundary station names indicate Stratum (transect) and target station depth, e.g., A1-50 indicates transect A1 and 50 m
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used for associating data from multiple events at station.
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Mesh_Smallest_mm	Text	Smallest mesh size in the gear; usually from codend, codend liner of net, or mesh of sieve. NA indicates not applicable
Swath	Number	Effective opening of the gear in meters (e.g., bottom trawls) or sq m (e.g., plankton nets, sediment grab); units are indicated. "No data" is assigned to nets without fixed opening and "NA" indicates not applicable
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise
Date	yyyy-mm-dd	Local date of Event
Time_StartHaul	hh:mm:ss	Local time at start of Haul or "no data". For oblique hauls by Bongo and IKMT, Time_StartHaul when net is at surface of water at beginning of deployment. For midwater hauls targeting a particular depth range, Time_StartHaul is when net arrives at target depth. For bottom trawls hauls, Time_StartHaul is when net is on the seafloor with wire fully deployed
Duration_min	Number	Number of minutes the gear was deployed. For bottom trawls, Duration_min is the number of minutes the gear was on the sea floor. “No data” indicates missing value and "NA" indicates not applicable
GearDepthMin_m	Number	Minimum depth of the Haul in meters
GearDepthMax_m	Number	Maximum depth of the Haul in meters
DepthStn_m	Number	Depth of station in meters; for bottom trawl hauls this is equal to DepthMax_m
Latitude	Number	Latitude of vessel at start of Haul in decimal degrees; xx.xxxx

Field	Type	Description
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
DistanceTowed_m	Number	Distance between start and end positions of haul in meters, not applicable (NA) or "no data"
CPUE_Quality	Text	CPUE area, CPUE distance, CPUE volume, CPUE proportional, Presence or "no data". CPUE area: catch data are quantitative per unit area & can be compared with hauls of same gear. CPUE distance and CPUE volume: catch data can be compared within a gear type. CPUE proportional: area, distance and time on bottom not known: analyze by proportional catch; Presence: analysis should be limited to taxon presence (e.g., specimens collected from haul that was incompletely sorted, gear deployment unsuccessful, haul not quantitative)
NameScientific	Text	Genus and species, or the most precise level of taxonomy available; set as "None captured" at hauls where no fishes were captured and CPUE_Quality is other than "NonQuant"
Midpoint_10mm	Number	Midpoint of 10-mm increment of total length, e.g. 25 for 21-30 mm, 35 for 31-40 mm. Field is set to "0" at hauls where no fishes were captured
Count_per_Haul	Number	Count of individuals in entire haul or "no data"; where only part of haul was sorted, count was extrapolated to 100% of the haul. Where CPUE_Quality = presence, this field is set to "no data" to discourage standardization of nonquantitative data
Wt_per_Haul_g	Number	Demersal gears only. Weight of taxon in the entire haul in grams; where only part of haul was sorted, this weight is extrapolated to 100% of the haul. Where CPUE_Quality = presence, field is set to "no data" to discourage standardization of nonquantitative data
Count_per_1000_sq_m	Number	Count of individuals standardized to 1000 sq m of sea floor (benthic nets), water surface (pelagic nets), or "no data". CBT: (Count_per_Haul / (DistanceTowed_m * 3 m NetSwath_m) * 1000; PSBT-A: (Count_per_Haul / (DistanceTowed_m * 2.257 m NetSwath_m) * 1000; IKMT: (Count_per_Haul / DistanceTowed_m * 1.5 m) * 1000, where 1.5 m is horizontal swath of IKMT
Weight_per_1000_sq_m_g	Number	Demersal gears only. Weight of taxon standardized to 1000 sq m of sea floor or "no data". CBT: (Weight_per_Haul_g / (DistanceTowed_m * 3 m NetSwath_m) * 1000; PSBT-A: (Weight_per_Haul_g / (DistanceTowed_m * 2.257 m NetSwath_m) * 1000
Count_per_1000_cu_m	Number	Count of individuals standardized to 1000 cubic meters volume or "no data". IKMT: (Count_per_Haul / DistanceTowed_m * 2.137 sq m) * 1000. Mouth of IKMT is 2.137 sq m when net is fished at 45 degree angle.
Comment	Memo	Comment about row of data or blank cell

3241 rows

Table 5. **tblZoop_Catch_2012-14.** Abundance and biomass of zooplankton taxa in each haul by plankton nets during cruises TB-2012-US, TB-2013-US and TB-2014-US and count of taxa in Vertical Net hauls during TB-2014-Ice.
Plankton nets include 505µ Bongo, 150µ Multinet and 150µ Vertical Net. ZoopRefNum is unique, as is each combination of Event, NameScientific and LifeHistory_Stage.

Field	**Type**	**Description**
ZoopRefNum	Number	Number that is unique identifier for row of zooplankton data. Assigned by Investigator
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores
CruiseStation	Text	Concatenation of Cruise and Station; used to associate multiple gear deployments at Station
Year	Number	Year of sample collection
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise
Mesh_mm	Text	Size of mesh aperture over which sample was sieved (mm)
Station	Text	Name identifying the site to associate multiple deployments of gear
StationCode_Zoop	Text	Investigator's code for Station
Latitude	Number	Latitude of vessel at start of haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
DepthGearMin_m	Number	Minimum depth of Haul (m)
DepthGearMax_m	Number	Maximum depth of Haul (m)
Depth_Stn_m	Number	Depth of station (m)
Date	yyyy-mm-dd	Local date of Event
Time	hh:mm	Time of sample collection or "no data"
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
LifeHistory_Stage	Text	Comment on life history stage or sex (e.g., larva, male). Blank cell indicates no data
Count_per_Haul	Number	Count of individuals in entire haul or "no data"
Count_per_cum	Number	Count of individuals standardized to 1 cubic meter volume
Weight_per_cum	Number	Weight of taxon standardized to 1 cubic meter volume or "no data"

9144 rows

Table 6. **tblInfauna_Catch_2012&14.** Count, weight, abundance and biomass of infaunal taxa collected in sediment samples during cruises TB-2012-US and TB-2014-US and count of infaunal taxa collected during cruise TB-2014-Ice.
Sediment samples were collected by Box Core (2012), single Van Veen (TB-2014-US) or Ponar Grab (TB-2014-Ice). All samples were sieved over 0.5 mm mesh. Each combination of Event and NameScientific is unique.

Field	Type	Description
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores. "x" is a placeholder for a missing gear or haul.
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity
Station	Text	Name or number identifying the site (location); usually assigned during cruise to associate multiple deployments of gear
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore
Latitude	Number	Latitude of Station in decimal degrees; xx.xxxx
Longitude	Number	Longitude of Station in decimal degrees; negative decimal degrees indicate western hemisphere; -xxx.xxxx
Replicate	Number	Replicate sample by Gear at Station during Cruise
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise; "no data" indicates deployment sequence unknown
Mesh_mm	Number	Size of mesh aperture over which sample was sieved (mm)
CPUE_Infauna	Text	CPUE area, CPUE proportional, Presence. CPUE area: catch data are quantifiable per unit area. CPUE proportional: area not known -- analyze by proportional catch. Presence: analysis should be limited to taxon presence
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
Voucher	Text	Populated only where sample was retained as species voucher and otherwise blank
FragOrColony	Text	Populated only where taxon is fragment or colonial and otherwise blank
Count_per_ Sample	Number	Count of individuals observed in sample. Fragments and colonial animals were assigned as 1
Weight__per_ Sample_g	Number	Wet weight of NameScientific (g) to the nearest 0.001 g; if sample did not register a value at 0.001 g, it was assigned as 0.0005 g. Assigned as "no data" if sample was not weighed
Count_per_sqm	Number	Count of NameScientific per square m seafloor. Where Gear = Van Veen, Count_per_Sample * 10, since Van Veen samples 0.1 sq m surface area. Where Gear = Box Core, Count_per_Sample * 8, since infauna sample was from half the surface of a 0.25 sq m Box Core. Assigned as "no data" if CPUE_Infauna is other than "CPUE area"
Weight_per _sqm_g	Number	Wet weight of NameScientific per square m seafloor in grams. Where Gear = Van Veen, which samples 0.1 sq m seafloor, value = Weight_per_Sample * 10. Where Gear = Box Core, which samples 0.25 sq m seafloor, value = Weight_per_Sample * 8. Assigned as "no data" if CPUE_Infauna is other than "CPUE area"

3537 rows data

Table 7. **tblEpifaunaBiomass_2013-14**. Biomass of epifaunal taxa at stations of cruises TB-2013-US and TB-2014-US sampled by beam trawl.
Data are averaged by station. Biomass is reported as grams per 1000 sq m. Data are arranged with two descriptive fields (NameScientific and TaxonGroup) followed by one column for each CruiseStation. Each combination of CruiseStation and NameScientific is unique.

Field	Type	Description
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
TaxonGroup	Text	Coarse level of taxonomic classification
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore
Biomass data for each CruiseStation is in a separate column		

175 rows

Table 8. **tblEpifaunaAbundance_2013-14.** Abundance of epifaunal taxa at stations of cruises TB-2013-US and TB-2014-US sampled by beam trawl.
Data are averaged by station. Abundance is in units of # per 1000 sq m. Data are arranged with two descriptive fields (NameScientific and TaxonGroup) followed by one column for each CruiseStation. Each combination of CruiseStation and NameScientific is unique.

Field	Type	Description
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
TaxonGroup	Text	Coarse level of taxonomic classification
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore
Abundance data for each CruiseStation is in a separate column		

175 rows

Table 9. **tblEpifaunaRelBiomass_2012**. Relative (proportional) biomass of epifaunal taxa in beam trawl hauls during cruise TB-2012-US, by gear.
Beam trawl gears include Canadian benthic trawl (CBT) and modified plumb staff beam trawl (PSBT-A). Data are arranged with two descriptive rows (CruiseStation and Gear) and two descriptive fields (NameScientific and TaxonGroup). Each combination of the fields CruiseStation and Gear with row NameScientific is unique.

Field	Type	Description
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore
Gear	Text	Beam trawls: PSBT-A and CBT
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
TaxonGroup	Text	Coarse level of taxonomic classification
Biomass data for each CruiseStation and Gear is in a separate column		

153 rows

Table 10. **tblEpifaunaRelAbund_2012.** Relative (proportional) abundance of epifaunal taxa in beam trawl hauls during cruise TB-2012-US, by gear.
Beam trawl gears include Canadian benthic trawl (CBT) and modified plumb staff beam trawl (PSBT-A). Data are arranged with two descriptive rows (CruiseStation and Gear) and two descriptive fields (NameScientific and TaxonGroup). Each combination of the fields CruiseStation and Gear with row NameScientific is unique.

Field	**Type**	**Description**
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore
Gear	Text	Beam trawls: PSBT-A and CBT
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
TaxonGroup	Text	Coarse level of taxonomic classification
Abundance data for each CruiseStation and Gear is in a separate column		

147 rows

SPECIMEN DATA

Table 11. **tblFish_Specimen.** Length, weight and list of analyses applied to individual fish specimens captured during cruises TB-2012-US, TB-2013-US, TB-2014-US; no fishes were captured during TB-2014-Ice.

Not all captured fishes are in this table. Fields indicate length, weight, sex, age and whether the specimen was used in analyses of diet, length-frequency, length-weight or stable isotopes. Fields indicate where tissues were provided to other researchers for genetics analysis and specimens are archived in a voucher collection. Rows are sorted by Event, NameScientific, LengthTotal_mm. Each SpecimenNum is unique.

Field	Type	Description
SpecimenNum	Text	Identifier for an individual fish specimen in the UAF Fisheries Oceanography Lab database. An integer was assigned to each fish whose tissues were sampled or information was recorded specific to that individual. Entries beginning with "LW" and “F” were measured only for length and weight and processed fish bodies were not individually labeled. Processed fishes with integer and “LW-“ SpecimenNums were retained for several years after project end; “F-“ SpecimenNums were discarded
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores. E.g., TB-2012-US_B1-500_IKMT_6
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple gear deployments at Station
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name identifying the site (location) of Event; usually assigned during cruise to associate multiple deployments of gear
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise
Latitude	Number	Latitude of vessel at start of haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
Date	yyyy-mm-dd	Local date of haul
DepthStn_m	Number	Depth of station in meters
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
LengthTotal_mm	Text	Total length is the preferred measure of fishes. Straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin; measured with the lobes compressed along the midline. Where exact total length was not measured, value is assigned as 10-mm length range (e.g., 11-20, 21-30, 31-40) or "no data"
Midpoint_10mm	Number	Midpoint of 10-mm increment of total length, e.g. 25 for 21-30 mm, 35 for 31-40 mm. Blank cell indicates total length not available

Field	Type	Description
LengthFork_mm	Text	Fork length is measured from the most anterior part of head to the deepest point of notch in the caudal fin. "No data" indicates fork length was not measured
LengthStandard_mm	Text	Standard length is the typical measure of larval fishes because caudal fin may not be fully developed and is often damaged. Straight-line measure from the most anterior part of head to the end of caudal peduncle. "No data" indicates standard length was not measured
Weight_g	Number	Weight in grams, after blotting to remove excess water. "No data" indicates weight was not measured
Sex	Text	Male, female. Blank cell indicates sex was not assessed
LifeStage	Text	Mature, juvenile, larvae, egg. Blank cell indicates LifeStage was not assessed
Age	Number	Assigned based on analysis of otoliths; 0 = young of the year, 1 = age-1, 2 = age-2, etc. Blank cell indicates age was not assessed
Diet_Analyzed	Text	Set as "X" where stomach contents of SpecimenNum were examined and reported in tblFish_Diet. Blank cell indicates diet was not assessed
LengthFrequency_Analyzed	Text	Set as "X" where fish was used in length frequency histograms in project final report. Blank cell indicates fish was excluded from analysis
LengthWeight_Analyzed	Text	Set as "X" where fish was used in length-weight regression analyses in project final report. Blank cell indicates fish was excluded from analysis
StableIsotopes_Analyzed	Text	Set as "X" where muscle tissue of SpecimenNum was analyzed for carbon and nitrogen stable isotopes. Blank cell indicates stable isotopes not assessed
GeneticsSample_SandyTalbot	Text	Set as "X" where tissue was provided to Sandy Talbot of United States Geological Survey/Anchorage/AK <stalbot@usgs.gov>. Blank cell indicates not provided
Voucher	Text	Notation indicating location and identifying code for voucher specimen or "X" if location and code are not known. Blank cell indicates specimen is not archived as a voucher
Comment	Memo	Comment about row of data. Blank cell indicates no comment

9538 rows

Table 12. **tblFish_Diet.** Stomach contents of fishes examined from cruises TB-2012-US, TB-2013-US and TB-2014-US.
Predators were captured with pelagic and demersal fishing gears. One row for each prey taxon identified from one predator's stomach or one row that reports predator's empty stomach. Data rows are sorted by SpecimenNum and PreyTaxon_Precise. Each combination of SpecimenNum and PreyTaxon_Precise is unique.

Field	Type	Description
SpecimenNum	Text	Identifier for an individual fish specimen in the UAF Fisheries Oceanography Lab database
Event	Text	Unique identifier for each deployment of fishing gear; includes Cruise, Station, Gear and Haul separated by underscores
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple gear deployments at Station
Sea	Text	E.g., Beaufort, Chukchi
StrataDiet	Text	The 11 transects of the Transboundary study region were grouped into four geographic regions to stratify diet analyses: Central Beaufort (B2, BX, B1), Camden Bay (A6, A5, A4), US-Canada Transboundary (A2, A1, TBS) and Mackenzie River (MAC, GRY)
Pelagic_or _Demersal	Text	Gear used to collect sample was assigned as pelagic, demersal or "no data"
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise; "no data" indicates deployment sequence unknown
Station	Text	Name identifying the site to associate multiple deployments of gear
DepthStn_m	Number	Depth of station in meters
Latitude	Number	Latitude of vessel at start of haul in decimal degree; xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
Year	Number	Year of haul
Date	yyyy-mm-dd	Local date of haul or "no data" indicating precise date unknown
PredatorSpecies	Text	Genus and species of the fish SpecimenNum
LengthTotal_mm	Text	Total length is the preferred measure of fishes: straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin, measured with the lobes compressed along the midline. 10-mm length range is reported where exact length was not measured, e.g., 11-20, 21-30, 31-40. "No data" indicates total length was not measured
Weight_g	Text	Weight of fish specimen after blotting to remove excess water (grams) or "no data"
StomachFullness _Est	Text	Visual estimate of fish stomach fullness on a scale of 0–100% or "no data"

Field	Type	Description
StomachWeight _Full_g	Text	Weight of fish stomach measured to the nearest 0.0001 g or "burst" indicating stomach wall ruptured and stomach not weighed
StomachWeight _Empty_g	Text	Weight of empty stomach measured to the nearest 0.0001 g or "no data"
PreyTaxon_Coarse	Text	Prey taxonomic groups used for summary purposes
PreyTaxon _Precise	Text	Most precise taxonomic nomenclature assigned to a respective prey item
PreyTotalLength _mm	Text	Length of body of prey in mm or "no data" indicating unmeasured. Invertebrates: length does not include antennae or setae
PreySize	Text	Small ≤5 mm, medium >5 to <10 mm, large >10 mm, "frags" indicating unmeasured fragmented prey or "no data" indicating unmeasured
PreyCount	Text	When non-fragmented prey were present, PreyCount was based on counts of each prey item. When prey were fragmented, PreyCount was on presence of distinguishable body parts (heads; tails; other). If prey was colonial or without distinguishable parts, PreyCount was assigned as 1. Due due to prey fragmentation, the number of prey length values in PreyTotalLength_mm may not match PreyCount
PreyWeight_g	Text	Prey weights were measured to the nearest 0.0001 g; if a prey item did not register a value at 0.0001 g, it was assigned as 0.00005 g. "No data" was assigned to empty stomachs and prey excluded from data analyses
Comment	Text	Blank cell or comment about row of data

8197 rows

Table 13. **tblStableIsotope_Data.** Carbon and nitrogen stable isotope ratios of fishes, invertebrates, sediment and particulate organic matter from cruises TB-2012-US, TB-2013-US and TB-2014-US. Each combination of SI_SampleID (or SpecimenNum for fishes) and ReplicateNum is unique.

Field	Type	Description
SI_SampleID	Text	Unique identifier for a sample that was analyzed for nitrogen and carbon stable isotope ratios
SpecimenNum	Text	Identifier for an individual fish specimen in the UAF Fisheries Oceanography Lab database
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple events at station
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name or number identifying the site (location) of Event; usually assigned during cruise to associate multiple deployments of gear
Latitude	Number	Latitude of vessel at start of haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
Year	Number	Year of field collection
Date	yyyy-mm-dd	Local date of sample collection or "no data" indicating precise date unknown
DepthStn_m	Number	Depth of station (m)
TaxonGroup	Text	Coarse taxonomic group for animals, e.g., Pisces (fishes), Bivalvia, Cumaca. Also sediment and particulate organic matter
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
LengthTotal_mm	Text	Total length is the preferred measure of fishes: straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin, measured with the lobes compressed along the midline. 10-mm length range is reported where exact length was not measured, e.g., 11-20, 21-30, 31-40. "No data" indicates total length was not measured
TissueType	Text	E.g., muscle, liver, whole animal homogenate. "NA" indicates not applicable and "no data" indicates not reported
Count_in_Sample	Number	Count of individual specimens in analyzed sample or "no data"
ReplicateNum	Number	Number indicating replicate within stratum (Cruise, Station, NameScientific). Blank cell indicates no replicate
Del_15N	Number	Stable isotope ratio of 15N/14N or "no data". Run on tissue that was not lipid-extracted
Del_13C	Number	Stable isotope ratio of 13C/12C or "no data". Fish tissues are lipid-extracted prior to stable isotope analysis; other samples are not lipid-extracted
Comment	Memo	Blank cell or comment about row of data

4707 rows data

Table 14. **tbl_Fish_FattyAcidPercent_of_total.** Record of 72 fatty acids (grams lipid per gram of whole-body homogenate) identified and quantified for specimens from three fish species (*Boreogadus saida, Lycodes polaris and Lycodes seminudis*), three cruises in the Beaufort Sea (BOEM-2011, TB-2012-US, TB-2013-US) and three cruises in the Chukchi Sea (AKCH10, AKCH11, RUSALCA-2012).
All specimens were collected with bottom trawl nets. Each SpecimenNum corresponds to an individual fish in the UAF Fisheries Oceanography database of which only a subset of are reported in the Transboundary database tblFish_Specimen, and therefore Haul and Specimen details are provided here for all specimens with fatty acid data. Each FA_SampleID and each SpecimenNum is unique.

Field	**Type**	**Description**
SpecimenNum	Text	Identifier for an individual fish specimen in the UAF Fisheries Oceanography Lab database
FA_SampleID	Text	Identifier for an individual fish that was analyzed for fatty acids (FA). Code indicates genus, species, Year, Region and consecutive sample. E.g., BS11B1: BS = Boreogadus saida, 11 = 2011, B = Beaufort, 1 = first sample.
Region	Text	E.g., U.S. Beaufort Sea, Canadian Beaufort Sea, U.S. Chukchi Sea
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name or number identifying the site (location) of HaulUnique; usually assigned during cruise to associate multiple deployments of gear
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple deployments of gear
Year	Number	Year of field collection
TargetStnDepth_m	Number	Depth stratum in meters
Date	yyyy-mm-dd	Local date of haul
Latitude	Number	Latitude of vessel at start of Haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
LengthTotal_mm	Number	Total length is the preferred measure of fishes: straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin, measured with the lobes compressed along the midline.
Weight_g	Number	Weight of fish specimen after blotting to remove excess water (grams) or "no data"
Stomach	Number	Set as 1 where stomach contents were analyzed of SpecimenNum; 0 where stomach contents were not examined
Lipid_per_Tissue	Number	Grams of lipid per gram of fish tissue, where the tissue is whole-body homogenate
One column reporting grams lipid per gram of whole-body homogenate for each of 72 fatty acids. Columns are labeled with fatty acid chemical names, e.g., 10:0, 14:1w0, iso 15:0.		

177 rows data

Table 15. **tbl_Fish_FattyAcid_per_g_Tissue.** Record of 72 fatty acids (micrograms fatty acid per gram of whole-body homogenate) for specimens from three fish species (*Boreogadus saida, Lycodes polaris and Lycodes seminudis*), three cruises in the Beaufort Sea (BOEM-2011, TB-2012-US, TB-2013-US) and three cruises in the Chukchi Sea (AKCH10, AKCH11, RUSALCA-2012).
All specimens were collected with bottom trawl nets. Each SpecimenNum corresponds to an individual fish in the Norcross database; only a subset of those specimens are reported for the Transboundary project and therefore Haul and Specimen details are provided in fatty acid tables. Each FA_SampleID and each SpecimenNum is unique.

Field	**Type**	**Description**
SpecimenNum	Text	Identifier for an individual fish specimen in the UAF Fisheries Oceanography Lab database
FA_SampleID	Text	Identifier for an individual fish that was analyzed for fatty acids (FA). Code indicates genus, species, Year, Region and consecutive sample. E.g., BS11B1: BS = Boreogadus saida, 11 = 2011, B = Beaufort, 1 = first sample.
Region	Text	E.g., U.S. Beaufort Sea, Canadian Beaufort Sea, U.S. Chukchi Sea
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name or number identifying the site (location) of HaulUnique; usually assigned during cruise to associate multiple deployments of gear
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple deployments of gear
Year	Number	Year of field collection
TargetStnDepth_m	Number	Depth stratum in meters
Date	yyyy-mm-dd	Local date of haul
Latitude	Number	Latitude of vessel at start of Haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
LengthTotal_mm	Number	Total length is the preferred measure of fishes: straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin, measured with the lobes compressed along the midline.
Weight_g	Number	Weight of fish specimen after blotting to remove excess water (grams) or "no data"
Stomach	Number	Set as 1 where stomach contents were analyzed of SpecimenNum; 0 where stomach contents were not examined
Lipid_per_Tissue	Number	Grams of lipid per gram of fish tissue, where the tissue is whole-body homogenate
One column reporting micrograms fatty acid per gram of whole-body homogenate for each of 72 fatty acids. Columns are labeled with fatty acid chemical names, e.g., 10:0, 14:1w0, iso 15:0.		

177 rows data

Table 16. **tbl_Fish_FattyAcid_per_g_Lipid.** Record of 72 fatty acids (milligrams fatty acid per gram of lipid) for specimens from three fish species (*Boreogadus saida, Lycodes polaris and Lycodes seminudis*), three cruises in the Beaufort Sea (BOEM-2011, TB-2012-US, TB-2013-US) and three cruises in the Chukchi Sea (AKCH10, AKCH11, RUSALCA-2012).
All specimens were collected with bottom trawl nets. Each SpecimenNum corresponds to an individual fish in the Norcross database; only a subset of those specimens are reported for the Transboundary project and therefore Haul and Specimen details are provided in fatty acid tables. Each FA_SampleID and each SpecimenNum is unique.

Field	**Type**	**Description**
SpecimenNum	Text	Identifier for an individual fish specimen in the UAF Fisheries Oceanography Lab database
FA_SampleID	Text	Identifier for an individual fish that was analyzed for fatty acids (FA). Code indicates genus, species, Year, Region and consecutive sample. E.g., BS11B1: BS = Boreogadus saida, 11 = 2011, B = Beaufort, 1 = first sample.
Region	Text	E.g., U.S. Beaufort Sea, Canadian Beaufort Sea, U.S. Chukchi Sea
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name or number identifying the site (location) of HaulUnique; usually assigned during cruise to associate multiple deployments of gear
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple deployments of gear
Year	Number	Year of field collection
TargetStnDepth_m	Number	Depth stratum in meters
Date	yyyy-mm-dd	Local date of haul
Latitude	Number	Latitude of vessel at start of Haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
LengthTotal_mm	Number	Total length is the preferred measure of fishes: straight-line measure from the tip of the snout to the tip of the longer lobe of the caudal fin, measured with the lobes compressed along the midline.
Weight_g	Number	Weight of fish specimen after blotting to remove excess water (grams) or "no data"
Stomach	Number	Set as 1 where stomach contents were analyzed of SpecimenNum; 0 where stomach contents were not examined
Lipid_per_Tissue	Number	Grams of lipid per gram of fish tissue, where the tissue is whole-body homogenate
g lipid/g tissue	Number	Grams of lipid per gram of fish tissue, where the tissue is whole-body homogenate
One column reporting milligrams fatty acid per gram of lipid for each of 72 fatty acids. Columns are labeled with fatty acid chemical names, e.g., 10:0, 14:1w0, iso 15:0.		

177 rows data

ENVIRONMENTAL DATA

Table 17. **tblEnvironSummary**. Compilation of environmental data for each CruiseStation, including surface and bottom water data from Conductivity Temperature Density (CTD) deployments, sediment characteristics, and bottom water mass. Used to associate fish and invertebrate Events with environmental data.

Field	Type	Description
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple events at station
CTDEvent	Text	Unique identifier for a deployment of CTD gear or note to see CTDComment. Identifier includes Cruise, Station, Gear and Haul separated by underscores. E.g., TB-2012-US_B1-100_CTD-25_3. "x" is a placeholder for a missing gear or haul
CTDDate	yyyy-mm-dd	Local date of CTD Haul or "no data" indicating precise date unknown
CTDTime	hh:mm:ss	Time of sample collection or "no data"
CTDDepthMax_m	Number	Maximum depth of CTD Haul in meters
DepthStn_m	Number	Depth of station (m)
SurfTemp_C	Number	Temperature near surface in degrees Celcius or "no data"
SurfSalinity	Number	Salinity near surface or "no data"
SurfDensity	Number	Density near surface (kg/m^3) or "no data"
SurfFluoresc	Number	pH near surface or "no data"
SurfPAR	Number	Fluorescence near surface (mg/m^3) or "no data"
SurfPH	Number	Photosynthetically Available Radiation near surface or "no data"
SurfO2	Number	Dissolved oxygen concentration near surface or "no data"
BotTemp_C	Number	Temperature near seafloor in degrees Celcius or "no data"
BotSalinity	Number	Salinity near seafloor or "no data"
BotDensity	Number	Density near seafloor (kg/m^3) or "no data"
BotFluorescence	Number	pH near seafloor or "no data"
BotPAR	Number	Fluorescence near seafloor (mg/m^3) or "no data"
BotPH	Number	Photosynthetically Available Radiation near seafloor or "no data"
BotO2	Number	Dissolved oxygen concentration near seafloor or "no data"
BotWaterMass	Text	Abbreviation for water mass near the sea floor or "no data". Arctic Halocline Water (AHC), Atlantic Water (AW) or Polar Mixed Layer (PML)
CTDComment	Memo	Blank cell or comment about CTD data
CTDData Restriction	Memo	Blank cell or comment about restricting use of CTD data
SedEvent	Text	Unique identifier for a deployment of gear that collected substrate or note to see SedComment. Identifier includes Cruise, Station, Gear and Haul separated by underscores. TB-2012-US_B1-1000_BoxCore_8. "x" is a placeholder for a missing gear or haul
SedGear	Text	Gear used to collect sediment sample. Gear is described more completely in table luGear
GravelPercent	Number	Percent weight of gravel in dried substrate (>2–64 mm); x.xx% or "no data"
SandPercent	Number	Percent weight of sand in dried substrate (0.0625–2 mm); x.xx% or "no data"
MudPercent	Number	Percent weight of mud in dried substrate (<0.0625 mm); x.xx% or "no data"; silt + clay = mud

Field	Type	Description
SiltPercent	Number	Percent weight of silt in dried substrate (3.90625–62.5 µm); x.xx% or "no data"
ClayPercent	Number	Percent weight of clay in dried substrate (< 3.90625 µm); x.xx% or "no data"
Substrate	Text	Qualitative description of substrate textural group with standardized terminology or "no data". Substrate is as assigned by GRADISTAT v.8.0 software (Blott 2010 as modified from Folk 1954) Blott SJ, Pye K (2001) GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surface Processes and Landforms 26(11):1237–1248. Folk RL (1954) The distinction between grain size and mineral composition in sedimentary-rock nomenclature. J Geology 62:344–359
PhiMean	Number	Mean phi size or "no data". Folk and Ward method as calculated using GRADISTAT v.8.0 software
PhiMean Description	Text	Qualitative description of the mean phi size or "no data". Folk and Ward method as assigned using GRADISTAT v.8.0 software
Sorting	Number	Sorting or "no data". Sorting is the standard deviation of the grain-size distribution and quantifies the “diversity” of grain sizes present
Kurtosis	Number	Kurtosis or "no data". Kurtosis (peakedness) of a grain-size distribution compares sorting in the central portion of the population with that in the tails; high kurtosis indicates an even distribution of sediment mass among grain size categories
Skewness	Text	Description of the degree of symmetry or asymmetry of the grain size distribution as assigned using GRADISTAT v.8.0 software or "no data"
Porosity	Number	Percent weight of water in substrate or "no data"
TOC	Number	Total organic carbon (mg per gram dry sediment) or "no data"
CN	Number	Carbon-to-nitrogen ratio or "no data". C:N ratio provides a relative measure of the food quality of organic matter
Lipid	Number	Lipid content of sediment (mg lipid per gram sediment) or "no data"
Chl-a_Inventory	Number	Amount of chlorophyll-a per area (mg chlorophyll-a per sq m of seafloor) or "no data"
Chl-a	Number	Concentration of chlorophyll-a in sediment (micrograms Chl-a per g sediment dry weight) or "no data"
Phaeopigment	Number	Concentration of phaeopigment or "no data". Phaeopigment is a degradation product of chlorophyll (micrograms Phaeopigment per g sediment dry weight)
Del_15N	Number	Stable isotope ratio of 15N/14N or "no data". Run on tissue that was not lipid-extracted
Del_13C	Number	Stable isotope ratio of 13C/12C or "no data". Fish tissues are lipid-extracted prior to stable isotope analysis; other samples are not lipid-extracted
SedComment	Memo	Blank cell or comment about sediment or substrate
SedData Restriction	Memo	Blank cell or comment about restricting use of sediment or substrate data

152 rows

Table 18. **tblCTD_Cast.** Record of each deployment (cast) of the Conductivity Temperature Density (CTD) measuring device during cruises TB-2012-US, TB-2013-US, TB-2014-US and TB-2014-Ice. Each Event is unique.

Field	**Type**	**Description**
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple deployments of gear
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name or number identifying the site (location); usually assigned during cruise to associate multiple deployments of gear
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise
Date_UTC	yyyy-mm-dd	Coordinated Universal Time (UTC) date of sample collection
Time_UTC	hh:mm	Coordinated Universal Time (UTC) of sample collection
Date_Local	yyyy-mm-dd	Local date of sample collection
Time_Local	hh:mm	Local time of sample collection
Latitude	Number	Latitude of vessel at start of haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
DepthStn_m	Number	Bottom depth of the station in meters
DepthGearMax_m	Number	Maximum depth of Haul in meters
Datafile	Text	E.g., CAST021AKBE11-EB02.hex.cnv or "no data"
Vessel	Text	Name of vessel from which gear was deployed
Agency	Text	Funding agency
PI	Text	Principal Investigator name and affiliation
Project	Text	Word or phrase indicating name of research project
Region	Text	E.g., U.S. Beaufort Sea, Canadian Beaufort Sea, U.S. Chukchi Sea
CTD_Operator	Text	Name of person responsible for CTD data collection
DataRestrictions	Text	E.g, indicate that data should not be associated with sea floor. Blank indicates no restriction
Comment	Text	Blank cell or comment about row of data

151 rows

Table 19. **tblCTD_Data_2012-14.** Environmental profile data (temperature, salinity, density, fluorescence, irradiance and dissolved oxygen) recorded by Conductivity Temperature Density (CTD) during cruises TB-2012-US, TB-2013-US, TB-2014-US and TB-2014-Ice.
One datum reported per vertical meter of CTD deployment. Data are sorted by Event and Depth_m. Each combination of Event and Depth_m is unique.

Field	**Type**	**Description**
Event	Text	Unique identifier for each deployment of gear; includes Cruise Station Gear and Haul separated by underscore symbols. Example: BOEM-2011_CB35_PSBT-A_89
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate Events
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name identifying the site (location) of Event; usually assigned during cruise to associate multiple deployments of Gear
Latitude	Number	Latitude of vessel at start of Haul in decimal degree; xx.xxxx
Longitude	Number	Longitude of vessel at start of Haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
Date	yyyy-mm-dd	Local date of sample collection
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number identifying the particular deployment of Gear. Usually assigned consecutively for each gear throughout the cruise. "No data" indicates data are not available
DepthStn_m	Number	Depth of station (m)
Depth_m	Number	Depth of sample (m)
Temp_C	Number	Temperature at sample depth in degrees Celcius or "no data"
Salinity	Number	Salinity at sample depth or "no data"
Density	Number	Density at sample depth (kg/m^3) or "no data"
pH	Number	pH at sample depth or "no data"
Fluorescence	Number	Fluorescence at sample depth (mg/m^3) or "no data"
PAR/Irradiance	Number	Photosynthetically Available Radiation at sample depth or "no data"
DissolvedO2	Number	Dissolved oxygen concentration at sample depth or "no data"
Count_Bins	Number	Count of data points averaged at sample depth or "no data"
Flag	Number	Numerical code indicating data processing; 0 = data untouched; 1 = data extrapolated (typically at top; or bottom of water column); 2 = primary temperature and salinity data are interpolated (typically at mid-water column depth). "No data" indicates this numerical code is not available
Level	Text	Indicates "surface" or "deepest" depth of each CTD Haul. Blank at other depths
DataRestriction	Text	E.g, indicate that data should not be associated with sea floor. Blank indicates no restriction
Comment	Text	Blank cell or comment about row of data

36,023 rows data

Table 20**. tblWater_Chl_Nutrients**. Phosphate, silicate, nitrate, nitrite, ammonium and chlorophyll-a in water samples collected at discrete depths of CTD Events during cruises TB-2012-US, TB-2013-US and TB-2014-US.
Each combination of Event and Water_SampleID or Event and DepthSample_m is unique.

Field	**Type**	**Description**
Water_SampleID	Text	Identifier for water sample collected at a particular Event and Depth_m. Identifier includes year and consecutive water sample
Event	Text	Unique identifier for each deployment of fishing gear; includes Cruise, Station, Gear and Haul separated by underscores.
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple deployments of gear
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity
Station	Text	Name or number identifying the site (location) of Event; usually assigned during cruise to associate multiple deployments of gear
DepthStn_m	Number	Depth of station (m)
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number indicating the consecutive deployment of Gear during Cruise
Date	yyyy-mm-dd	Local date of haul
Time	HH:MM:SS	Time of sample collection
Latitude	Number	Latitude of vessel at start of haul in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel at start of haul; negative decimal degrees indicate western hemisphere; -xxx.xxxx
Depth_m	Number	Depth of sample (m)
Phosphate	Number	Phosphate (umol/kg)
Silicate	Number	Silicate (umol/kg)
Nitrate	Number	Nitrate (umol/kg)
Nitrite	Number	Nitrite (umol/kg)
Ammonium	Number	Ammonium (pmol/kg)
ChlA	Number	Chlorophyll-a (mg/kg) or "no data"

791 rows

Table 21. **tblSediment**. Substrate characteristics (description, grain size, stable isotopes, total organic carbon and concentration of lipid and chlorophyll-a) at stations during cruises TB-2012-US, TB-2013-US, TB-2014-US and TB-2014-Ice.
Porosity and grain size were examined from 0-5 mm substrate depth; chlorophyll-a, phaeopigment, stable isotopes and total organic carbon were examined from 0-1 cm substrate depth. Each combination of Event and Replicate or combination of CruiseStation and Replicate is unique.

Field	**Type**	**Description**
Event	Text	Unique identifier for each deployment of gear; includes Cruise, Station, Gear and Haul separated by underscores. E.g., TB-2012-US_B1-500_IKMT_6. "x" is a placeholder for a missing gear or haul
CruiseStation	Text	Concatenation of Cruise and Station separated by underscore. Used to associate multiple events at station
Cruise	Text	Name associating a series of field sampling events that are in physical and temporal proximity. E.g., BOEM-2011, BOEM-2013-Ice, TB-2012-US
Station	Text	Name or number identifying the site (location); usually assigned during cruise to associate multiple deployments of gear
Latitude	Number	Latitude of vessel when Gear was deployed in decimal degrees; xx.xxxx
Longitude	Number	Longitude of vessel when Gear was deployed; negative decimal degrees indicate western hemisphere; if only one longitude was reported for the haul that longitude is assigned in this field; -xxx.xxxx
Gear	Text	Abbreviated description of gear. Gear is described more completely in table luGear
Haul	Text	Name or number identifying the particular deployment of Gear. Usually assigned consecutively for each gear throughout the cruise. Blank cell indicates no data
Replicate	Number	Name identifying separate deployments of Gear at one Cruise and Station. Blank cell indicates no data
Date	yyyy-mm-dd	Local date of sample collection or "no data" indicating precise date unknown
DepthStn_m	Number	Depth of station (m)
GravelPercent	Number	Percent weight of gravel in dried substrate (>2–64 mm); x.xx% or "no data"
SandPercent	Number	Percent weight of sand in dried substrate (0.0625–2 mm); x.xx% or "no data"
MudPercent	Number	Percent weight of mud in dried substrate (<0.0625 mm); x.xx% or "no data"; silt + clay = mud
SiltPercent	Number	Percent weight of silt in dried substrate (3.90625–62.5 µm); x.xx% or "no data"
ClayPercent	Number	Percent weight of clay in dried substrate (< 3.90625 µm); x.xx% or "no data"

Field	Type	Description
Substrate	Text	Qualitative description of substrate textural group with standardized terminology or "no data". Substrate is as assigned by GRADISTAT v.8.0 software (Blott 2010 as modified from Folk 1954) Blott SJ, Pye K (2001) GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surface Processes and Landforms 26(11):1237–1248. Folk RL (1954) The distinction between grain size and mineral composition in sedimentary-rock nomenclature. J Geology 62:344–359
PhiMean	Number	Mean phi size or "no data". Folk and Ward method as calculated using GRADISTAT v.8.0 software
PhiMeanDescription	Text	Qualitative description of the mean phi size or "no data". Folk and Ward method as assigned using GRADISTAT v.8.0 software
Sorting	Number	Sorting or "no data". Sorting is the standard deviation of the grain-size distribution and quantifies the “diversity” of grain sizes present
Kurtosis	Number	Kurtosis or "no data". Kurtosis (peakedness) of a grain-size distribution compares sorting in the central portion of the population with that in the tails; high kurtosis indicates an even distribution of sediment mass among grain size categories
Skewness	Text	Description of the degree of symmetry or asymmetry of the grain size distribution as assigned using GRADISTAT v.8.0 software or "no data"
Porosity	Number	Percent weight of water in substrate or "no data"
TOC	Number	Total organic carbon (mg per gram dry sediment) or "no data"
CN	Number	Carbon-to-nitrogen ratio or "no data". C:N ratio provides a relative measure of the food quality of organic matter
Lipid	Number	Lipid content of sediment (mg lipid per gram sediment) or "no data"
Chl-a_Inventory	Number	Amount of chlorophyll-a per area (mg chlorophyll-a per sq m of seafloor) or "no data"
Chl-a	Number	Concentration of chlorophyll-a in sediment (micrograms Chl-a per g sediment dry weight) or "no data"
Phaeopigment	Number	Concentration of phaeopigment or "no data". Phaeopigment is a degradation product of chlorophyll (micrograms Phaeopigment per g sediment dry weight)
Del_15N	Number	Stable isotope ratio of 15N/14N or "no data". Run on tissue that was not lipid-extracted
Del_13C	Number	Stable isotope ratio of 13C/12C or "no data". Fish tissues are lipid-extracted prior to stable isotope analysis; other samples are not lipid-extracted
Comment	Memo	Blank cell or comment about row of data

73 rows

MISCELLANEOUS

Table 22. **luSpecies.** Look up table that indicates taxonomy of each species reported in datasets Fish, FishDiet, Epifauna, Infauna and Zooplankton of the Transboundary 2012–2014 survey. Taxonomy is per the World Register of Marine Species (WoRMS; access date 2017-06-17) unless otherwise noted in field WoRMS-MatchType. Most columns are direct output from "match taxa" query at http://www.marinespecies.org. Each combination of DataSet and NameScientific is unique.

Field	**Type**	**Description**
DataSet	Text	E.g. Fish, FishDiet, Epifauna, Infauna, Zooplankton
NameScientific	Text	Genus and species, or the most precise level of taxonomy available
WoRMS _MatchType	Text	Two sources: 1) Output from WoRMS (e.g., exact, exact subgenus), or where no match in WoRMS 2) note by researcher on source of TSN etc.
AphiaID	Text	Output from WoRMS: Number representing NameScientific; blank if not assigned in WoRMS
TSN	Text	Taxonomic Serial Number; output from WoRMS species match function if available and from www.ITIS.gov if not available via WoRMS. Blank if not assigned
QualityStatus	Text	Output from WoRMS: quality of name; blank if not assigned
TaxonStatus	Text	Output from WoRMS: status of taxon; blank if not assigned
ScientificName _accepted	Text	Output from WoRMS: accepted scientific name; blank if not assigned
Authority _accepted	Text	Output from WoRMS: authority for scientific name; blank if not assigned
Kingdom	Text	Taxonomic classification of kingdom; blank if not assigned
Phylum	Text	Taxonomic classification of phylum; blank if not assigned
Class	Text	Taxonomic classification of class; blank if not assigned
Order	Text	Taxonomic classification of order; blank if not assigned
Family	Text	Taxonomic classification of family; blank if not assigned
Genus	Text	Taxonomic classification of genus; blank if not assigned
Subgenus	Text	Taxonomic classification of subgenus; blank if not assigned
Species	Text	Taxonomic classification of species; blank if not assigned
Subspecies	Text	Taxonomic classification of subspecies; blank if not assigned
isMarine	Text	Output from WoRMS: 1 if known and 0 if not known to be in marine ecosystem. Blank if not assigned in WoRMS
isBrackish	Text	Output from WoRMS: 1 if known and 0 if not known to be in brackish water. Blank if not assigned in WoRMS
isFresh	Text	Output from WoRMS: 1 if known and 0 if not known to be in fresh water. Blank if not assigned in WoRMS
isTerrestrial	Text	Output from WoRMS: 1 if known and 0 if not known to be in terrestrial ecosystem. Blank if not assigned in WoRMS
FamilyCommon	Text	Populated only for fishes - common name of taxonomic family; blank if not assigned. Standard used for fishes is the American Fisheries Society's (AFS) Book of Scientific and Common Names (Page et al. 2013). Page LM, Espinosa-Pérez H, Findley LT, Gilbert CR, Lea RN, Mandrak NE, Mayden RL, Nelson JS (2013) Common and scientific names of fishes from the United States, Canada, and Mexico, 7th edition. American Fisheries Society, Special Publication 34, Bethesda MD.

Field	Type	Description
NameCommon	Text	Populated only for fishes - common name of species. Common names for fishes are primarily from Page et al. (2013); if the fish has no common name in that source, an English vernacular name reported by WoRMS (2017) or other source may be listed. Blank if not assigned Page LM, Espinosa-Pérez H, Findley LT, Gilbert CR, Lea RN, Mandrak NE, Mayden RL, Nelson JS (2013) Common and scientific names of fishes from the United States, Canada, and Mexico, 7th edition. American Fisheries Society, Special Publication 34, Bethesda MD. 384 pp.WoRMS Editorial Board (2017). World Register of Marine Species. Available from http://www.marinespecies.org doi:10.14284/170
Comment	Memo	Blank cell or comment about row of data

1067 rows

Table 23. **luGear**. Lookup table - Detailed description of field sampling gear used during cruises TB-2012-US, TB-2013-US, TB-2014-US and TB-2014-Ice.
One row for each type of gear (net; substrate sampler; CTD; etc.).

Field	**Type**	**Description**
Gear	Text	Abbreviated description of gear
Mesh_Smallest_mm	Text	Smallest mesh size in the gear; usually from codend, codend liner of net, or mesh of sieve. NA indicates not applicable
Horizontal_Opening_m	Text	Horizontal opening of the sampling gear while being deployed, e.g., of net while fishing or mouth of sediment grab. NA indicates not applicable
Vertical_Opening_m	Text	Vertical opening of the sampling gear while being deployed. NA indicates not applicable
Description	Memo	Full and detailed description of gear

21 rows

Table 24. **tblRevisions.** Notation to track revisions of data after submission to BOEM on 19-Dec-2017, e.g., errors repaired, taxon identification revised.
RevisionNum is unique.

Field	**Type**	**Description**
RevisionNum	Autonumber	Assigned sequentially as changes are made to database
Table_Affected	Text	Name of affected database table(s)
Global	yes or no	Does the change affect all rows of table?
Scope	Text	E.g., all, many, cruise BOEM-2011, or list the particular Event(s) affected
Original_Data	Text	Text of the original data
Comment_from_Reviewer	Memo	Comments from Reviewer
Reviewer	Text	Name and affiliation of person reviewing data
Review_Date	Date	Date of review
DatabaseMgr_Response_to_Review	Memo	Database manager name, date of response, response to reviewer comment

0 rows as of 19-Dec-2017