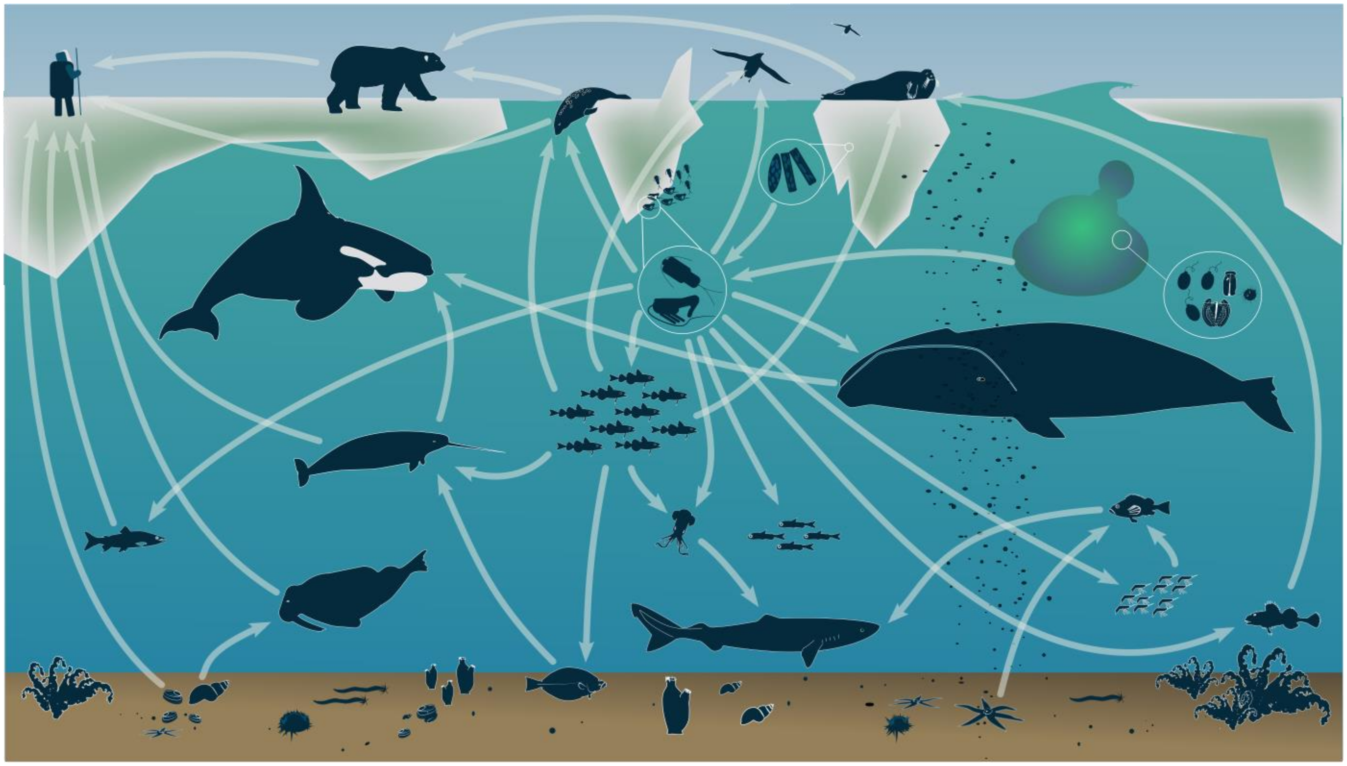
A FOOD WEB MODEL FOR THE BAFFIN BAY COASTAL AND SHELF ECOSYSTEM

Part I

Ecopath Technical Report



UNIVERSITÉ LAVAL

NEOLab
Numerical Ec0systems & 0cean0graphy
Numérisati0n des Éc0systèmes 0céaniques

LITTORAL
CHAIRE DE RECHERCHE EN PARTENARIAT SENTINELLE NORD EN APPROCHES ÉCOSYSTÉMIQUES DE LA SANTÉ
SENTINEL NORTH PARTNERSHIP RESEARCH CHAIR IN ECOSYSTEM APPROACHES TO HEALTH

TAKUVIK

Québec OCÉAN

A FOOD WEB MODEL FOR THE BAFFIN BAY COASTAL AND SHELF ECOSYSTEM
Part I: Ecopath Technical Report

Project collaborators
Takuvik & Québec Océan, Université Laval: Sara Pedro, Tiff-Annie Kenny, Frédéric Maps, Mélanie Lemire, Blanche Saint-Béat, Marcel Babin, Jean-Éric Tremblay, Gustavo Yunda-Guarin, Justin Boissinot, Marie-Ange Moisan
Dalhousie University: Carie Hoover
Department of Fisheries and Oceans Canada: Muhammad Yamin Janjua
Memorial University of Newfoundland: Jennifer Herbig, Maxime Geoffroy
University of Victoria: Matthew Little
University of Ottawa: Laurie Chan

Additional contributions from
Nigel Hussey, Steven Ferguson, Caroline Bouchard, Cory Matthews, Kyle Elliot, Marcus Dyck, Marianne Marcoux, Courtney Watt-Wheeler, Mark Mallory, and Margaret Treble.

Corresponding author
Sara Pedro
sara.pedro.1@ulaval.ca

All files to calculate parameters and the Ecopath model are available at https://github.com/sjppedro/Qik_Ecopath_model.

Funding

CIHR IRSC
Canadian Institutes of Health Research
Instituts de recherche en santé du Canada

MEOPAR

CANADA FIRST RESEARCH EXCELLENCE FUND
APOGÉE CANADA FONDS D'EXCELLENCE EN RECHERCHE

Sentinelle Nord

CONTENT

PREFACE

This work was undertaken as part of a multidisciplinary research project funded by the Marine Observation Prediction and Assessment Network - MEOPAR (at ULaval), Canadian Institute of Health Research – CIHR (at University of Ottawa), and Sentinel North (at ULaval), and hosted at Université Laval, in Canada. The objective of the overall project is to support the food security (i.e., the availability and access to sufficient, safe, nutritious food that meets dietary preference) of Inuit communities of the Eastern Canadian Arctic, as well as to explore ways to adapt to effects of climate change. Inuit fish and hunt local marine species, from invertebrates to fish and marine mammals, which make a large part of their diet and are central to their food security. With temperatures increasing twice as fast as the global average and sea ice becoming thinner and forming later, climate change effects on the distribution and abundance of Arctic marine species are already taking place. To better understand the effects of climate change in important subsistence species, a multi-species model (Ecopath with Ecosim) will be used to inform the development of an integrated ecosystem assessment. The model will be used as a tool to co-create scenarios of ecosystem change with the community of Qikiqtarjuaq, Nunavut, to inform adaptation strategies regarding food security (e.g., potential of new fisheries in the region). This report describes the development of an Ecopath model of the Baffin Bay coastal and shelf ecosystem. The methodology, data used to construct the model, data gaps and limitations are described.

BASIC INPUT PARAMETERS

THE BAFFIN BAY COASTAL AND SHELF ECOSYSTEM

The present model was updated from a preliminary version developed by Janjua et al for this region (Janjua et al., 2015).

The Baffin Bay, with a total estimated area of 689,000 km², is a semi-enclosed sea located at the southern boundary of the Arctic Ocean and delimited by Greenland to the east and Baffin Island to the west. In the south, it opens to the North Atlantic through the Davis Strait, whereas in the north it connects to the greater Arctic Ocean through the much narrower Jones Sound, Nares Strait and Lancaster Sound. The ecologically relevant North Water polynya is also located to the north of the bay, providing key habitat for many marine species. The continental shelf along the Greenlandic coast is wider compared to the Canadian coast, which expands to approximately 200 km from the coast. In offshore waters, the central abyssal basin reaches more than 2000 m in depth. The water mass along the Canadian coast is colder compared to the Greenland coast, with surface waters varying from 0 to 5 °C and 30 to 32 ‰ in summer and deep offshore waters of about − 0.5 °C and 34.5 ‰ (Wang et al., 1994). These differences are associated with the oceanic currents within the bay, that differ between the east and west sides. On the east side, the West Greenland current moves northward, originating from the merging of North Atlantic water and the Irminger current, and resulting in warm and salty waters (Tang et al., 2004). On the west side, the ocean current moves southward from the Canadian Archipelago, originating from the Arctic Ocean with colder and fresher water masses (Tang et al., 2004). Sea ice melt begins as early as April along the eastern side of the bay and the whole bay is completely ice free in September. Freeze-up starts in October, from north to south, reaching its maximum in March (Wang et al., 1994; Tang et al., 2004).

In this modelling project, we are considering the western coastal and shelf area of Baffin Bay, along the Canadian side (Figure 1). The modelling area is comprised of the ecologically and biologically significant area (EBSA) Baffin Bay Coastline (2.10) and Baffin Bay Shelf Break (2.11) defined by the Department of Fisheries and Oceans (DFO) Canada (DFO, 2011). The EBSAs were identified to support the development of ecosystem-based management of the marine environment, define marine protected areas, and facilitate sustainable fisheries. Baffin Bay EBSA 2.10 and 2.11 were identified based on the importance of the extensive fjord habitat of Baffin Island coastline for marine species and productivity (e.g., nursery grounds for bowhead whale, seabird colonies, polar bear denning/foraging areas, walrus haul-out sites, habitat for coral and sponges, and seabird colonies), which extends offshore onto the floe-edge; and as a migratory pathway for marine mammals (including narwhal, and for Arctic char migration), respectively. This region also encompasses the largest National Wildlife Area (NWA), the Ninginganiq NWA, and the Qaqulluit NWA (Environment and Climate Change Canada and Canadian Wildlife Service (CWS), 2016). The first measures over 336,397 hectares and is located about 120 km south of Clyde River. Within this NWA, the single largest known concentration of bowhead whale has been observed, and it supports polar bear, ringed seal, narwhal, and several seabird species such as northern fulmar. The Qaqulluit NWA, about 100 km southeast of Qikiqtarjuaq, has the largest breeding colony of northern fulmars in the country, and provides habitat for other seabirds, ringed seal and walrus. Given this, we defined the modelling area extending from the coast of Baffin Island to the approximate location of the floe-edge, including the outer land fast ice zone and the shelf break approximately 200 km from the coast. It makes an area of 81,448 km^2, having a maximum depth of 1,256 m, with almost 73% of the area deeper than 500 m. This area encompasses important hunting grounds supporting subsistence harvest for the communities of Qikiqtarjuaq and Clyde River (Government of Nunavut, 2010; Government of Nunavut, 2014).

While Inuit have harvested in this region for more than 4000 years, commercial open-water fishing is relatively new. The main commercial fishery in the region nowadays is the Greenland halibut fishery. Yet, intensive whaling from the 1800s up until the early 1900s had a large impact in bowhead whale populations that are still recovering. After that, fisheries for grenadier and redfish started in the area, collapsing in the 1970s, which might have had repercussions in these fish populations (Hurtubise, 2016). The emerging halibut fishery in the region is complex, as fish populations are not clearly differentiated and therefore the allocations are shared between Canada and Greenland. In Canada, these are shared among the federal government, the Nunavut government’s Wildlife Management Board and industry. Inuit-owned companies are now starting to claim the rights of these fisheries, especially in inshore areas within the Nunavut Settlement Area (NSA) (Hurtubise, 2016). Although most of the halibut fishery is classified as commercial, the portion that falls within the NSA is considered exploratory, with a quota for the Nunavut inshore fisheries development (Nanang, 2020). Thus, Greenland halibut represents the only commercial fishery represented in the model and is harvested in both inshore and offshore areas.

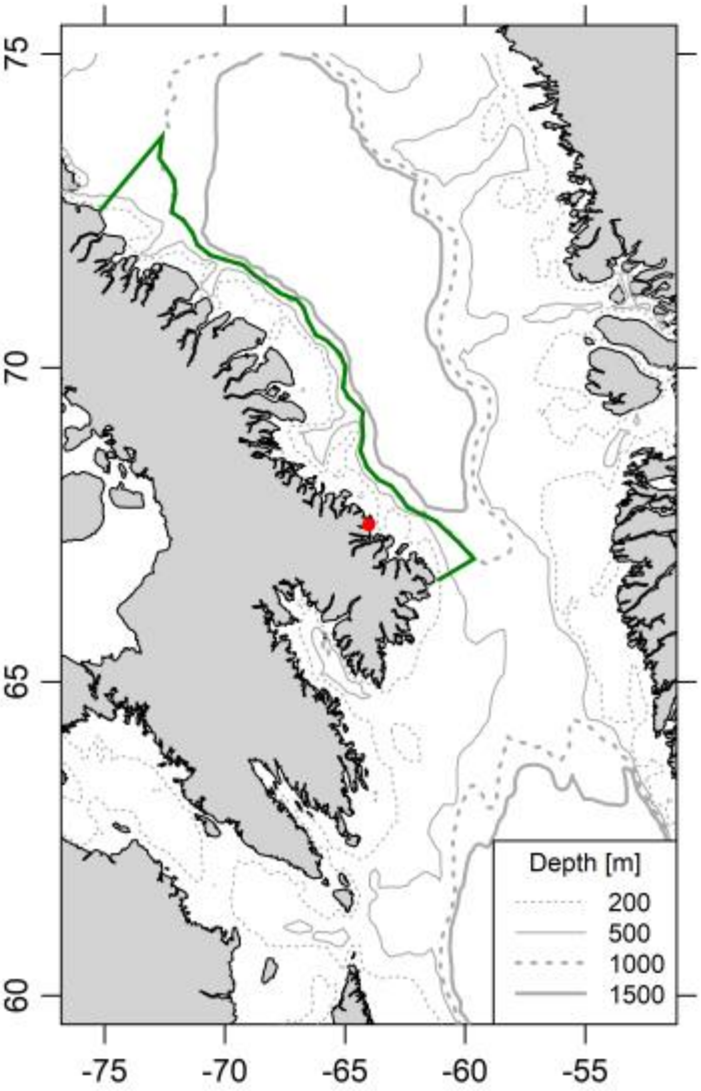


Figure 1. Model area in Baffin Bay is delineated in green and Qikiqtarjuaq location is marked with the red dot. The model area extends approximately 200 km from the coast of Baffin Island, including the outer land fast ice zone and the shelf break.

MODELLING WITH ECOPATH AND ECOSIM

Ecopath with Ecosim (EwE) is an ecosystem modelling approach and software widely used for ecosystem-based fisheries management, impact and placement of protected areas throughout the world. EwE has three main components: Ecopath, a static, mass-balanced snapshot of the system; Ecosim, a time dynamic simulation module; and Ecospace, a spatial and temporal dynamic module (Christensen et al., 2005). Among its many applications, EwE can be used to address effects of fishing and harvest (Gaichas et al., 2010; Coll and Libralato, 2011), community-based fisheries management (e.g., Cisneros-Montemayor et al. 2020), and effects of environmental and climate change (e.g., Overholtz and Link 2009; Tomczak et al. 2013) in a marine ecosystem. In the Arctic, it has been used to model the Alaskan Chukchi and Bering Seas (Aydin et al., 2007; G. Andy Whitehouse et al., 2014), Lancaster Sound (Guénette et al., 2001), Hudson Bay (Hoover et al., 2013) and West Greenland (Pedersen and Zeller, 2001).

Ecopath creates a static mass-balanced snapshot of the species in an ecosystem and their feeding interactions, represented by linked biomass ‘pools’. The biomass pools consist of a single species, or species groups representing ecological guilds. Pools may be further split into ontogenetic linked groups. It is mainly based in two master equations. The first Ecopath equation describes how the production term for each functional group i can be split in components:

1. $P_i = \sum B_j . M2_{ij} + Y_i + E_i + BA_i + P_i . (1 - EE_i)$

where P_i is the total production rate of i, B_j the biomass of the predator group j with predation mortality on i $M2_{ij}$, Y_i is the total fishery catch rate of i, E_i the net migration rate (emigration - immigration), BA_i is the biomass accumulation rate for i, while $P_i.(1-EE_i)$ is the ‘other mortality’ rate for i. In other words, EE_i is the ecotrophic efficiency or proportion of production that is consumed within the system by predators or exported out of the system through fishing or migration. This equation can also be expressed as:

2. $B_i . \left(\frac{P}{B}\right)_i = \sum B_j . \left(\frac{Q}{B}\right)_j DC_{ji} + Y_i + E_i + BA_i + \left(\frac{P}{B}\right)_i . (1 - EE_i)$

where: $(P/B)_i$ is the production to biomass ratio, generally equal to natural mortality Z, $(Q/B)_j$ is the consumption by predator j per unit biomass, and DC_{ji} of prey i in the average diet of predator j.

The first equation estimates the parameters to ensure mass balance between groups, while the second master equation ensures energy balance within each group by describing the consumption term as:

3. $B_i . \left(\frac{Q}{B}\right)_i = \left(\frac{P}{B}\right)_i . B_i + UN + R_i$

where: UN is the portion of food that is not assimilated (e.g. excreted) and R_i is respiration, i.e. the portion of consumed food that is not used for production or excreted (e.g. used for reproduction).

Ecopath equations express a balance between the net production of a group with all sources of its mortality. To balance a model Ecopath runs these linear equations for each functional group in the system, connecting them through the predator mortality parameter. To do that, three of the four basic parameters (*P/B*, *Q/B*, *B* and *EE*), as well as diet composition and fisheries catches (and migration if known) have to be input. Ideally, the biomasses, production/biomass and consumption/biomass ratios are entered for all groups and only the ecotrophic efficiency is estimated, given that no procedure exists for its field estimation.

Ecosim is the dynamic component of EwE that allows to do simulations over time at the ecosystem level. This tool uses Ecopath output, i.e., mass-balance results, as the initial values for the simulation. Ecosim uses a series of coupled differential equations that express biomass flux rates among compartments of the system as a function of time varying biomasses and harvest rates, derived from the Ecopath master equation as:

4. $\frac{dB_i}{dt} = g_i . \sum_j Q_{ji} - \sum_j Q_{ji} + I_j - (MO_i + F_i + e_i). B_i$

where dB_i/dt represents the growth rate during the time interval *dt* of group *i* in terms of its biomass, B_i, g_i is the net growth efficiency calculated $(P/B)_i$ over $(Q/B)_i$, $M0_i$ the non-predation natural mortality rate estimated from the ecotrophic efficiency, F_i is fishing mortality rate, e_i is emigration rate, I_i is immigration rate (assumed constant over time), and $e_i \times B_i - I_i$ is the net migration rate E_i. The two sums estimate consumption rates, the first expressing the total consumption by group *i*, and the second the predation by all predators on the same group *i*. The consumption rates, Q_{ji}, are calculated based on the ‘foraging arena’ concept. The default routine used in Ecosim to solve the equations is an Adams–Basforth integration routine.

The ‘foraging arena’ concept divides the biomasses of the prey into vulnerable and invulnerable components (Walters et al., 1997; Christensen and Walters, 2004). That is, a prey can be not vulnerable to predation when e.g. hiding from predators, or vulnerable when leaving their shelter to feed. The transfer of prey biomasses between these components determines if control is top-down (Lotka-Volterra) or bottom-up (donor-driven), or intermediate between the two. The model considers a continuum between both types of control. Low vulnerabilities (<2) imply bottom-up control, i.e., an increase in predator biomass will not cause any noticeable increase in the predation mortality on a given prey. High vulnerabilities (e.g., of a 100) imply top-down control, so if the predator biomass increases, the predation mortality will also increase.

FUNCTIONAL GROUPS

Table 1. Species included as representative of each functional group and relevant references on distribution and ecology.

	Functional group	Species included	
1	**Killer whale**	*Orcinus orca*	(Higdon, 2007; Lefort, Garroway, et al., 2020)
2	**Polar bear**	*Ursus maritimus*	(SWG, 2016)
3	**Narwhal**	*Monodon monoceros*	(NAMMCO, 2018)
4	**Bowhead whale**	*Balaena mysticetus*	(COSEWIC, 2009)
5	**Ringed seal**	*Pusa hispida*	(Kelly et al., 2010; Ogloff et al., 2021)
6	**Other seals**	Bearded seal (*Erignathus barbatus*), harp seal (*Pagophilus groenlandicus*), hooded seal (*Cystophora cristata*)	(NAMMCO, 2016)
7	**Walrus**	*Odobenus rosmarus rosmarus*	(COSEWIC, 2017)
8	**Seabirds**	Black-legged kittiwake (*Rissa tridactyla*), northern fulmar (*Fulmarus glacialis*), thick-billed murre (*Uria lomvia*)	(Mclaren, 1982; Mallory, 2006; Frederiksen et al., 2016; Mallory et al., 2019)
9	**Greenland shark**	*Somniosus microcephalus*	(Yano et al., 2007; Hussey et al., 2018)
10	**Greenland halibut**	*Reinhardtius hippoglossoides*	(Treble, 2020)
11	**Arctic char**	*Slavelinus alpinus*	-
12	**Arctic/Polar cod**	*Boreogadus saida*, *Arctogadus glacialis*	(Mecklenburg et al., 2011)
13	**Small pelagic fish**	lanternfishes and smelts e.g., glacier lanternfish (*Benthosema glaciale*) and goiter blacksmelt (*Bathylagus euryops*)	(Nunavut Department of Environment Fisheries and Sealing Division., 2018)
14	**Sculpins/Eelpouts**	Atlantic hookear sculpin (*Artediellus atlanticus*), bigeye sculpin (*Triglops nybelini*), ribbed sculpin (*Triglops pingelii*), polar sculpin (*Cottunculus microps*), Arctic eelpout (*Lycodes reticulatus*), doubleline eelpout (*Lycodes eudipleurostictus*), pale eelpout (Lycodes pallidus)	(Jørgensen et al., 2011)
15	**Small demersal fish**	lumpsuckers, poachers, snailfishes and flounders, e.g., sea tadpole (*Careproctus reinhardt*), gelatinous sea snail (*Liparis fabricii*), Atlantic spiny lumpsucker (*Eumicrotremus spinosus*), Atlantic poacher (*Leptagonus decagonus*) and Arctic flounder (*Pleuronectes glacialis*).	(Jørgensen et al., 2011)
16	**Large demersal fish**	grenadiers and other gadiformes, redfishes, rays and wolffishes, e.g., roughhead grenadier (*Macrourus berglax*), threadfin rockling (*Gaidropsarus ensis*), Arctic skate (*Amblyraja hyperborean*) and thorny skates (*Amblyraja radiate*), deepwater redfish (*Sebastes mentella*) and spotted wolffish (*Anarhichas minor*)	(Nunavut Department of Environment Fisheries and Sealing Division., 2018)
17	**Large crustaceans**	shrimps and crabs with *Pandalus* spp. as the representative species due to their abundance in Baffin Bay and importance as a food item	(Reeves, 1998; Hammill and Stenson, 2000; DFO, 2019)
18	**Cephalopods**	*Rossia palpebrosa* and *R. moelleri* (sepiolids), and *Gonatus steenstrupi* (pelagic squid)	(Xavier et al., 2018)
19	**Carnivorous zooplankton**	*Aglantha digitale*, *Eukrohnia hamata*, *Gaetanus tenuispinus*, *Heterorhabdus norvegicus*, *Paraeuchaeta* spp. and *Themisto abyssorum*	(Massicotte et al., 2019; Saint-Béat et al., 2020)
20	**Omnivorous zooplankton**	*Boroecia maxima*, *Discoconchoecia elegans*, *Heterostylites major*, *Limacina helicina*, *Metridia longa*, *Microcalanus*, *Oithona similis*, *Oncaea notopus*, *Pseudocalanus* spp., *Spinocalanus longicornis* and *Triconia borealis*	(Massicotte et al., 2019; Saint-Béat et al., 2020)
21	***Calanus* copepods**	*Calanus glacialis*, *Calanus hyperboreus* and *Calanus finmarchicus*	(Massicotte et al., 2019; Saint-Béat et al., 2020)
22	**Microzooplankton**	heterotroph, flagellate and ciliate microzooplanktonic species	(Massicotte et al., 2019; Saint-Béat et al., 2020)

23	**Polychaetes**	polychaetes (polychaetes) and sipunculids e.g., *Nothria conchylega*, *Aglaophamus malmgreni* and *Jasmineira schaudinni*	(Thomson, 1982; Janjua et al., 2015) G. Yunda-Guarin, unpublished data
24	**Echinoderms**	starfish (Asteroidea), brittle stars (Ophiuroidea), sea urchins, (*Strongylocentrotus sp.*) and sea cucumbers (Holothuroidea), common in Baffin Bay. Some common species include *Ophiopholis aculeate* and *Ophioscolex glacialis*	(Aitken and Fournier, 1993; Sifred, 2005)
25	**Bivalves**	*Portlandia artica, Hiatella arctica, Chlamys islandica, Axinopsida orbiculata, Similipecten greenlandicus, Mya truncata*	(Aitken and Fournier, 1993; Sifred, 2005)
26	**Other benthos**	sea anemones (Cnidaria), sea pen (Pennatulacea), corals (*Duva florida*, Nephtheidae), sponges (*Craniella cranium*) and agglutinated foraminifera	(Aitken and Fournier, 1993; Janjua et al., 2015)
27	**Bacteria**	-	(Massicotte et al., 2019; Saint-Béat et al., 2020)
28	**Sea ice algae**	-	(Deal et al., 2011; Massicotte et al., 2019; Saint-Béat et al., 2020)
29	**Phytoplankton**	-	(Van Leeuwe et al., 2018; Oziel et al., 2019; Randelhoff et al., 2019; Saint-Béat et al., 2020)

ECOPATH MODEL PARAMETERS

MARINE MAMMALS

We considered seven marine mammal functional groups in the model area (Table 2). All of these groups contain only one species except for *Other seals*, that contains 3 species. The biomass *B* of each group/species were calculated as the number of animals multiplied by the average weight (in tonnes) and divided by the area used (km^2).

The *P/B* was calculated as the sum of natural mortality *Z* and harvest mortality. Natural mortality rates for marine mammals were calculated based on values from life history tables and estimates of longevity based on equations from Barlow and Boveng (1991). The authors calculated *Z* over all life stages up to a maximum age using survivorship as an inverse for natural mortality based on life histories of fur seals, monkeys and humans (full equations and parameters for P/B calculations are available in Appendix A). Harvest mortality was calculated as catch over biomass, based on reported catches.

When no bioenergetics models were available for the species, the Q/B for marine mammals was calculated based on the energetic equation 4 as a first step (Williams et al., 2020):

5. $FMR = 651.2 \, . \, M^{0.87}$

where *FMR* is the field metabolic rate in kcal/day and *M* is mean body weight in kg. After, we used the average energy density of prey items previously reported (Hunt et al., 2000; Guénette et al., 2005; Harter et al., 2013; Pagano et al., 2018) and diet composition of marine mammals to calculate their consumption rates.

Table 2. Values used for estimating parameters for marine mammals and seabirds in the Baffin Bay coastal and shelf ecosystem model. CV is coefficient of variation, and CI is confidence interval.

	Population size		Average weight kg		Longevity years		Natural mortality year^{-1}	Harvest mortality ton km^{-2}		P/B year^{-1}	Q/B year^{-1}	
1. Killer whale	163 ± 27 SD	(Lefort, Garroway, et al., 2020)	2,280.5	(Trites and Pauly, 1998)	80	(Ford, 2002)	0.030	-	-	0.030	9.11	(Lefort, Garroway, et al., 2020)
2. Polar bear	2,826 (95% CI 2,059-3,593)	(SWG, 2016)	300	(Stirling and Parkinson, 2006)	25	(Stirling, 2002)	0.096	0.0001	(SWG, 2016)	0.15	6.00	(Williams et al., 2020)
3. Narwhal	17,555 (CV 0.35) individuals	(DFO, 2015a)	874	(Laidre et al., 2004)	115	(Garde et al., 2015)	0.024	0.0014	(NAMMCO, 2018)	0.031	19.8	(Laidre et al., 2004)
4. Bowhead whale	6,745 (CV 0.22) individuals	(COSEWIC, 2009; Wiig et al., 2011)	31,076	(Trites and Pauly, 1998)	200	(George et al., 1999)	0.013	0.0001	(DFO, 2015b)	0.013	14.2	(Laidre et al., 2007; Banas et al., 2021)
5. Ringed seal	1.46 individuals per km^2	(Kingsley, 1998; Reeves, 1998)	73.5	(Ferguson et al., 2018)	43	(Ferguson et al., 2018)	0.065	0.0087	(Priest and Usher, 2004)	0.146	15.3	(Ochoa-Acuña et al., 2008)
6. Other seals	8,203,500 individuals	(Hammill and Stenson, 2006; Cameron et al., 2010; Hammill et al., 2015)	138.9	(Trites and Pauly, 1998)	30	(Trites and Pauly, 1998)	0.088	0.00088	(Priest and Usher, 2004; Hammill and Stenson, 2006; Hammill et al., 2014)	0.091	39.6	(Ochoa-Acuña et al., 2008; Williams et al., 2020)
7. Walrus	18,900 individuals	(Hammill et al., 2016)	586.5	(Trites and Pauly, 1998)	33	(Trites and Pauly, 1998)	0.083	0.00002	https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/walrus-atl-morse/walrus-nunavut-morse-eng.html	0.085	30.4	(Acquarone et al., 2006)
8. Seabirds	353,800 individuals	(Gaston et al., 2012; Mallory et al., 2019)	0.638	(Hunt et al., 2000)	26	(Schreiber and Burger, 2001; Aydin et al., 2007)	0.023	0.00002	(Merkel and Barry, 2008)	0.235	254	(Bech et al., 2002; Welcker et al., 2010; Elliott et al., 2013; Mallory and Forbes, 2013)

KILLER WHALE

Killer whales (*Orcinus orca*) in the western North Atlantic and the eastern Canadian Arctic are considered a single population listed as Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2008). Yet not much is known about their structure and migration patterns. Killer whales are present in the Eastern Canadian Arctic seasonally during the open-water period from July to September, often near summering grounds for belugas and narwhals. This includes fjords around Baffin Island such as Eclipse Sound, Admiralty Inlet, and Prince Regent Inlet. Killer whales have been recorded on only a few occasions over thousands of kilometres of aerial and ship-based surveys, suggesting that numbers are too low to make surveys an effective way to measure population size (Higdon, 2007). Killer whales have been reported as common (0.20-0.40 individuals per 100 km^2) in the eastern Canadian Arctic (Higdon, 2007; Young et al., 2011), while a recent study estimated a total population size estimate of 163 ± 27 in the eastern Canadian Arctic using photo-ID, during an assumed 90-day residency in the Arctic (Lefort, Garroway, et al., 2020). Observations over the years suggest that killer whale abundance is increasing in the eastern Canadian Arctic, which might pose top-bottom pressure on local food webs especially through predation on narwhal and bowhead whale (Ferguson et al., 2012; Lefort, Matthews, et al., 2020; Matthews et al., 2020). We assumed killer whales follow narwhal and occupy the same area in the model. We reduced their residence time in the model area based on the frequency of sightings of killer whales near Qikiqtarjuaq compared to other eastern Canadian Arctic regions (Higdon et al., 2012; Lefort, Matthews, et al., 2020). There are no quotas on killer whales in the Canadian Arctic, and their harvest in this region is sporadic and many times associated with ice entrapment. Known harvests are low, totalling only 21 whales since the 1950s (Higdon, 2007). Due to this, we neglected harvest in the model area. The P/B was calculated as 0.03 $year^{-1}$. The Q/B was calculated as 9.11 $year^{-1}$ based on killer whale daily prey energy requirements in the Arctic (Lefort, Garroway, et al., 2020). Killer whale diet in the eastern Canadian Arctic is largely unknown. The only studies that give insight on their diet in the region are based on reported sightings of killer whale predation events (Ferguson et al., 2012; Higdon et al., 2012). Narwhal was the most recorded prey species followed by beluga, bowhead whales and seals. Additional cetacean prey species include northern pilot whales, fin, minke, and humpback whales (Higdon et al., 2014). Killer whales might also feed on fish, but predation on fish is not visible from observer standpoints. Stomach contents from a few killer whales landed in Disko Bay included only lumpsucker fish. Killer whales in Davis Strait also prey on Greenland halibut, while Greenland killer whales prey on cephalopods (Higdon, 2007; Ferguson et al., 2012; Higdon et al., 2012; Lefort, Matthews, et al., 2020). The diet was set to 32.5 % narwhal, 15.2 % bowhead whale, 10 % ringed seal, 6.7 % other seals, 0.7 % walrus, 1 % large demersal fish, 0.3 % cephalopods; 1 % Greenland shark, 32.6 % import (to account for beluga and other whales not considered in the model).

POLAR BEAR

Polar bears are listed as a species of ‘Special Concern’ under the *Species at Risk Act* since 2011, implying that this species is not under threat of extinction, but conservation measures are in place. Polar bears (*Ursus maritimus*) are extremely mobile, and absolute barriers to movements have not been identified. Yet, they show seasonal fidelity to local areas, especially in areas where the sea ice melts completely and in areas where movements are constrained by island archipelagos. Six distinct populations were identified across the Arctic: Viscount Melville Sound, Lancaster Sound, Norwegian Bay, Kane Basin, Baffin Bay, and Davis Strait (Taylor and Lee, 1995; Taylor et al., 2001). The Baffin Bay bear population is bounded by the North Water Polynya to the north, Greenland to the east and Baffin Island to the west (Taylor et al., 2001). In the 2000s, seasonal ranges were significantly smaller in all seasons, ranging from 255,000 to 729,000 km^2 (SWG, 2016). In the winter, non-denning bears can be found on the sea ice in the bay, and many cross from Baffin to Greenland waters. During open water season the polar bears use either eastern Baffin Island or the Melville Bay area as a summer retreat (Taylor et al., 2001). Some bears may move as far south as the whelping areas of the offshore hooded seal, which vary between years from southeastern Baffin Island to Nuuk, Greenland (SWG, 2016). The mean estimate of total abundance of this bear population in 2012-2013 was 2,826 (95% CI = 2,059-3,593) bears, while the mean estimate of total abundance 1994-1997 was 2,173 (95% CI = 1,252-3,093) bears (SWG, 2016). Management of polar bears is shared among the federal, provincial/territorial governments, and wildlife co-management boards (Nunavik Marine Regional Wildlife Board (NMRWB), 2018). Both Canada (Nunavut) and Greenland harvest this polar bear population. During 1993-2005 the combined annual harvest averaged 165 (range: 120-268) polar bears, while during 2006-2014 the harvest averaged 161 (range: 138-176) polar bears (SWG, 2016). The mean estimates of total survival in 2011-2013 were reported as 0.90 (SE = 0.05) for females and 0.78 (SE = 0.06) for males age 2 ≥ years, while for cubs-of-the-year and yearlings survival was 0.87 (SE = 0.06) (SWG, 2016). These values yield an average P/B of 0.15 year^{-1}. The Q/B was calculated as 6 year^{-1} based on the energetic equation in (Williams et al., 2020). Polar bears feed mainly on ringed seal, but also other more seasonal seals and beluga whales, while narwhal and walrus make up only a small portion of the diet (Thiemann et al., 2011; Mckinney et al., 2013; Galicia et al., 2015). Arctic char and seabird eggs can also be an important source of energy to bears (Mallory et al., 2009; SWG, 2016). The diet was set to 47.5 % ringed seal, 1 % walrus, 51.8 % other seals, 1 % narwhal, 1 % Arctic char, 1 % seabirds, 30 % import (to account for beluga whale which is not present in the model area).

NARWHAL

The narwhal (*Monodon monoceros*) functional group represents the East Baffin Island narwhal population. This population spends the summer (approx. June to September) within the model area, in the fjords and inlets of Baffin Island (Heide-Jorgensen et al., 1993; Richard et al., 2014; NAMMCO, 2018). They typically begin their autumn migration in September/October and travel ~1,700 km to their wintering area in the northern Davis Strait and southern Baffin Bay where they remain until late March/early April when they begin their spring migration (Heide-Jorgensen et al., 1993; Richard et al., 2014; NAMMCO, 2018). This population is considered stable, with latest abundance estimates of 17,555 ± 0.35 individuals done in 2013 (DFO, 2015a). Narwhals are harvested in this region by hunters from the Clyde River and Qikiqtarjuaq communities. Yet, the communities hunt primarily in autumn when narwhal from other stocks are migrating along the Baffin Island coastline making it difficult to know which stock is being harvested. Recent catch levels appear to have been sustainable and relatively constant (97 to 183 landed, 2000-2015), so we used the value of 135 individuals reported for 2013 (NAMMCO, 2018). The P/B was calculated as 0.031 year^{-1} and the Q/B was calculated as 19.8 year^{-1} based on a narwhal bioenergetic model in Baffin Bay (Laidre et al., 2004). Narwhal diet was reported in summer of 1978-9 in Pond Inlet in open water, ice crack and ice edge (Finley and Gibb, 1982). Yet there are considerable seasonal differences in diet: in spring, narwhals take Arctic (*Boreogadus saida*) or polar cod (*Arctogadus glacialis*), as well as cephalopods, at the sea ice edge, in summer food consumption is at a minimum, and in fall/winter, narwhals feed intensely on Greenland halibut (*Reinhardtius hippoglossoides*) and cephalopods in their wintering grounds (Laidre et al., 2004). Diet was set to 56.38 % Arctic/polar cod, 36.6 % Greenland halibut, 1 % small demersal fish, 6.92 % cephalopods, 1 % crustaceans. A 25 % import was added to account for more intense feeding in wintering grounds, outside the model area.

BOWHEAD WHALE

The International Whaling Commission (IWC) has recognized four mainly geographically defined bowhead whale (Balaena mysticetus) stocks: the Okhotsk Sea stock, the Bering-Chukchi-Beaufort Seas stock, the Eastern Canada-West Greenland stock, and the Spitsbergen stock (Heide-Jørgensen et al., 2006; COSEWIC, 2009). The Eastern Canada-West Greenland bowhead whale stock summers in Baffin Bay, the Canadian High Arctic, Foxe Basin, and northwestern Hudson Bay (Fortune et al., 2020). In fall, whales along Baffin Island are thought to move south along the east coast of Baffin Island or cross over to the West Greenland coast, appearing there in September and October, whereas whales in Foxe Basin are thought to move south and east and winter in Hudson Strait. Low numbers of bowhead whales may also be found in winter in the North Water and in polynyas along the east coast of Baffin Island (Heide-Jørgensen et al., 2006; Matthews and Ferguson, 2015). The Eastern Canada-West Greenland stock is estimated to consist of at least 6,745 ± 0.22 animals in 2013 with increasing trend (COSEWIC, 2009; Wiig et al., 2011; Nielsen et al., 2014). The subsistence hunts recorded for Nunavut and Nunavik from 2008-2014, have been 2-3 whales per year (DFO, 2015b). We are considering catches of 2 individuals per year in the model area. The P/B was calculated as 0.013 year^{-1}. Bowhead Q/B was calculated as 14.23 year^{-1} based on a bioenergetics model for bowhead whales in Disko Bay feeding on a copepod-based diet (Laidre et al., 2007; Banas et al., 2021). In the model area, bowheads occur mainly in the summer in fjords along the east coast of Baffin Island (Heide-Jørgensen et al., 2003). Diet composition was estimated for bowhead whales in several regions of the Canadian Arctic, including Baffin Bay, using SI mixing models, and was mainly based of large Arctic calanoid copepods (e.g. *Calanus hyperboreus*), mysids and euphausiids (Pomerleau et al., 2012). The diet was set to 14.79 % omnivorous zooplankton, 47.62 % carnivorous zooplankton, 6.97 % Calanus copepods, and 30.6 % import (to account for feeding on euphausiids).

RINGED SEAL

Ringed seals (*Pusa hispida*) are present in the model area year-round. This species is completely adapted to ice-covered waters and does not migrate to open water areas in the winter. They are quite mobile and can travel distances up to ~ 4800 km in Baffin Bay, yet individuals vary in their movements and do not follow a common route (Ogloff et al., 2021). In the summer and fall, when land-fast ice is not available, ringed seals forage intensively to rebuild energy reserves for the breeding season, making extensive movements into open water (Kelly et al., 2010; Ogloff et al., 2021). During the winter, their distribution is more diverse with some animals establishing territories and maintaining their breathing holes in the shore-fast ice while others disperse along coastlines or move through the pack ice (Reeves, 1998; Ogloff et al., 2021). There are nine stocks of ringed seal across the Arctic, but no recent estimates are available for the Baffin Bay stock. Kingsley (1998) calculated seal abundance for Baffin Bay based on polar bears and their energetic needs, through a predator-prey relationship model, using abundance estimates for polar bear available for the area. He estimated that 1.2 million ringed seals are needed in Baffin Bay and associated waters to sustain the polar bear population. In the same model, Kingsley considered an estimated 100,000 hunter kills for ringed seal in Baffin Bay and associated waters. Reeves (1998) summarized density estimates for ringed seal in several areas calculated separately for three ice types, including fjords (1.72 seals per km^2), coastal shelf (1.31 seals per km^2) and pack ice (1.39 seals per km^2). We averaged all these abundance estimates for ringed seal. Reeves et al. (1998) reported annual catches of ringed seals of 4,590 for Qikiqtarjuaq, 4,733 for Clyde River and 2,487 for Pond Inlet in 1981-83; and more recently, the Nunavut wildlife harvest study reported from 1996 to 2001 an annual average of 2004 seals for Clyde River, 2113 for Pond Inlet and 2950 for Qikiqtarjuaq, yielding a total of 6,011 when considering that only half the seals for Pond are caught in the model area (Priest and Usher, 2004). The P/B was calculated as 0.147 year^{-1} and the Q/B was calculated as 15.32 year^{-1} based on digestible energy intake calculated for two captive ringed seals (Ochoa-Acuña et al., 2008). Ringed seal feed mainly on small pelagic fish and crustaceans such as amphipods, euphausiids, Arctic cod, polar cod (*Arctogadus glacialis*), but also on other small fishes. Holst et al. (2001) reports the summer diet of ringed seals in east and west sides of the North Water Polynya, Northern Baffin Bay, while Yurkowski et al. (2016) reported ringed seal diet near Pangnirtung. The latter showed that the contribution of Arctic cod to seal diet varies regionally and with life stage, and it is higher in more northern regions. The diet was set to 31 % Carnivorous zooplankton, 2.55 % Omnivorous zooplankton, 50.45 % Arctic/polar cod, 10 % sculpins/eelpouts, 6 % large crustaceans.

OTHER SEALS

Other seals that are important components of the Baffin Bay ecosystem are bearded seal (*Erignathus barbatus*), hooded seal (*Cystophora cristata*) and harp seal (*Pagophilus groenlandicus*). Bearded seals inhabit Arctic waters year-round and may undertake local movements in response to ice conditions. In late winter some may occupy offshore pack ice over deep water (>500m) in northern Baffin Bay and widely distribute in low densities over much of the Baffin Bay offshore pack ice in June (Finley and Evans, 1983). Thus, their distribution appears to be restricted by the extent of pack ice and shallow water. They usually prefer areas of 250 meters deep based on their foraging ecology. The total population estimates are unknown. From 1958-1979 it was estimated that 190,000 seals occurred in the Canadian waters' component, including the Arctic Archipelago, Davis-Baffin and Hudson Bay (Cameron et al., 2010). For the western Hudson Bay, the density of bearded seals in 1995 was estimated as 0.024 seals per km^2 for a total of 1,980 seals (Lunn et al., 1997). Bearded seal is taken in relatively small numbers in virtually all coastal communities. From 1996-2001, Clyde River reported 19 seals per year, Qikiqtarjuaq reported 22 seals per year, and Pond Inlet reported 28 seals per year (we considered only half of Pond Inlet harvest within the model area) totalling 55 seals/year (Priest and Usher, 2004). Diet composition of bearded seals in Pond Inlet, Grise Fiord and Clyde River in summer of 1978-1980 included large proportion of sculpins, followed by Arctic cod and smaller amounts of eelpouts, snailfishes, shrimps, clams and polychaetes (Finley and Evans, 1983).

Hooded seal whelps in late March on the pack ice in two areas: a major concentration around Newfoundland and a small one in the Davis Strait. In Baffin Bay hooded seals may occur mainly from April-September, as some areas along the Baffin Bay basin appear to be important feeding areas. Some hooded seals can be found all through the winter in some areas in Baffin Bay, but most of the seals are thought to spend the winter in the waters around Newfoundland (Andersen et al., 2009). Hooded seals occur mostly in areas deeper than 200 m where they feed (Andersen et al., 2009). The total NW Atlantic population (Davis-Baffin and Atlantic Arctic) has been estimated to consist of 593,500 seals (SE = 67,200) in 2005, although there is considerable uncertainty around these estimates due to limited understanding of the relationships between whelping areas (Hammill and Stenson, 2006). Hooded seal harvests are not regulated. For 2005 the harvest estimates were 13,473 (Hammill and Stenson, 2006). There are no studies reporting hooded seal diet near Baffin Island. A study in Southwest Greenland, Central West Greenland, Ummannaq and Upernavik reported diets from 1986-1993. Greenland halibut was found to be the most important prey for hooded seals in these regions, followed by Arctic cod and to a less extent other fish, cephalopods and shrimps (Kapel, 2000).

Harp seals are the most abundant pinnipeds and have a wide distribution throughout the eastern Canadian Arctic, Northwest Atlantic, Greenland Sea, White and Barents Seas. Seals that whelp and moult in the Gulf of St. Lawrence and Newfoundland intermingle during the non-breeding period, summering in the Canadian Arctic and/or West Greenland. Some of the harp seal population remains in Arctic regions year-round, while approximately 80% are considered to migrate south beginning in mid-November and remain in southern waters until about mid-June (Finley et al., 1990; Hammill and Stenson, 2000; NAMMCO, 2016). In the NW Atlantic (Davis-Baffin and Atlantic Arctic), the estimated population number for 2012 was 7,420,000 (95% CI 6,360,000 - 8,360,000) (Hammill et al., 2015). Removals from subsistence harvest as well as commercial and bycatch were 208,482.25 seals per year averaged for years 2008, 2010, 2012 and 2013. Yet, in the Arctic only ~1000 seals were taken per year in the last few years (Hammill et al., 2014). The same study by Kapel (2000) reports harp seal diet in NW Greenland with small pelagic fish (capelin, which here we consider as Arctic/polar cod due to similar ecological roles) as the most important prey, followed by small crustaceans, and small amounts of other fish, shrimps and cephalopods.

Parameter calculations for the functional group were weighed by biomass contribution of each species. We considered the seals occupy an area encompassing Baffin Bay, Hudson Bay and Strait, Ungava Bay, Foxe Basin, Labrador Sea, and Lancaster Sound. The P/B was calculated as 0.091 year^{-1} and the Q/B as 39.6 year^{-1} based on bioenergetic models for phocids (Ochoa-Acuña et al., 2008; Williams et al., 2020). The diet composition of the functional group was set to 56.94 % Arctic/polar cod, 9.5 % Greenland halibut, 5.64 % sculpin/eelpout, 5.38 % small demersal fish, 2.8 % omnivorous zooplankton, 1.2 % large crustaceans, 0.95 % cephalopod, 0.08 % bivalves, 0.02 % polychaetes, 17.4 % import (to account for feeding on euphausiids outside the model area).

ATLANTIC WALRUS

The Atlantic walrus (*Odobenus rosmarus rosmarus*) that frequent the model area belong to the Hudson Bay-Davis Strait stock. In the summer, this stock is distributed through the east coast of Baffin

Island, northern Hudson Bay, Hudson Strait, Davis Strait, and west Greenland. Between June and September, walruses occur along the outer coastline of southeastern Baffin Island up to Clyde inlet (Heide-Jørgensen et al., 2014; COSEWIC, 2017). Their migration and distribution are not very clear, but some walruses that summer at southeastern Baffin Island winter off West Greenland, while others might winter in southern Baffin Island and Davis Strait. Walruses wintering West Greenland leave in April-May and swim across Davis Strait, arriving at East Baffin Island by the end of May. The timing of the spring dispersal and migration towards Canada is closely linked to the extent and timing of the retreat of the pack ice edge. The reverse migration also occurs (DFO, 2000). There are no complete or recent estimates of walrus stocks in Nunavut. Stewart et al. (2013) estimated the Southeast Baffin Island summer aggregation to be 2,502 (95 % CI 1,660-3,345) individuals in 2007; in 2014 an aerial survey in north and west Hudson Bay estimated 5,500 walruses; while a 2012 survey estimated the population wintering in Hudson Strait at 6,020 walruses, probably from various stocks (DFO, 2000). Based on these, Hammill et al. (2016) suggested a minimum population size of 18,900 individuals occupying an area of 1,759,137 km². Walrus prey is largely found in waters less than 100 m; therefore, walruses are associated with waters of 20-80 m deep. They are found only up to Clyde Inlet. This walrus stock is hunted in Canada from the communities of Whale Cove through Hudson Strait to Clyde River on eastern Baffin Island and Killiniq in Nunavik (Priest and Usher, 2004). From 2006-2016 the catches reported for this region were on average of 50.1 individuals per year (DFO 2018). The P/B was calculated as 0.085 year^{-1} and the Q/B was calculated as 30.4 year^{-1} based on walrus' daily feeding rates in Northeast Greenland (Acquarone et al., 2006). Diet for walrus in the Arctic is available for Foxe Basin, northern Hudson Bay for summer and fall months for 1987-1988 (Fisher and Stewart, 1997). The diet was set to 94.11 % bivalves, 0.97 % polychaetes, 4.53 % echinoderms, 0.14 % omnivorous zooplankton.

SEABIRDS

Biomass and P/B calculations for seabirds were similar to marine mammals, i.e., biomass was calculated as number of individuals times weight per km2, while P/B was calculated as the sum of reported natural mortality and harvest mortality rates (Table 2).

The Q/B was calculated using the daily energy requirements calculations according to reported field metabolic rates (Bech et al., 2002; Welcker et al., 2010; Elliott et al., 2013; Mallory and Forbes, 2013). After, we used the average energy density of prey items previously reported (Hunt et al., 2000; Guénette et al., 2005; Harter et al., 2013) and diet composition of seabirds to calculate their consumption rates.

Thick-billed murre (*Uria lomvia*), black-legged kittiwake (*Rissa tridactyla*), and northern fulmar (*Fulmarus glacialis*) are the most numerous seabirds in the East coast of Baffin Island. Other seabirds, such as little auk (*Alle alle*), black guillemots (*Cepphus grylle*) and white gulls (*Larus hyperboreus*) breed in eastern Baffin Island, but not much is known regarding their abundance. Little auk, for example, is quite numerous in Baffin Bay, but their colonies are located in West Greenland, and they forage close to that area. There is only one known colony of little auk in east Baffin Island in Home Bay, but this colony is small and there are no good estimates of abundance (Mark Mallory, pers. Comm.). The most important seabird colonies within the model area are located in Scott Inlet (263 km^2), Buchan Gulf (387 km^2), Cape Searle and The Minarets. These last two can be considered a large colony - Qaqulluit/Akpait (12,894 km^2) (Mallory et al., 2019). Seabirds are present in these colonies from mid-April through October. In the open sea (typically >1km from shore), Arctic marine birds use both benthic and pelagic resources, up to a depth of 200 m (Mallory et al., 2019).

Thick-billed murres that summer in the eastern Canadian Arctic spend the winter off southwest Greenland and Newfoundland. The major influx into the Canadian Arctic begins about mid-May and continues throughout May and into June (Frederiksen et al., 2016). Within the model area, they have a massive breeding colony in Akpait (near Qikiqtarjuaq) (Mark Mallory, pers. Comm.). This colony comprises 130,000 pairs, i.e., 260,000 individuals using a marine area of 12,894 km^2 (Gaston et al., 2012; Mallory et al., 2019). Murres are among the most commonly harvested seabirds in Arctic Canada (Merkel and Barry, 2008), yet numbers are low. Donaldson (1988) (in Merkel and Barry 2008) estimated that, of about 15,000 birds taken annually in the Baffin Region communities of Arctic Canada, about 80% of the harvest was common eiders, 13% murres and the remaining were black guillemots. The survival rate of murres has been estimated from 0.75-0.95 for adults and 0.52 per year for juveniles and chicks (Schreiber and Burger, 2001), for a maximum age of 29 years old. Murres are deep-diving seabirds that regularly dive to depths >100 m to feed, and occasionally below 200 m (Gaston and Hipfner, 1998; Gaston and Elliott, 2014), feeding mostly on small fish and invertebrates. Gaston and Bradstreet (1993) quantified murre diet composition in the North Water Polynya in spring, summer and fall (1998-1999), in the Minarets, Davis Strait in summer (1985) and in Cape Hay, Bylot Island in summer (1976-1979). The relative contribution of invertebrates relative to fish increased with latitude, while the prey diversity decreased.

Kittiwakes breed in the eastern Canadian Arctic, where they arrive in mid-May to early June, and spend the winter in open-water areas of Davis Strait, the Labrador Sea and the north Atlantic Ocean (Mclaren, 1982; Frederiksen et al., 2014). Similar to murres, kittiwakes have a major colony in Akpait (within the model area) counting 1,900 pairs or 3,800 individuals (Gaston et al., 2012; Mallory et al., 2019). Survival rate has been estimated between 0.88-0.93 per year for adult kittiwakes and 0.541 for juveniles (Aydin et al., 2007), for a maximum age of 18 years old. Diet of kittiwakes, a surface feeder, was reported in the North Water Polynya in summer, spring and fall of 1998-99, mainly consistent of amphipods such as Themisto libellula, pteropods, copepods and Arctic cod (Karnovsky et al., 2008).

Northern fulmars return to their breeding colonies along west Baffin Bay in May, where they remain until mid- to late September before migrating south to Davis Strait (Mclaren, 1982; Mallory et al., 2010). In winter fulmars tend to remain in the Labrador Sea (Mallory et al., 2008). Within the model area, northern fulmars have colonies in Scott Inlet (10,000 pairs), Buchan Gulf (10,000 pairs), Cape Searle (35,000 pairs) and The Minarets (15,000 pairs), occupying a marine area of 13,544 km2 in total (Gaston et al., 2012; Mallory et al., 2019). Fulmar population numbers in these colonies seem to be declining (Mark Mallory, personal communication). Survival rate of fulmars has been estimated to be between 0.94-0.97 for adults and 0.541 for juveniles (Hatch, 1993), with a maximum age of 31 years, whereas others calculated an annual mortality rate of 0.055 for fulmars (Furness and Monaghan, 1987). Similar to kittiwakes, fulmars are surface feeders. Stomach contents of this species near Pond Inlet in 1979 and more recently near Qik, indicate small pelagic fish are their main prey, especially Arctic cod, but also lantern fish (Bradstreet and Cross, 1982; Leblanc et al., 2019).

Parameter calculations for the functional group were weighed by biomass contribution of each species. The P/B was calculated as 0.235 year^{-1} and the Q/B as 254 year^{-1}. The diet composition of the functional group was set to 16.52 % omnivorous zooplankton, 2 % *Calanus* copepods, 13.23 % carnivorous zooplankton, 10.05 % Arctic/polar cod, 14.74 % small pelagic fish, 2.64 % small demersal fish, 3.59 % sculpin/eelpouts, 15.00 % shrimp, 2 % cephalopods, 20.23 % import (to account for feeding on euphausiids outside the model area).

FISH AND LARGE INVERTEBRATES

We included 10 fish groups, of which three include only one species. Natural mortality for fish was estimated from the empirical relationship linking mortality, the parameters of the von Bertalanffy Growth Function (VBGF) and mean environmental temperature (Pauly, 1980):

6. $M = K^{0.65}.L_{\infty}.T_c^{0.463}$

where M is natural mortality (/year), K is the curvature parameter of the VBGF (/year), L_{∞} is the asymptotic length (cm) and T_c is the mean ambient temperature (°C). We used the life-history tool in Fishbase to do these calculations for the different fish species (Froese and Pauley, 2008). Surface water temperatures in Western Baffin Bay can vary from 0 to 5 in summer, while deeper waters are usually near or at 0°C (Wang et al., 1994; Treble, 2011). Thus, for fishes that inhabit the bottom at deeper waters, we used a temperature of 0.1°, for pelagic fish and fish in more coastal areas, we used a temperature of 1°C, while for anadromous fishes we considered a temperature of 4°C, which is about the lower end of their preferred temperature.

Greenland halibut comprises the only commercial fishery in the area, while Arctic char is a key species for substance harvest for local communities. Fishing mortality was taken from fishery catch reports when available or considered negligible when these studies were not available in the area.

For species which there is no published information on feeding, empirical formulae implemented in the life-history routine of Fishbase was used (Palomares and Pauly, 1998):

7. $\log\frac{Q}{B} = 7.964 - 0.204.\log W_\infty - 1.965.T' + 0.083A + 0.532h + 0.398d$

where W_∞ is the asymptotic weight (kg), $T´$ is 1000/Kelvin (Kelvin = °C + 273.15), A is the aspect ratio (height^2 (cm)/ surface area (cm) of the caudal fin), h is a dummy variable expressing food type (1 for herbivores, 0 for detritivores or carnivores) and d is a dummy variable also expressing food type (1 for detritivores, and 0 for herbivores and carnivores).

Table 3. Values used for estimating P/B and Q/B for fish groups in the Baffin Bay coastal and shelf ecosystem model.

	Length at infinity cm	**Temperature °C**	**K**	**Aspect ratio**	**Natural mortality year^{-1}**	**Landings ton km^{-2}**	**P/B year^{-1}**	**Q/B year^{-1}**
9. Greenland shark	546	1	0.007	1.63	0.007	0.0007	0.007	0.29
10. Greenland halibut	92.7	1	0.108	1.32	0.15	0.1034	0.14	1.65
11. Arctic char	61.6	4	0.06	1.32	0.11	0.05	0.19	2.3
12. Arctic/Polar cod	28-34	1	0.24-0.39	1.32	0.44-0.50	0	0.44-0.50	2.7-3.8
13. Small pelagic	8.6-13.8	0.1	0.26-0.45	1.32-1.9	0.56-0.7	0	0.56-0.70	3.9-5.8
14. Sculpins/Eelpouts	12.9-54.4	0.1-1	0.11-0.54	1.32	0.16-0.73	0	0.16-0.73	1.9-4.5
15. Small demersal	12.5-39.8	0.1-1	0.33-0.99	1.32	0.11-1.17	0	0.11-1.17	2.4-4.8
16. Large demersal	44.3-181	0.1-1	0.04-0.13	1.32	0.07-0.18	0	0.07-0.18	0.9-2.0

GREENLAND SHARK

Greenland sharks (*Somniosus microcephalus*) inhabit deep-water and coastal regions of the Arctic and North Atlantic within water temperatures <5°C. This species has been observed both at the surface and at depths up to 1,800 m (Yano et al., 2007; MacNeil et al., 2012). Although seasonal or annual movements are not known for this species, sharks can travel more than 1000 km (Hussey et al., 2018). Abundance of Greenland shark in the Arctic is unknown, but this is a common by-catch species in halibut fisheries, which consists of otter trawling, longlining and gill netting. Greenland Shark bycatch occurs throughout the range of inshore and offshore commercial fisheries off the coast of Baffin Island, in NAFO Subarea 0 (Cosandey-Godin et al., 2015; Wheeland and Devine, 2018). In 2015 mean annual catch was 160.9 tons (Jørgensen and Treble, 2016). Greenland shark population biomass for the modeled area was calculated by the Ecopath model assuming an EE of 0.50 (since this is a top predator). The P/B was calculated from a maximum length of 502 cm, an estimated lifespan of at least 272 years, age at first maturity of 156 years (length of first maturity of 350 cm), and a VBGF growth function K of 0.007 per year (Beverton, 1992; Yano et al., 2007; Nielsen et al., 2016), using empirical relationships by (Beverton, 1992; Froese and Binohlan, 2000). This yielded a P/B of 0.007 year^{-1}. The Q/B was calculated as 0.29 year^{-1} using an empirical equation (Palomares and Pauly, 1998). Diet composition for Greenland shark is available in East and West Greenland from a large sample including different age classes from 2013-17 (Nielsen et al., 2019). Diet was set to 23.16 % large demersal fish, 3.34 % Greenland halibut, 4.01 % small demersal fish, 0.34 % sculpins/eelpouts, 1.14 % Greenland shark, 13.97 % other seals, 0.71 % ringed seal, 0.05 % polar bear, 45.19 % cephalopods, 1 % large crustaceans, 1.1 % seabirds, 3.99 % echinoderms, 2 % other benthos.

GREENLAND HALIBUT

Greenland halibut (*Reinhardtius hippoglossoides*) is a deepwater benthopelagic fish, found in nearshore and offshore waters of Baffin Bay, preferentially below 500 m but also at low densities up to 350 m (Walsh, 2008). Habitat area of this species was calculated as 33% of the model area (Janjua et al., 2015). Although there are no abundance estimates for this species covering the entire model area, research surveys conducted in the southern part of NAFO Division 0A in 2016 reported a mean biomass of 2.83 ton km^{-2} (Treble, 2017).This species makes up the only commercial fishery in western Baffin Bay. The offshore portion has been given commercial status since 2007 while the inshore portion falls within the Nunavut Settlement Area. This fishery uses single and twin bottom otter trawls, as well as longline and gillnets, taking place from June to November (Janjua et al., 2015; Hurtubise, 2016; Nanang, 2020). The mean annual catch was estimated as 6,676 ton for NAFO Division 0A from 2006-2016, yielding a fishery rate of 0.108 ton km^{-2} year^{-1} (Treble and Nogueira, 2020). Natural mortality was calculated from a maximum length of approximately 90 cm in NAFO 0A area (Janjua et al., 2015), maximum age of 27 years, age at maturity of >11 (Atkinson et al., 1982) and length at maturity from 62-67 cm, and a VBGF growth function K of 0.108 per year (Froese and Binohlan, 2000). This yielded a P/B of 0.14 year^{-1}. The Q/B was calculated as 1.65 year^{-1} based on length-weight relationships from Walsh (2008). Diet composition for this species was reported in Davis Strait in 1986 (Orr and Bowering, 1997), and more recently in the Beaufort Sea in 2012-2014 (Giraldo et al., 2018). As the fish grows, smaller fish like Arctic cod and redfish become less important, whereas other halibut become more important in diet. Diet was set to 24.25 % Arctic/polar cod, 2 % Greenland halibut, 5 % sculpin/eelpouts, 24.5 % small demersal fish, 13.75 % cephalopods, 17.75 % large demersal fish, 2.13 % carnivorous zooplankton, 1.075 % omnivorous zooplankton, 0.025 % *Calanus* copepods, 7.525 % large crustaceans, 2 % polychaetes.

ARCTIC CHAR

Arctic char (*Slavelinus alpinus*) is an anadromous fish (or landlocked fish) common in subArctic and Arctic regions. In the Baffin region, anadromous char spawn and overwinter in rivers and lakes in Baffin Island, migrating as adults through the fjords and into Baffin Bay coastal areas when the rivers are ice free. They normally spend the summers feeding in marine waters near shore along the coast and migrate back into fresh water during the fall (Janjua et al., 2015). The calculated marine habitat of Arctic char is only 10% of the total modeled area Baffin Bay shelf and coastal ecosystem (Janjua et al., 2015). In the absence of abundance estimates we let Ecopath estimate the biomass by setting EE to 0.95. Janjua *et al* are currently studying population dynamics of Arctic char in fjords and lakes near the community of Qikiqtarjuaq, including Paddle Fjord, Nudluit Fjord and Circle Lake. Inuit from Qik catch Arctic char mainly near Paddle Fjord, Nudlung Fjord, Nedluseak Fjord and Confederation Fjord, especially Paddle Fjord. These authors calculated mortality rates based on natural mortality and fishing mortality in the studied regions, resulting in a P/B of 0.19 year^{-1} (Muhammad Y. Janjua, per. Comm.). The Q/B was calculated as 2.3 year^{-1} using the life tool in fish base. Diet composition was available for Frobisher Bay, in Hudson Strait in 2008-2009 (Spares et al., 2012). Diet was set to 33.765 % carnivorous zooplankton, 45.055 % omnivorous zooplankton, 2 % *Calanus* copepods, 3.18 % Arctic/polar cod (replaced from capelin), 3 % sculpins/eelpouts, 3 % small demersal fish, 1 % Polychaetes.

ARCTIC/POLAR COD

Polar cod (*Arctogadus glacialis*) and Arctic cod (*Boreogadus saida*) are the two codfish species endemic to the Arctic Ocean and adjacent seas (Mecklenburg et al., 2011). These species are closely associated with sea ice at certain life stages, comprising an important part of the sympagic fauna. Polar cod inhabits the fjords and shelf areas of the Arctic seas and appears to be absent from the deeper parts of the Arctic Central Basin (Christiansen et al., 2012), while Arctic cod is widely distributed throughout these regions (Mecklenburg et al., 2011). Therefore, Arctic cod dominates in surface waters down to about 1000 m depth, inshore and offshore. Arctic cod inhabits mostly near-bottom layers in the shelf area, whereas in deeper waters over the continental slopes and the central Arctic basins, Arctic cod inhabits layers closer to the surface, under the sea ice (Mecklenburg et al., 2018). This species occurs in large shoals and schools both in open water and under the ice. Biomass estimates from a hydroacoustic-trawl surveys conducted in the Canadian Service ice zone region of west Baffin Bay on the CCGS Amundsen from July through September of 2016 yielded a biomass of 5.74 ton km^{-2} of Arctic cod (unpublished data, J. Herbig et al). The P/B and Q/B were calculated using the life tool in fish base as 0.47 year^{-1} and 3.5 year^{-1}, respectively, averaged for the two species. Stomach contents were studied for Arctic cod in Cornwallis Island in 2010 for different age classes (Matley et al., 2013). The values are in % weight for three different age classes, which we averaged. Polar cod diet is quite similar to that of Arctic cod, and since Arctic cod tend to be more abundant in Baffin Bay, we assumed the diet of Arctic cod as representative of this functional group. Diet composition was set to 46.15 % omnivorous zooplankton, 12.1 % carnivorous zooplankton, 41.75 % *Calanus* copepods.

SMALL PELAGIC FISH

This functional group includes other forage fish such as lanternfishes and smelts, including glacier lanternfish (*Benthosema glaciale*) and goiter blacksmelt (*Bathylagus euryops*) as representative species. These species are epi to bathypelagic and can inhabit waters from 100 to 3200 m deep (Nunavut Department of Environment Fisheries and Sealing Division., 2018). The EE was set to 0.95 to let Ecopath estimate the biomass of this group. The P/B and Q/B were calculated using the life tool in fish base as 0.63 and 4.85 year^{-1}, averaging the two representative species. No diet composition was available for these species from Baffin Bay, so we adapted reported diets for goiter blacksmelt from the Mid-Atlantic ridge (Sweetman et al., 2014), and for glacier lanternfish from the North Atlantic (Sameoto, 1980). Diet composition was set to 47.58 % *Calanus* copepods, 19.10 % omnivorous zooplankton, 33.03 % carnivorous zooplankton.

SCULPINS/EELPOUTS

This functional group includes Atlantic hookear sculpin (*Artediellus atlanticus*), bigeye sculpin (*Triglops nybelini*), ribbed sculpin (*Triglops pingelii*), polar sculpin (*Cottunculus microps*), Arctic eelpout (*Lycodes reticulatus*), doubleline eelpout (*Lycodes eudipleurostictus*), pale eelpout (*Lycodes pallidus*), all sculpins and eelpouts common in Baffin Bay (Jørgensen et al., 2005; Jørgensen et al., 2011; Janjua et al., 2015). These species are epibenthic or mesobenthic, inhabiting waters of various depths depending on the species from 10 to 1750 m (Nunavut Department of Environment Fisheries and Sealing Division., 2018). Given the lack of abundance estimates in the area the EE was set to 0.95 to let Ecopath estimate the biomass of this group. The P/B and Q/B were calculated using the life tool in fish base as 0.35 and 2.89 year^{-1}, averaging all species. A study in the Barents Sea reports diet of Atlantic hookhear sculpin, polar sculpin, Arctic eelpout, bigeye sculpin and ribbed sculpin (Eriksen et al., 2020). The diet was weighed for the functional group based on the Q/B contribution of each species to the total Q/B. The diet was set to 18.725 % omnivorous zooplankton, 34.175 % carnivorous zooplankton, 0.33 % *Calanus* copepods, 7.81 % Arctic cod/polar cod, 3.88 % small demersal fish, 14.40 % polychaetes, 5 % bivalves, 7.65 % large crustaceans, 2.62 % cephalopods, 3 % echinoderms, 2.12 % other benthos; 0.2 % sculpin/eelpouts.

SMALL DEMERSAL FISH

This group includes lumpsuckers, poachers, snailfishes and flounders, such as sea tadpole (*Careproctus reinhardt*), gelatinous sea snail (*Liparis fabricii*), Atlantic spiny lumpsucker (*Eumicrotremus spinosus*), Atlantic poacher (*Leptagonus decagonus*) and Arctic flounder (*Pleuronectes glacialis*). Snailfishes for example are very common in Baffin Bay shelf area (Jørgensen et al., 2005; Jørgensen et al., 2011; Janjua et al., 2015). Species in this group are meso to epibenthic, inhabiting waters from shallow up to 1,800 m deep (Nunavut Department of Environment Fisheries and Sealing Division., 2018). Flounders are a by-catch of the halibut fisheries, with about 1.2 tons caught in 2015 (Jørgensen and Treble, 2016). The EE was set to 0.95 to let Ecopath estimate the biomass of this group. The P/B and Q/B were calculated using the life tool in fish base as 0.53 and 3.13 year^{-1}, averaging seven representative species. Studies in the Barents Sea reported diet of gelatinous snailfish, sea tadpole, Atlantic spiny lumpsucker and Atlantic poacher (Dolgov, 1994; Eriksen et al., 2020), while diet for flounders was available from the western Arctic (Atkinson and Percy, 1991). The diet was weighed for the functional group based on the Q/B contribution of each species to the total Q/B. The diet composition was set to 25.35 % omnivorous zooplankton, 50.56 % carnivorous zooplankton, 14.22 % polychaetes, 1.33 % bivalves, 3.93 % *Calanus* copepods, 1.18 % large crustaceans, 1.25 % echinoderms, 6.58 % other benthos, 0.61 % small demersal fish.

LARGE DEMERSAL FISH

This functional group includes grenadiers and other gadiformes, redfishes, rays and wolffishes. Some of the species include roughhead grenadier (*Macrourus berglax*), threadfin rockling (*Gaidropsarus ensis*), Arctic skate (*Amblyraja hyperborean*) and thorny skates (*Amblyraja radiate*), deepwater redfish (*Sebastes mentella*) and spotted wolffish (*Anarhichas minor*). These species are benthic to benthopelagic, inhabiting waters from 25-800 m in the case of spotted wolffish, up to 2,500 m deep for Arctic skate (Nunavut Department of Environment Fisheries and Sealing Division., 2018). Deepwater redfish were considered threatened in April 2010 by the COSEWIC (Committee on the Status of Endangered Wildlife in Canada). Grenadiers, skates, redfish and wolffishes are by-catch species of the Greenland halibut fisheries, with 147.5 tons per year caught in 2015 (DFO, 2014). The EE was set to 0.95 to let Ecopath estimate the biomass of this group. The P/B and Q/B were calculated using the life tool in fish base as 0.136 and 1.58 year^{-1}, averaging five representative species. Diet composition was available for spotted wolffish, roughhead grenadier and thorny skate and deepwater redfish in the Barents Sea (Eriksen et al., 2020) and adjusted where appropriate to prey available in western Baffin Bay. Diet composition was set to 13.32 % other benthos, 8.55 % omnivorous zooplankton, 6.13 % *Calanus* copepods, 2.88 % bivalves, 14.26 % echinoderms, 4.53 % polychaetes, 13.21 % carnivorous zooplankton, 0.59 % sculpins/eelpouts, 21.30 %

large crustaceans, 4.22 % large demersal fish, 3.29 % small demersal fish, 2.44 % Arctic/polar cod, 2.54 % cephalopods, 2.54 small pelagic fish.

LARGE CRUSTACEANS

This functional group includes shrimps and crabs. *Pandalus* spp. were used as the representative species of the functional group, due to their abundance in Baffin Bay and importance as a food item (Reeves, 1998; Hammill and Stenson, 2000; DFO, 2019). Northern Shrimp (*Pandalus borealis*) is found in the Northwest Atlantic from Baffin Bay to the Gulf of Maine, while striped Shrimp (*Pandalus montagui*) is found from Davis Strait south to the Bay of Fundy. These species tend to occupy the same locations although striped shrimp prefers cooler water from -1 to 2°C at depths of 200–500 m than Northern shrimp, which inhabits waters from 0 to 4°C at depths of 300–500 m (DFO, 2019). The EE was set to 0.95 to estimate biomass. Mortality rates were estimated for shrimp in the Shrimp Fishing Area 5 as 0.78 year^{-1} (Orr et al., 2006), while in Alaska and the Barents Sea this estimate was between 0.24 and 1.58 year^{-1} (Fu et al., 2001), and an West Greenland model considered a P/B of 0.9 year^{-1} (Pedersen and Zeller, 2001). By averaging previous estimates, the P/B was calculated as 0.858 year^{-1}, which approximates the estimates for the neighboring region of West Greenland. Moles (1999) calculated feeding rates for Pandalid shrimp from Alaska in a lab experiment. These were kept in water at 4°C and 29.5 ppt salinity. The feeding rates ranged from 0.05 - 0.15 grams eaten per shrimp per week, i.e., on average 0.1 grams each per week. While we do not have biomass estimated for shrimp, we will use the same Q/B of 6 year^{-1} for shrimp in the West Greenland model (Pedersen and Zeller, 2001). Northern shrimp is an opportunistic species whose diet consists mainly of detritus, zooplankton and some benthos (Shumway et al., 1985; Hopkins et al., 1989). Adapting from the West Greenland model, the diet composition was set to 5% *Calanus* copepods, 12.5% omnivorous zooplankton, 12.5% carnivorous zooplankton, 5% other benthos, 5% echinoderms, 10% polychaetes, 5% phytoplankton, 45% detritus.

CEPHALOPODS

Only 10 species of cephalopods are found in high Arctic latitudes and complete their entire life cycle (including reproduction) in the Arctic. These are *Cirroteuthis muelleri* (cirrate), *Bathypolypus arcticus*, *B. bairdii*, *B. pugniger*, *Muusoctopus* sp., *M. sibiricus* and *M. leioderma* (incirrates), *Rossia palpebrosa* and *R. moelleri* (sepiolids), and *Gonatus fabricii* (pelagic squid) (Xavier et al., 2018). In Baffin Bay and the modelled area, *G. fabricii*, *Rossia sp.* and *C. muelleri* are the most important cephalopods (Gardiner and Dick, 2010; Janjua et al., 2015). *G. fabricci* and *C. muelleri* are meso-bathypelagic while *Rossia* sp. live in shelf to slope environments. In the absence of abundance estimates, the EE was set to 0.95 to let Ecopath calculate cephalopod biomass. Previous models used a P/B of 2.4 year^{-1} in West Greenland and

2.55 year^{-1} in Hudson Bay and Aleutian Islands (Pedersen and Zeller, 2001; Aydin et al., 2007; Hoover et al., 2013). By averaging these previous values, the P/B was set to 2.45 year^{-1}. Similarly, the Q/B was set to 6.5 year^{-1} averaging previously modelled Q/Bs (Pedersen and Zeller, 2001; Aydin et al., 2007; Hoover et al., 2013). The diet of Arctic cephalopods includes mainly crustaceans and fish, yet the data available are limited. While incirrate octopods and sepiolids generally tend to prey on benthic organisms (mostly crustaceans), the main prey of squid are fish and pelagic crustaceans. Cannibalism is also common, especially in squid. *G. fabricci* feed on planktonic crustaceans, pteropods and chaetognathes before hooks appear, while after hooks appear they feed on fish and other *G. fabricci*. *Rossia* sp. feed on crustaceans and fish (Xavier et al., 2018). Diet composition was set to 10 % carnivorous zooplankton, 10 % omnivorous zooplankton, 10 % *Calanus* copepods, 10 % Arctic cod, 10 % sculpins/eelpouts, 10 % small demersal fish, 15 % small pelagic fish, 5 % cephalopods, 20 % large crustaceans.

ZOOPLANKTON

Calanoid copepods are the most abundant type of zooplankton in Arctic waters. The zooplankton biomass in the Arctic is dominated by *Calanus glacialis* and Calanus *hyperboreus*, which range between 3 to 8 mm. Other species such as *Calanus finmarchicus*, Pseudocalanus spp., *Metridia longa, Triconia borealis* and *Microcalanus* spp. are also present. *Calanus* copepods are herbivores and graze on large amounts of phytoplankton and ice algae, especially during the spring bloom. These species are important sources of energy in the food web as they convert carbon from primary producers into energy-rich lipid reserves. Amphipods, which are typically between 12 and 25 mm, comprise a diverse group of crustacean zooplankton. The two main families in the Arctic are Gammaridae and Hyperiidae. Gammaridae are primarily found beneath the sea ice and on the sea bottom, while Hyperiidae are surface-dwelling and most common in open waters. Pteropods are a zooplankton group of free-swimming molluscs. One of the most abundant species is the shelled species *Limacina helicina*, which can get to up to 8 cm, and feeds as an omnivorous filter feeder.

Here, zooplankton species were separated according to their feeding habits. Zooplankton species abundances were determined during the Green Edge expedition in spring/summer of 2016, following the sea-ice retreat in Baffin Bay, as well as in an ice-camp site on the west coast of Baffin Island in 2015 and 2016 (Massicotte et al., 2019; Massicotte et al., 2020; Saint-Béat et al., 2020). Average weights per species were calculated based on length-weight relationships and conversion factors from literature (Appendix B). Biomasses were calculated for minimum and maximum size, of zooplankton individuals collected for each functional group. The average of these values was used in Ecopath. Production and consumption rates, as well as diet composition, were calculated in Saint-Béat et al. 2020, through linear inverse modeling (Vézina and Platt, 1988). To define boundaries of consumption and production, Saint-Béat et al. (2020) used the temperature dependent equations in Moloney and Field (1989) and Hirst and Bunker (2003), respectively (Appendix B).

The P/B and Q/B were calculated as the production and consumption flows calculated in Saint-Béat et al. (2020), respectively divided by biomass estimates per group. For zooplankton groups the unassimilated food was set to 0.4, instead of the Ecopath predefined value of 0.2 (Christensen et al., 2005).

CARNIVOROUS ZOOPLANKTON

Representative species of the carnivorous zooplankton group considered here are *Aglantha digitale*, *Eukrohnia hamata*, *Gaetanus tenuispinus*, *Heterorhabdus norvegicus*, *Paraeuchaeta* spp. and *Themisto abyssorum* (Saint-Béat et al., 2020). Carnivorous zooplankton species feed and grow all year round. Abundance of the functional group was 3,640.48 individuals per m^2 and length varied between 1.1 and 31 mm (Massicotte et al., 2019). The P/B was calculated as 3.10 (1.96-7.42) year^{-1} and the Q/B as 17.7 (11.2-42.5) year^{-1}. Diet composition was set to 7.3 % microzooplankton, 62.9 % *Calanus* copepods, 19.8 % omnivorous zooplankton.

OMNIVOROUS ZOOPLANKTON

This group includes *Boroecia maxima*, *Discoconchoecia elegans*, *Heterostylites major*, *Limacina helicina*, *Metridia longa*, *Microcalanus*, *Oithona similis*, *Oncaea notopus*, *Pseudocalanus* spp., *Spinocalanus longicornis* and *Triconia borealis* (Saint-Béat et al., 2020). This mesozooplankton feed all year round and do not accumulate significant reserves during summer. Thus, their production and consumption rates were assumed to reflect the whole year. Abundance of the functional group was 91,135.3 per m^2 and length varied between 0.2 and 13 mm. The P/B was calculated as 6.3 (3.31-58.6) year^{-1} and the Q/B as 20.1 (10.6-188) year^{-1}. Diet composition was set to 66.0 % sea ice algae, 15.2 % phytoplankton, 0.4 % bacteria, 2.1 % microzooplankton, 16.4 % detritus.

CALANUS COPEPODS

This group includes the herbivores *Calanus glacialis*, *Calanus hyperboreus* and *Calanus finmarchicus* (Saint-Béat et al., 2020). Species of this genus are able to limit their metabolic costs in winter in order to survive their unfavorable surroundings (Saint-Béat et al., 2020). They accumulate energy-rich compounds (lipids) that form up to 70% of their body mass (e.g., Maps et al. 2014), which allows them to be auto-sufficient during the winter. By this life trait, they transfer the carbon produced by primary producers during the short summer period to higher trophic levels during the whole year.

Abundance of the functional group was 7,247,410,000 individuals per km^2, and length varied between 0.6 and 7.2 mm. The P/B was calculated as 4.9 (3.97-6.38) $year^{-1}$ and the Q/B as 12.6 (10.2-16.4) $year^{-1}$, assuming they produce and consume only in summer. Diet composition was set to 24.1 % sea ice algae, 51.4 % phytoplankton, 1.7 % microzooplankton, 22.9 % detritus.

MICROZOOPLANKTON

This functional group includes ciliates, heterotrophs flagellates, and copepod nauplii. The abundance was recorded in cells per litre (for ciliates and heterotroph flagellates) (Massicotte et al., 2019) or counts (for nauplii). For the first two, cells per litre were converted to biomass based on biovolume to carbon conversions (Menden-Deuer and Lessard, 2000; Saint-Béat et al., 2020):

$$Carbon\ content\ (pgC\ cell^{-1}) = 0.216 * (Vol\ in\ \mu m^3)^{0.939}$$

And the conversion for protozoa of 1 gWW = 0.165 gC (Delaca, 1986). For copepod nauplii, biomass was determined based on relationships between pro-some length and carbon content (references in Bouchard et al., 2014). The P/B was calculated as 33 $year^{-1}$ and the Q/B as 100 $year^{-1}$. Diet composition was set to 48.4 % phytoplankton, 1.7 % bacteria, 49.9 % detritus.

BENTHIC ORGANISMS

Epibenthic surveys in Baffin Bay were carried out in 2016 with an Agassiz trawl, aboard the Amundsen science expedition (G. Yunda-Guarin, unpublished data). This yielded a biomass estimate for polychaetes of 0.019 ton km^{-2}, echinoderms of 0.733 ton km^{-2}, bivalves and gastropods of 0.09 ton km^{-2}, and 13.4 ton km^{-2} of other benthos. Yet, these results seem relatively low to sustain upper trophic levels. Hence, here we used either biomass estimates from the literature or let Ecopath estimate benthic biomass (with the exception of other benthos). For benthos the unassimilated food was set to 0.4, instead of the Ecopath predefined value of 0.2 (Christensen et al., 2005).

POLYCHAETES

Polychaetes are abundant benthic organisms in the Eastern Canadian Arctic, especially polychaete worms, while sipunculid worms are abundant at greater depths (Thomson, 1982). Some common species include *Nothria conchylega*, *Aglaophamus malmgreni* and *Jasmineira schaudinni* (G. Yunda-Guarin, unpublished data). Biomass of polychaetes was reported for central Baffin Bay in late 70s at different depth ranges (based on relative composition of infaunal benthos as a function of depth) (Thomson, 1982; Janjua et al., 2015). The P/B of 1 $year^{-1}$ was taken as the average from Weddell Sea model and West Greenland model (Hoover et al., 2013). The Q/B of 4 $year^{-1}$ was also taken from the Weddell Sea model

(Hoover et al., 2013). The diet was taken from Hudson Bay models (Hoover et al., 2013) and set to 1 % *Calanus* copepods, 4 % omnivorous zooplankton, 3 % carnivorous zooplankton, 3 % microzooplankton, 1 % polychaetes, 1 % echinoderms, 10 % other benthos, 4 % phytoplankton, 12 % ice algae, 61 % detritus.

ECHINODERMS

This group includes starfish (Asteroidea), brittle stars (Ophiuroidea), sea urchins, (*Strongylocentrotus sp.*) and sea cucumbers (Holothuroidea), common in Baffin Bay (Aitken and Fournier, 1993; Janjua et al., 2015). Some common species include *Ophiopholis aculeate* and *Ophioscolex glacialis* (G. Yunda-Guarin, unpublished data). Similar to polychaetes, biomass was estimated from Thomson (1982). Sea stars are caught in the halibut fishery as by-catch, with 2.2 tons caught in 2015 (Jørgensen and Treble, 2016). The P/B of 0.55 year^{-1} and Q/B of 1.8 year^{-1} were taken from the Beaufort Sea model (C. Hoover et al unpublished data). Echinoderm diet varies widely depending on class/species. Crinoids are mainly filter feeders, Asteroids can be predators or scavengers, Ophiuroids can be predators, scavengers, deposit and filter feeders, Echinoids can be predators, herbivores and filter feeders, and Holothutians can be deposit or filter feeders. The diet was taken from Hudson Bay models (Hoover et al., 2013) and set to 3.5 % omnivorous zooplankton, 4.5 % carnivorous zooplankton, 1 % *Calanus* copepods, 3 % microzooplankton, 10 % polychaetes, 1 % echinoderms, 10 % bivalves, 15 % other benthos, 3 % phytoplankton, 8 % ice algae, 41 % detritus.

BIVALVES AND GASTROPODS

Important species in the modelled area are *Portlandia artica*, *Hiatella arctica*, *Chlamys islandica*, *Axinopsida orbiculata*, *Delectopecten groenlandicus*, *Mya truncate* (Aitken and Fournier, 1993). *Mya truncata* is an important clam species for harvest in Qikiqtarjuaq. Abundance of *M. truncata* were estimated near Qik (Sifred, 2005). They estimated an average density for Old Broughton of 104.4 individuals m^{-2} at 16 m and 108.3 ± 34.5 individuals m^{-2} at 10 m (average ± 95% confidence interval). In Lowland the average density was 95.4 ± 25.5 individuals m^{-2}. First River samples had an average density of 8.3 ± 4.5 individuals m^{-2}. This study also estimated a natural mortality of 0.049 year^{-1} for this species. Yet, these estimates only covered a small area and one species. Biomass of bivalves was reported for central Baffin Bay by depth (Thomson, 1982; Janjua et al., 2015), yet we let Ecopath estimate bivalve/gastropod biomass assuming an EE of 0.95. The P/B of 0.57 year^{-1} and Q/B of 6.33 year^{-1} was used from other ecosystem models (Hoover et al., 2013). Diet composition was taken from Hudson Bay models (Hoover et al., 2013) and set to 3% omnivorous zooplankton, 5% carnivorous zooplankton, 5% microzooplankton, 5% phytoplankton, 12% ice algae and 70% detritus.

OTHER BENTHOS

This group includes anemones (Cnidaria, e.g. *Actiniaria* sp.), sea pen (Pennatulacea), corals (*Capnella florida*, *Duva florida*, Nephtheidae), sponges (Porifera, e.g. *Craniella cranium*) and agglutinated foraminifera (Aitken and Fournier, 1993; Janjua et al., 2015). Sponges are caught in the halibut fishery as by-catch, with 1.5 tons caught in 2015 (Jørgensen and Treble, 2016). The biomass was calculated as 13.4 ton km^{-2} of other benthos (G. Yunda-Guarin, unpublished data). The P/B of 2.5 year^{-1} and Q/B of 12.5 year^{-1} were taken from Hudson Bay models based on Gulf of Alaska, Kerguelen Islands and Newfoundland models (Guénette et al., 2005; Hoover et al., 2013). Diet was also adapted from Hudson Bay models (Hoover et al., 2013) and set to 1% omnivorous zooplankton, 1% carnivorous zooplankton, 1% microzooplankton, 1% polychaetes, 1% echinoderms, 1% bivalves, 1% other benthos, 5% phytoplankton, 22% ice algae, and 66% detritus.

PRIMARY PRODUCERS AND DETRITUS

Abundance and production of phytoplankton and sea ice algae, bacteria and detritus were also measured during the Green Edge project in open water of Baffin Bay, and under the ice in the ice-camp off the west coast of Baffin Island (Massicotte et al., 2019; Massicotte et al., 2020; Saint-Béat et al., 2020). The P/B and Q/B (where applicable) were calculated as the production and consumption, respectively, divided by biomass estimates per group.

BACTERIA

Abundance of bacteria was calculated as 3.0 x 10^{13} cells per m^{-2} in 2016. Production was estimated as 526,083.2 µgC m^{-2} month^{-1}, resulting in a P/B of 11.1 year^{-1}. Consumption was calculated as 4,031,000 µgC m^{-2} month^{-1} with a Q/B of 170.2 year^{-1}. We considered the mean carbon content of 8.5 fg C per cell (1fgC = 10^{-15} gC) (Saint-Béat et al., 2020) and the conversion for protozoa of 1 gWW = 0.165 gC (Delaca, 1986). Bacteria feed 100 % on detritus.

SEA ICE ALGAE

Sea ice algae live beneath the sea ice and within brine channels inside the ice and are a critical food source in the Arctic, especially in the winter. These algae originate in autumn when cells are trapped during ice formation. They may continue to grow, encapsulated in the grazer-protected ice environment (Grossi and Sullivan, 1985; Aumack et al., 2014). Microalgae may survive the dark period by formation of resting cells or spores that can be used for short-term dormancy in the case of diatoms or of cysts that often require a dormancy period before the germination in the case of dinoflagellates. When ice-melt starts in spring (end of May in the Canadian Archipelago/Baffin sector), the sub-ice community of diatoms is the first to be sloughed off the bottom of the sea ice (Deal et al., 2011). Within one month, ice algal biomass can drop from tens of mgs chla m^{-2} to less than 1 mg chla m^{-2} (Deal et al., 2011). Previous estimates of total sea ice primary production in the Arctic range from 23.7 to 35.7 TgC $year^{-1}$ (Arrigo and van Dijken, 2011), about 2–10% of total primary production in Arctic waters. Based on the GreenEdge project (Massicotte et al., 2019), chlorophyll-a levels in the ice averaged 17,082 µg chla m^{-2} (CI 95% 1,260 - 58,492) in May-June of 2015-2016. Primary production averaged 8,778,555 µgC m^{-2} $month^{-1}$, resulting in a P/B of 149.5 $year^{-1}$. We assumed ice algae carbon:chla = 20-35 (average 27.5) and 1 gC = 9 gWW (Strathmann, 1967; Kang et al., 2001).

PHYTOPLANKTON

Phytoplankton bloom occurs in the spring/summer, being a key energy source at the base of the food web. These primary producers are mostly comprised of diatoms and flagellates in the Arctic. Diatoms have a silica-based cell wall that differs in shape from species to species, while dinoflagellates have distinct flagella, which allow them to move through the water column. In the Arctic there are more than 4,000 species of phytoplankton (Van Leeuwe et al., 2018). Phytoplankton blooms start underneath the ice (under-ice blooms) before the pelagic spring blooms. With increased light availability and consequent sea ice and snow melt, the ice algal bloom comes to an end, and the increase in transmitted light and stratification under the ice provide favorable conditions to under-ice phytoplankton blooms (Oziel et al., 2019; Ardyna et al., 2020). These can reach magnitudes similar to or greater than open water blooms (Oziel et al., 2019; Randelhoff et al., 2019; Ardyna et al., 2020). As the sea ice continues to melt, the pelagic blooms start in the ice edge and open water. Previous estimates of phytoplankton chlorophyll-a in Baffin Bay (open water) were 1.26 mgChl m^{-3} in summer of 1978 (Harrison et al., 1982) and 0.25 mgChl m^{-3} from 1998-2006 (Pabi et al., 2008). Large-scale estimates of annual primary production in the Arctic range from 329 (Sakshaug, 1997) to 350–500 Tg C $year^{-1}$ (Pabi et al., 2008). The GreenEdge project recorded levels of chla in 2015 and 2016 from 27 April to 14 July including under-ice and open water blooms (Oziel et al., 2019; Randelhoff et al., 2019; Saint-Béat et al., 2020). These totalled 46,357 µgChla m^{-2} (95% CI 16,847- 89,732) in the eastern side of Baffin Bay and 15,908 µgChla m^{-2} (95% CI 3,324-32,013) in the western side of the bay. Pelagic production was estimated as 14,210,059 (95% CI 4,741,350-24,781,125) and 10,669,809 (2,232,563-21,762,675) µgC m^{-2} $month^{-1}$ in the eastern and western sides of Baffin Bay, respectively. During this expedition, on the east side of Baffin Bay the phytoplankton bloom was caught in the end while on the west side it was caught in the beginning, but not measured until the end. As a result, phytoplankton biomass and production might be underestimated.

Only the western stations of this expedition are within the model area, but in an attempt to have a better estimate of the biomass and production we averaged the chla levels from both sides of the bay. Further, we considered minimum and maximum values of the different sampling stations as boundaries in the model. The resulting P/B was 172.4 year^{-1}. We assumed phytoplankton carbon:chla = 53 and 1 gC = 9 gWW (Strathmann, 1967; Kang et al., 2001).

DETRITUS – PARTICULATE ORGANIC MATTER (POC)

All detritus (pelagic and benthic) were included in one group, and no export was considered. The detritus biomass corresponds to the non-living portion of the particulate organic matter concentrations measured in the GreenEdge project. It was calculated as 6.57 gC m^{-2} in the euphotic zone. We assumed the conversion of 1 gC = 9 gWW, similar to primary producers.

DATA PEDIGREE

The uncertainty pedigree used in the model averaged 5, with a confidence interval of ± 30 % (Table 4). The data pedigree in Ecopath was implemented to define confidence intervals based on data source. This pedigree consists of a pre-defined qualitative scale (see Table C1) that simplifies assigning uncertainty ranges to input parameters. The confidence intervals are used to describe parameter uncertainty in the balanced ecosystem model using Ecosim modules. These values are defaults that can be changed by users.

Table 4. Pedigree (± confidence interval %) of biomass in the model area (B, t·km^{-2}·year^{-1}), Production/Biomass (P/B, year^{-1}), Consumption/ Biomass (Q/B, year^{-1}), and Landings (t·km^{-2}) for the first year of the west Baffin Bay shelf and coastal ecosystem model.

Group name	**B**	**P/B**	**Q/B**	**Diet**	**Landings**
Killer whale	5 (30)	4 (50)	6 (30)	4 (50)	
Polar bear	6 (10)	4 (50)	6 (30)	5 (30)	6 (10)
Narwhal	6 (10)	4 (50)	6 (30)	6 (10)	6 (10)
Bowhead whale	5 (30)	4 (50)	6 (30)	5 (30)	6 (10)
Ringed seal	4 (50)	4 (50)	6 (30)	6 (10)	6 (10)
Other seals	4 (50)	4 (50)	6 (30)	5 (30)	5 (30)
Walrus	5 (30)	4 (50)	6 (30)	5 (30)	6 (10)
Seabirds	5 (30)	4 (50)	6 (30)	5 (30)	5 (30)
Greenland shark	1(80)	4 (50)	4 (50)	5 (30)	5 (30)
Greenland halibut	6 (10)	8 (10)	4 (50)	5 (30)	6 (10)
Arctic char	1(80)	4 (50)	4 (50)	5 (30)	5 (30)
Arctic/Polar cod	6 (10)	4 (50)	4 (50)	6 (10)	
Small pelagic fish	1(80)	4 (50)	4 (50)	5 (30)	
Sculpins/Eelpouts	1(80)	4 (50)	4 (50)	5 (30)	
Small demersal fish	1(80)	4 (50)	4 (50)	5 (30)	
Large demersal fish	1(80)	4 (50)	4 (50)	5 (30)	5 (30)
Large crustaceans	1(80)	3 (60)	3 (60)	4 (50)	
Cephalopods	1(80)	3 (60)	3 (60)	4 (50)	
Carnivorous zooplankton	6 (10)	8 (10)	8 (10)	5 (30)	
Omnivorous zooplankton	6 (10)	8 (10)	8 (10)	5 (30)	
Calanus	6 (10)	8 (10)	8 (10)	5 (30)	
Microzooplankton	6 (10)	8 (10)	8 (10)	5 (30)	
Polychaetes	5 (30)	3 (60)	3 (60)	2 (10)	
Echinoderms	5 (30)	3 (60)	3 (60)	2 (10)	5 (30)
Bivalves	1(80)	3 (60)	3 (60)	2 (10)	
Other benthos	1(80)	3 (60)	3 (60)	2 (10)	5 (30)
Bacteria	6 (10)	8 (10)	8 (10)	6 (10)	
Ice algae	5 (30)	8 (10)			
Phytoplankton	5 (30)	8 (10)			
Detritus	5 (30)				

BALANCING THE ECOPATH MODEL

UNBALANCED ECOPATH MODEL

The initial parameterization exercise did not balance the model as 11 functional groups were unbalanced (Table 5). To balance the Ecopath model, the EE of each group needs to be a value between 0 and 1. From an ecological perspective, this value should be below, but closer to 1 for low to mid-trophic level individuals, assuming almost all production is used within the ecosystem. Top predators that are not hunted or predated upon have and EE of 0, as none of their production is consumed in the ecosystem. For primary producers, the EE commonly falls around 0.5 as a large portion of their production is not consumed outside of the microbial loop (Link, 2010). When the EE of a functional group exceeds 1 this indicates that the energy demand placed upon that group exceeds its production and therefore needs to be reduced.

Balancing followed guidelines in Ecopath best practice methodologies (Heymans et al., 2016) and ecological rules of thumb (Link, 2010).

Table 5. Ecopath parameters in the unbalanced model of the West Baffin Bay coastal and shelf ecosystem: Trophic Level (TL), Biomass in the model area (B, t·km^{-2}·year^{-1}), Production/Biomass (P/B, year^{-1}), Consumption/ Biomass (Q/B, year^{-1}), Ecotrophic Efficiency (EE), Production/Consumption (P/Q), and Landings (t·km^{-2}) for the first year of the model. Blue (and red) parameters were estimated by Ecopath. Unbalanced or ecologically unreasonable parameters are in red.

Group name	TL	B	P/B	Q/B	EE	P/Q	Landings
Killer whale	5.30	0.0001	0.03	9.11	0.00	0.00	
Polar bear	5.20	0.0017	0.15	6.00	0.40	0.03	0.0001
Narwhal	4.66	0.0470	0.03	19.80	1.27	0.00	0.0014
Bowhead whale	3.71	0.0460	0.01	14.23	0.43	0.00	5.74E-05
Ringed seal	4.10	0.1070	0.15	15.32	0.91	0.01	0.008656655
Other seals	4.32	0.0610	0.09	39.60	8.73	0.00	0.000878507
Walrus	3.20	0.0024	0.09	30.40	0.50	0.00	2.56E-05
Seabirds	3.88	0.0010	0.24	254.40	0.42	0.00	2.30798E-05
Greenland shark	4.82	1.061	0.01	0.29	0.50	0.02	0.0018
Greenland halibut	4.43	0.934	0.14	1.65	4.95	0.08	0.1081
Arctic char	3.54	0.028	0.19	2.30	0.95	0.08	0.005
Arctic/Polar cod	3.14	5.74	0.47	3.25	1.48	0.15	
Small pelagic fish	3.35	1.02	0.63	4.85	0.95	0.13	
Sculpins/Eelpouts	3.68	2.16	0.35	2.89	0.95	0.12	1.94E-05
Small demersal fish	3.54	2.73	0.53	3.13	0.95	0.17	0.00097
Large demersal fish	3.64	5.25	0.14	1.58	0.95	0.09	
Large crustaceans	2.69	3.90	0.86	6.00	0.95	0.14	
Cephalopods	3.98	0.39	2.55	6.90	0.95	0.37	
Carnivorous zooplankton	3.02	14.90	3.10	17.70	0.49	0.18	
Omnivorous zooplankton	2.02	13.78	6.30	20.10	1.18	0.31	
Calanus	2.02	33.10	4.90	12.60	1.11	0.39	
Microzooplankton	2.02	0.43	32.6	100.4	2.81	0.32	
Polychaetes	2.28	18.1	1.00	4.00	0.53	0.25	
Echinoderms	2.59	10.3	0.55	2.20	0.94	0.25	3.56E-05
Bivalves	2.18	8.64	0.57	6.33	0.95	0.09	

Other benthos	2.09	13.4	2.50	12.50	0.46	0.20	2.43E-05
Bacteria	2.00	1.72	11.1	170.2	0.15	0.07	
Ice algae	1.00	1.06	149.5		2.13		
Phytoplankton	1.00	3.71	172.4		0.46		
Detritus	1.00	14.8			0.80		

PRE-BALANCE DIAGNOSTICS – PREBAL

Pre-balance (PREBAL) diagnostics draw from ecological and fisheries principles to ensure rigor in model balancing (Link, 2010). These diagnostics were used to help detect ecological issues in model structure and guide balancing the network.

TROPHIC LEVEL

In general, trophic levels calculated in Ecopath were along the range of those reported in the literature in similar Arctic ecosystems (Appendix D, Tables D1-D3). For killer whales, the lower reported trophic level reported in the literature was likely calculated based on a generalized diet of killer whales around the globe (Trites et al., 1995). A higher trophic level would be expected for killer whales in Baffin Bay feeding to a larger extent on marine mammals. For some groups such as large crustaceans, polychaetes and other benthos, our model estimated trophic levels lower than those found for some species in the literature. Yet, these groups include several species within the respective taxa, potentially increasing the variability in trophic level of the functional groups.

BIOMASS

According to Link (2010), biomass should span 5-7 orders of magnitude. The slope of the relationship between biomass and trophic level on the log scale should be between 5-10% decline from lower to higher trophic levels. Biomass of the different taxa should follow the slope closely, with not many groups much higher or much lower than the slope. Yet, there are some exceptions as benthos tend to have larger standing biomass than most groups. Detritus should not be much more than the same order of magnitude as primary producer biomass estimates.

Standing biomasses of trophic level 2 zooplankton tend to be comparable to those of trophic level 1 phytoplankton (this is an exception to the ratio rule of thumb). This is given to the high productivity and low standing stock biomass of primary producers.

When comparing biomasses of predators and their prey, a predator should have at least a decimal point in a ratio to prey at an immediately lower trophic level and additional zeroes when comparing to even lower trophic levels. Ratios above 1 indicate too much predation pressure on prey, while too many zeroes indicate predators may not be feeding enough or an over-connected food web.

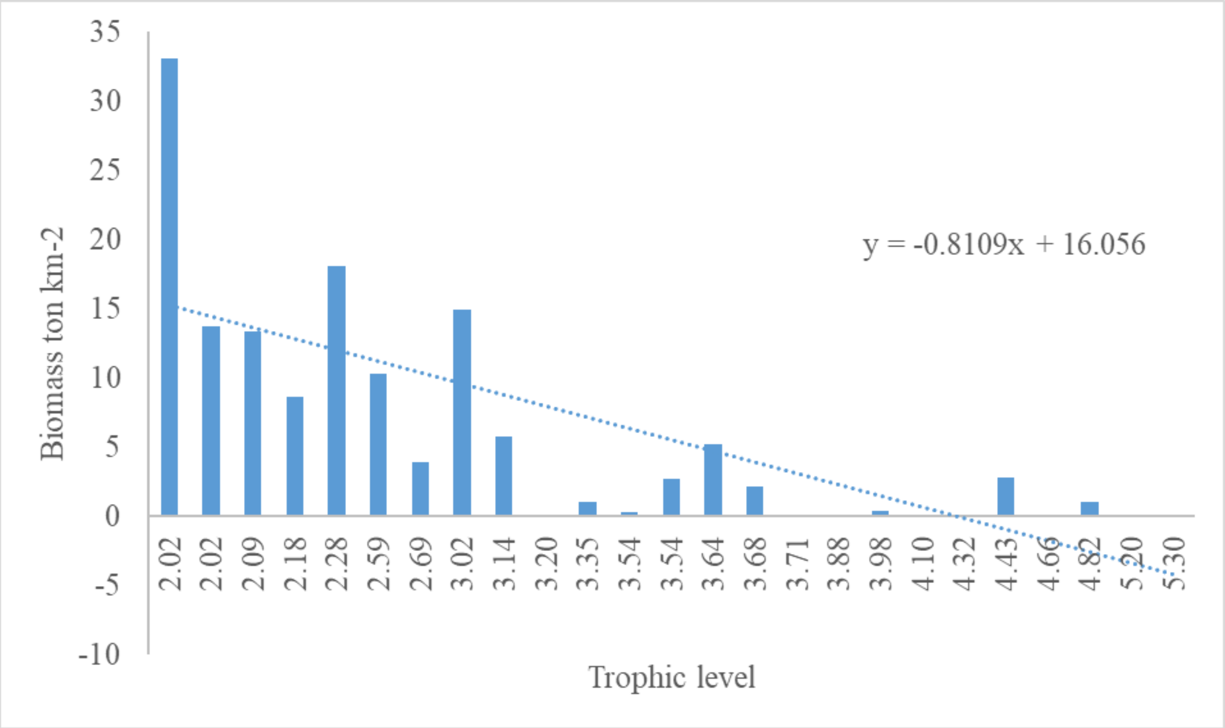


Figure 2. Biomass per trophic level PREBAL diagnostics of the unbalanced Baffin Bay coast and shelf ecosystem.

Table 6. Ratio diagnostics of the unbalanced West Baffin Bay coast and shelf ecosystem model.

	Biomass ratios	**P/B ratios**	**Q/B ratios**	**RB ratios**
Demersal piscivores to small pelagics	0.62	0.15	0.25	0.27
Small pelagics to zooplankton	0.19	0.15	0.33	0.69
Zooplankton to phytoplankton	13.2	0.15		
Small pelagics to phytoplankton	2.48	0.01		
Demersal to benthic invertebrates	0.14	0.06	0.14	0.24
Sharks to small pelagics	0.05	0.003	0.01	0.02
Marine mammal and birds to small pelagics	0.02	0.36	23.7	28.3
Whales to zooplankton	0.001	0.001	0.28	0.71

Biomass in the unbalanced West Baffin Bay coastal and shelf ecosystem spanned five orders of magnitude, falling within the ecological range suggested by Link (2010). However, multiple groups show variance from the trendline. Groups with peaks unusually larger than the trend line include *Calanus* copepods (TL = 2.02), polychaetes (TL = 2.28), carnivorous zooplankton (TL = 3.02), Greenland halibut (TL = 4.43), and Greenland shark (TL = 4.82). The biomass of Greenland shark was calculated within Ecopath and do not seem ecologically-sound (Table 5). On the other extreme are walrus (TL = 3.20), small pelagic fish (TL = 3.35), small demersal fish (TL = 3.54), and Arctic char (TL = 3.54) below the trend line. This may be expected for walrus since this species is a marine mammal, which tend to be at lower biomass than fish, but since they feed mostly on bivalves, their trophic level is in the same range of that of fishes. The biomasses of these fish groups were estimated by Ecopath based on the diet of predators. Since the overall predation on these groups is low, Ecopath estimated a relatively low biomass compared to other fish groups.

Biomass of detritus was much less than one order of magnitude above that of primary producers. Standing biomass of zooplankton was one order of magnitude higher than that of primary producers, which could indicate that biomass of zooplankton was too high in the model, or that the biomass of primary producers was too low. This was confirmed by the large biomass ratio between zooplankton and primary producers (Table 6). A biomass ratio above 1 was also observed for small pelagics to primary producers, indicating too much predation pressure on primary producers.

PRODUCTION / BIOMASS

There should be a general decline in P/B with increasing trophic level, except for homeotherms at high trophic levels (marine mammals and seabirds) which tend to have lower values than the trend line. A few taxa above or below the trend may be okay, but none is preferable.

When looking at ratios of P/B of predators and their prey, predator vital rates should be less than those of their prey. A predator should have at least a decimal point in a ratio to prey at an immediate lower trophic level and additional zeroes if compared to even lower trophic levels.

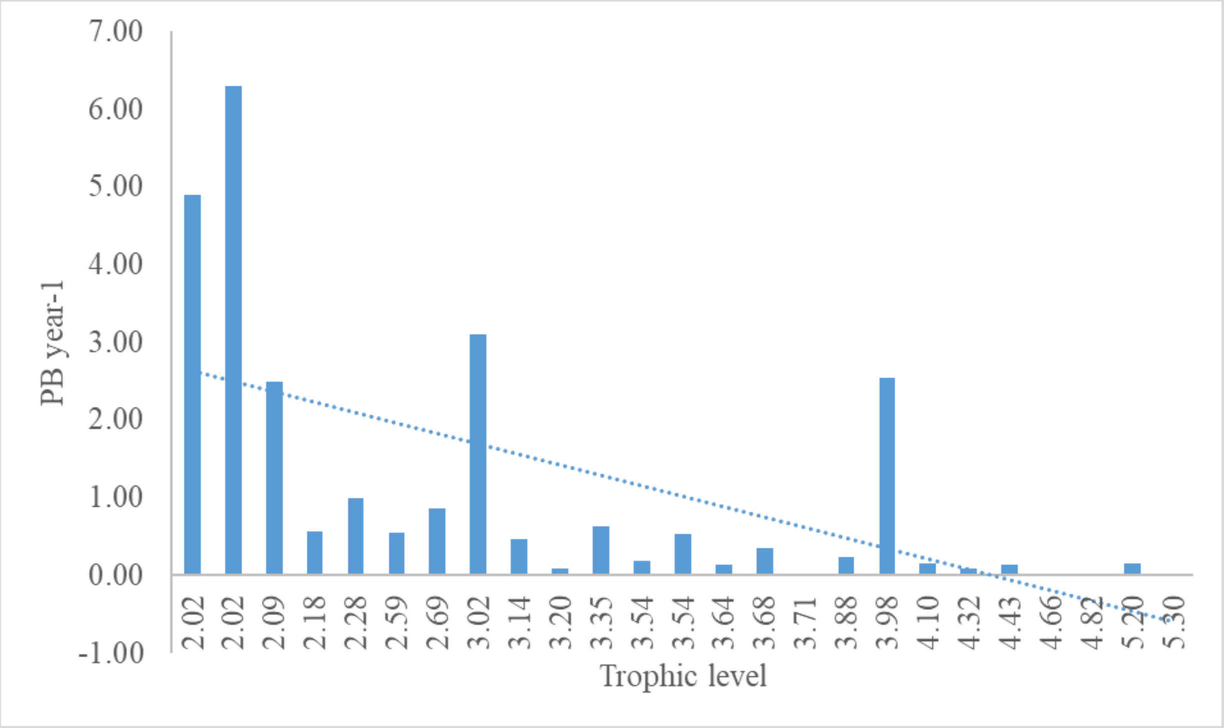


Figure 3. Production/Biomass (P/B) per trophic level PREBAL diagnostics of the unbalanced Baffin Bay coast and shelf ecosystem.

In the model, groups that showed P/Bs much higher than the trend line included *Calanus* copepods and omnivorous zooplankton (TL = 2.02), carnivorous zooplankton (TL = 3.02), and cephalopods (TL = 3.98). The P/B ratios were below 1 for all groups (Table 6).

CONSUMPTION / BIOMASS

Similar to P/B, there should be a general decline in Q/B with increasing trophic level, except for homeotherms at high trophic levels. Most fish should have Q/Bs on the order of 2-4 /year or less (since most fish consume ~0.5-1% their body weight per day). A few taxa above or below the trend may be okay, but none is preferable.

When looking at ratios of Q/B of predators and their prey, predator vital rates should be less than those of their prey. A predator should have at least a decimal point in a ratio to prey at an immediate lower trophic level and additional zeroes if compared to even lower trophic levels. The exception are homeotherms, which tend to have much larger Q/Bs than other groups.

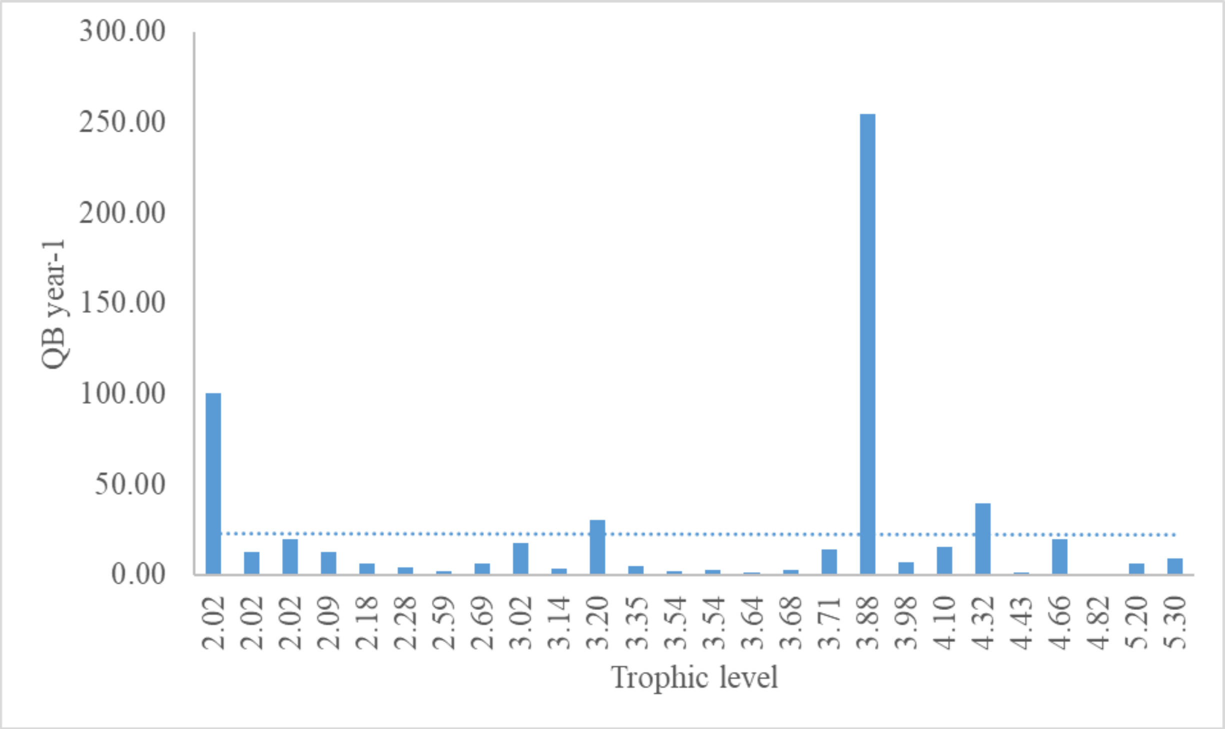


Figure 4. Consumption/Biomass (Q/B) per trophic level PREBAL diagnostics of the unbalanced Baffin Bay coast and shelf ecosystem.

Groups that showed Q/Bs much higher than the trend line included Calanus copepods (TL = 2.02), seabirds (TL = 3.88), and to a certain extent other seals (TL = 4.32). Calanus copepods may have consumption rates larger than expected due to Arctic seasonality in primary production. These copepods consume food in the spring/summer and convert it into lipid storage for the winter, period in which they undergo diapause (Saint-Béat et al., 2020). High Q/B rates for seabirds are also expected based on field metabolic rates of these species. The Q/B ratios were too high for marine mammal and seabirds to small pelagics (Table 6), which may be expected as homeotherms tend to have high consumption rates compared to poikilotherms.

PRODUCTION / CONSUMPTION

Production should not exceed Consumption (P/Q ratio, also known as growth efficiency), meaning that a taxa group cannot produce more than what is eaten. Therefore, P/Q should be between 0.1-0.3. This parameter may be lower for baleens and higher for very small organisms. Values greater than 0.5 are not often found but may be encountered in groups such as bacteria or in specially bred farmed fish. P/Q can never exceed unassimilated consumption.

The P/Q was below 0.1 for marine mammals and seabirds. This parameter was also low for Greenland shark, Greenland halibut, Arctic char, and bacteria, indicating these groups are not eating enough for their production. For cephalopods and *Calanus* copepods P/Q was above 0.3, exceeding unassimilated consumption for cephalopods.

RESPIRATION / BIOMASS

This parameter indicates the metabolic activity level of a group. These ratios are expected to be within 1–10 year^{-1} for fish and may be as high as 50–100 year^{-1} for groups with higher turnover such as copepods. The default value for the proportion of unassimilated food (20%) may be changed to better reflect the R/B ratio value expected of the group in question. When looking at ratios of R/B of predators and their prey, predator vital rates should be less of those of their prey. A predator should have at least a decimal point in a ratio to prey at an immediate lower trophic level and additional zeroes if compared to even lower trophic levels.

In the Baffin Bay model, the R/Bs seemed reasonable for fish groups, except for Greenland shark that had an R/B < 1. The R/Bs were on the lower range for zooplankton. Ratios of predator to prey were below 1 for all groups but marine mammals and seabirds to their prey. This could be related to the higher consumption and respiration rates of marine mammals, and especially seabirds, compared to fish.

BALANCING THE ECOPATH MODEL

To achieve model balance parameters certain functional groups were edited (Table 5). Although many parameters were edited, the main adjustments were made due to high predation pressure exerted by marine mammals on lower trophic levels, relatively high fish biomass, and consequent high predation pressure on zooplankton groups and primary producers. Parameter adjustments were made in conjunction in order to achieve mass balance, prioritizing parameters with higher uncertainty (based on the pedigree); hence we started by adjusting diet composition, followed by Q/Bs or P/Bs, and then biomasses. We also started with top predators and went down the food web until mass-balance was achieved, adjusting parameters within a functional group with the lowest pedigrees that allowed the model to balance. Diet composition studies in the Arctic only represent summer diets and may therefore be quite uncertain relative to the prey items and respective percentage of mass. Useful outputs of Ecopath are the mortalities and predator mortality rates that allow to identify the sources of mortality for each group and which ones are causing high EE. So, if the mortality was too high from predation pressure, we adjusted diet composition of the predator; then, if it was not sufficient to lower the EE of the prey, we altered the Q/B of the predator, the P/B of the prey, the biomass of the predator or the prey, or a mix of all. The model was balanced manually, by adjusting the parameters incrementally, through an iterative process during which small changes (e.g., ± 10 %) were made to the parameters and the results on EE for the groups with high EEs were checked.

In the unbalanced WBB food web, the EE was too high for narwhal, other seals, Greenland halibut, Arctic cod, omnivorous zooplankton, *Calanus* copepods, microzooplankton, and sea ice algae (primary producers' EE should be ~0.5). The biomasses estimated by the model for Greenland shark was too high for a top predator at 1 ton km^{-2}. When checking Predation Mortality Rates in Ecopath outputs the following were flagged as unbalanced: predation by narwhal on Greenland halibut, predation by other seals on Greenland halibut, predation by Greenland shark on other seals, predation by carnivorous zooplankton on *Calanus* copepods and microzooplankton. When checking Mortalities outputs, the following were flagged: other mortalities of narwhal, other seals, Greenland halibut, Arctic cod, omnivorous zooplankton, *Calanus* copepods, microzooplankton and sea ice algae. For narwhal fishing mortality was higher than predation mortality.

MARINE MAMMALS

The EE was above 1 for narwhal and other seals. The EE was especially high for other seals due to predation mortality caused by Greenland shark. This was a consequence of the calculated Q/B and P/Bs for Greenland shark, which made the model estimate an unrealistically large biomass for sharks. The P/B estimate by Fishbase for Greenland shark is very low. It is based on the calculation of VBGF K as 0.007, which is unrealistic for 392 years maximum age. These age estimates are currently being re-evaluated. Assuming a maximum age of 100 years is more realistic and closer to the adjusted value (M. Y. Janjua, pers. Comm.). We adjusted these parameters according to Janjua et al (2015) and decreased predation pressure by sharks on seals. These adjustments decreased the EE of other seals, although this was still > 1, and decreased the EE of ringed seal, which was close to 1. It also decreased the model-estimated biomasses for Greenland shark and other fish species. We further decreased predation pressure of polar bear on other seals, a well as polar bear biomass to the minimum value of the range of reported abundance for this species, which finally decreased other seal EE <1.

The EE of narwhal was above 1, mainly due to predation and harvest pressure. We started by increasing narwhal P/B by small increments to accommodate these pressures. As this was not sufficient, we tried decreasing predation pressure by polar bear and killer whale on narwhal, but this did not sufficiently lowered narwhal's EE. Then, we decreased harvest pressure on narwhal, which lowered their

EE. It is possible that hunters are also catching narwhal from other stocks during their migration across Baffin Bay.

FISH

High consumption rates of marine mammals lead to high EE of Greenland halibut and Arctic cod. We adjusted diet compositions of their main predators (other seals and narwhal for Greenland halibut; other seals and ringed seal for Arctic cod) and increased the P/B of these species in small increments until the EE was lower than ~0.95. The P/Bs were increased within values previously used for these species in other high latitude models (Pedersen and Zeller, 2001; Hoover et al., 2013; G Andy Whitehouse et al., 2014). For Greenland halibut, the P/B and Q/B values were further adjusted to achieve reasonable P/Q ratios.

ZOOPLANKTON

The biomasses of omnivorous and carnivorous zooplankton were adjusted within the range of reported abundances to decrease predation pressure on *Calanus* copepods and microzooplankton, while the biomass of *Calanus* copepods was decreased to lower pressure on primary producers. In this case we started by reducing zooplankton biomass since the PREBAL diagnostics suggested an overestimate of this group's biomass in the area. The biomass of microzooplankton was still too low to balance the model, so it was incrementally changed until the model balanced.

PRIMARY PRODUCERS

The biomass of sea ice algae was increased to further lower the EE for this group, within the range of values estimated during the GreenEdge expedition.

After these adjustments the EE of all functional groups was below 1.

BALANCED MODEL AND POST-BALANCE DIAGNOSTICS

TROPHIC LEVEL

After balancing the model trophic levels remained within those reported in the literature (Appendix D).

BIOMASS

After balancing the model, only *Calanus* copepods (TL = 2.02) and polychaetes (TL = 2.28) were still above the trendline. Despite the adjustments on zooplankton's biomasses, the biomass ratio between zooplankton and primary producers, as well as small pelagics and primary producers, was still above 1 (Table 7). Primary producers tend to have low standing biomasses and high production levels, which could explain these results. Yet, it is possible that the biomass of primary producers was underestimated in the region (see input parameter section).

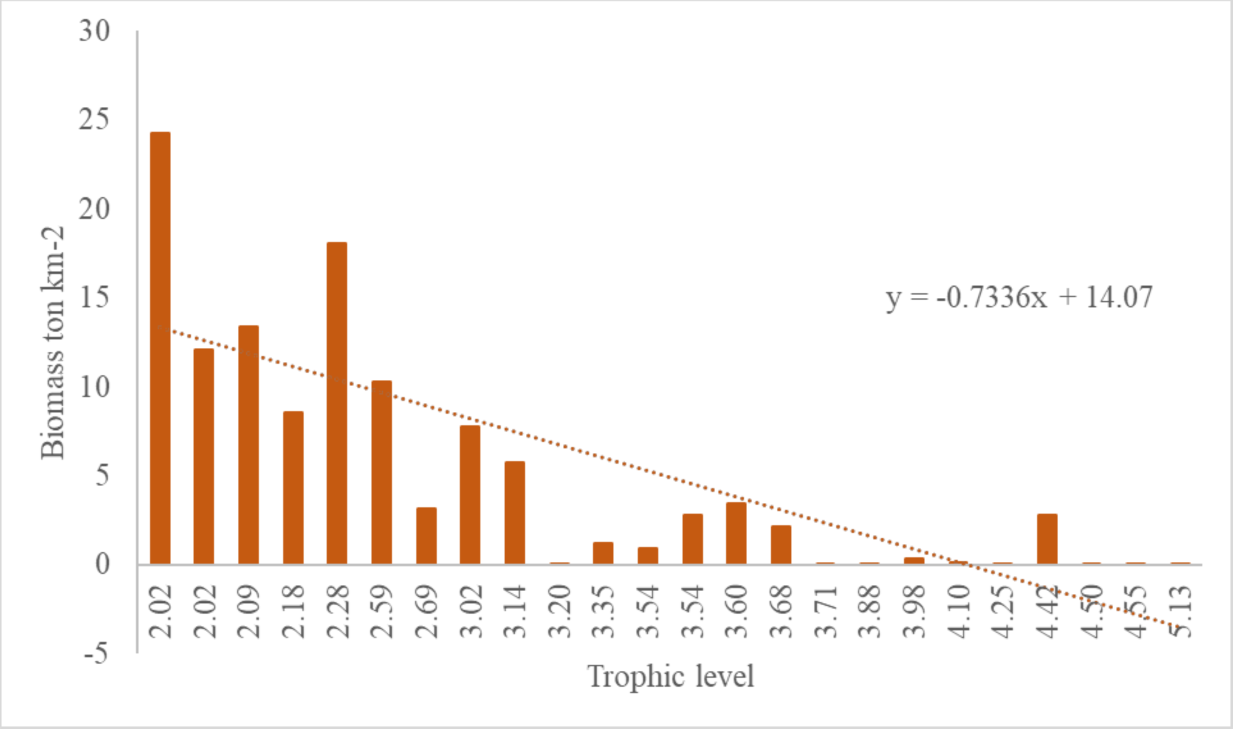


Figure 5. Biomass per trophic level PREBAL diagnostics of the balanced Baffin Bay coast and shelf ecosystem.

Table 7. Ratio diagnostics of the unbalanced West Baffin Bay coast and shelf ecosystem model.

	Biomass ratios	**P/B ratios**	**Q/B ratios**	**RB ratios**
Demersal piscivores to small pelagics	0.38	0.32	0.30	0.26
Small pelagics to zooplankton	0.27	0.16	0.33	0.68
Zooplankton to phytoplankton	7.54	0.15		
Small pelagics to phytoplankton	2.00	0.01		
Demersal to benthic invertebrates	0.09	0.15	0.17	0.23
Sharks to small pelagics	0.005	0.01	0.02	0.02
Marine mammal and birds to small pelagics	0.02	0.34	23.7	28.8
Whales to zooplankton	0.001	0.001	0.28	0.71

PRODUCTION / BIOMASS

Since no changes were made to the P/Bs of these groups, *Calanus* copepods, omnivorous zooplankton (TL = 2.02), carnivorous zooplankton (TL = 3.02), and cephalopods (TL = 3.98) were still above the trendline.

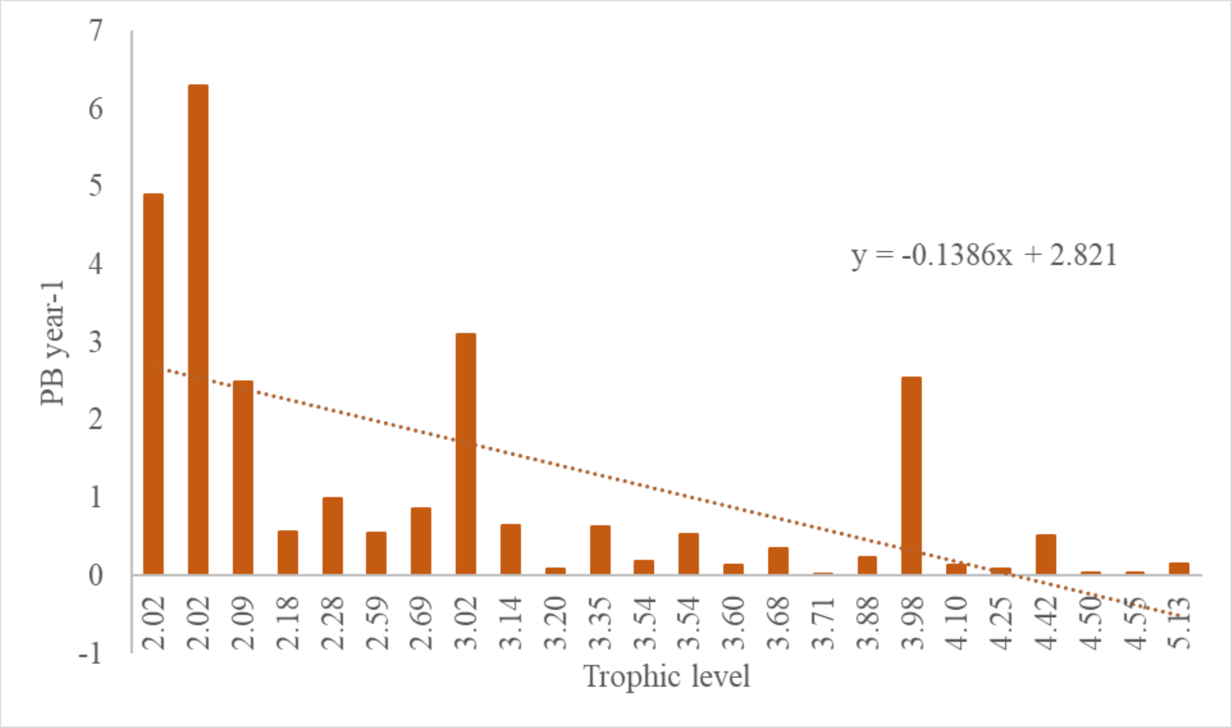


Figure 6. Production/Biomass per trophic level PREBAL diagnostics of the balanced Baffin Bay coast and shelf ecosystem.

CONSUMPTION / BIOMASS

Calanus copepods (TL = 2.02), seabirds (TL = 3.88), and other seals (TL = 4.32) were still above the trendline as no adjustments were made to their Q/Bs. For cephalopods, P/B and Q/B seemed high and generally above the trend lines. Vital ratios for cephalopod species are largely unknow so we decided to keep the original input values for these parameters as these have been generally assumed higher compared to fish in other polar system models (Pedersen and Zeller, 2001; Hoover et al., 2013).

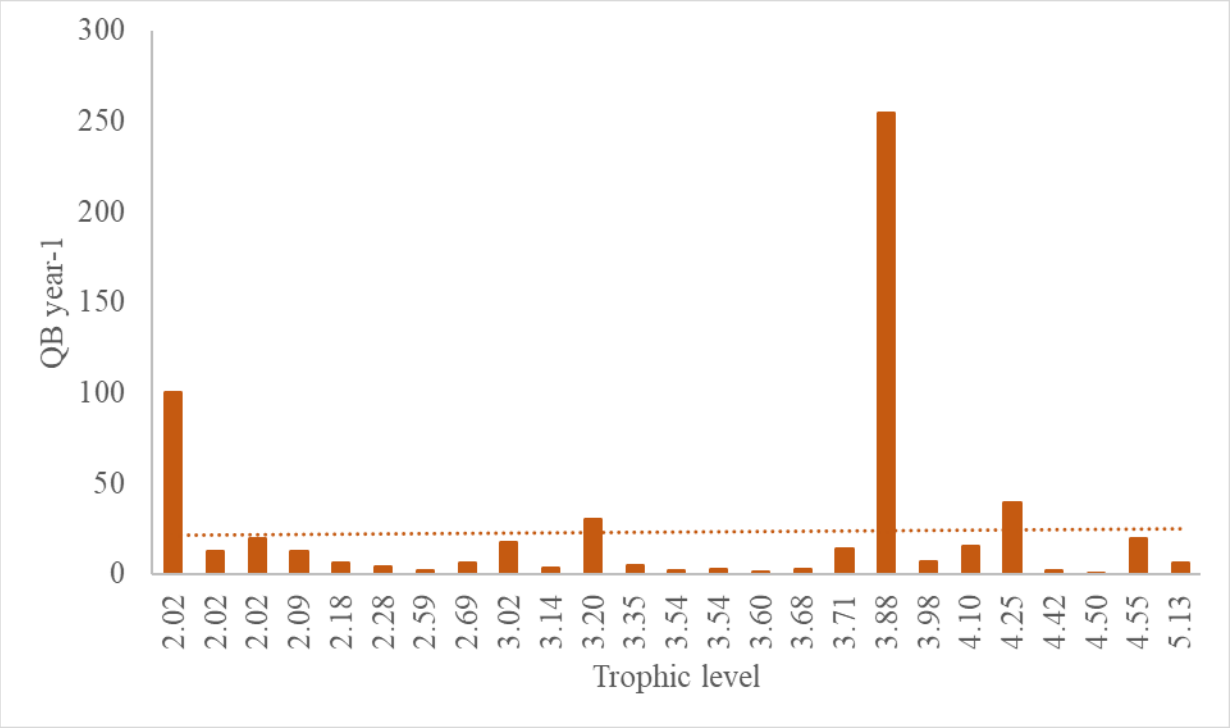


Figure 7. Consumption/Biomass per trophic level PREBAL diagnostics of the balanced Baffin Bay coast and shelf ecosystem.

PRODUCTION / CONSUMPTION

After adjustments, the P/Q of Greenland halibut and Greenland shark was at reasonable levels. We changed unassimilated consumption of cephalopods to 0.4 as the P/Q was exceeding this parameter.

RESPIRATION / ASSIMILATION

The R/A ratios kept reasonable after adjustments.

Table 8. Ecopath parameters used in the balanced model: Trophic Level (TL), Biomass in the model area (B, t·km^{-2}·year^{-1}), Production/Biomass (P/B, year^{-1}), Consumption/ Biomass (Q/B, year^{-1}), Ecotrophic Efficiency (EE), Production/Consumption (P/Q), and Landings (t·km^{-2}) for the first year of the model. Bolded values were estimated by Ecopath. Values estimated by Ecopath are in blue and values adjusted during model balancing are in bold.

Group name	**TL**	**B**	**P/B**	**Q/B**	**EE**	**P/Q**	**Landings**
Killer whale	5.23	0.0001	0.03	9.11	0.00	0.00	
Polar bear	5.13	**0.0013**	0.15	6.00	0.52	0.03	0.0001
Narwhal	4.55	0.0470	**0.04**	19.80	0.76	0.00	**0.0010**
Bowhead whale	3.71	0.0460	0.01	14.23	0.32	0.00	5.74E-05
Ringed seal	4.10	0.1070	0.15	15.32	0.76	0.01	0.0086
Other seals	4.25	0.0610	0.09	39.60	0.80	0.00	0.00088
Walrus	3.20	0.0024	0.09	30.40	0.44	0.00	2.56E-05
Seabirds	3.88	0.0010	0.24	254.40	0.35	0.00	2.31E-05
Greenland shark	4.50	0.100	**0.05**	**0.40**	0.50	0.11	0.0018
Greenland halibut	4.42	0.934	**0.51**	**2.30**	0.97	0.22	0.108
Arctic char	3.54	0.095	0.19	2.30	0.95	0.08	0.005
Arctic/Polar cod	3.14	5.74	**0.65**	3.25	0.95	0.20	
Small pelagic fish	3.35	1.23	0.63	4.85	0.95	0.13	
Sculpins/Eelpouts	3.68	2.15	0.35	2.89	0.95	0.12	
Small demersal fish	3.54	2.78	0.53	3.13	0.95	0.17	1.94E-05
Large demersal fish	3.60	3.45	0.14	1.58	0.95	0.09	0.00097
Large crustaceans	2.69	3.16	0.86	6.00	0.95	0.14	
Cephalopods	3.98	0.36	2.55	6.90	0.95	0.37	
Carnivorous zooplankton	3.02	**7.80**	3.10	17.70	0.93	0.18	
Omnivorous zooplankton	2.03	**12.1**	6.30	20.10	0.85	0.31	
Calanus	2.02	**24.3**	4.90	12.60	0.84	0.39	
Microzooplankton	2.02	**1.10**	32.6	100.4	0.77	0.33	
Polychaetes	2.28	18.1	1.00	4.00	0.51	0.25	
Echinoderms	2.59	10.3	0.55	2.20	0.82	0.25	3.56E-05
Bivalves	2.18	8.58	0.57	6.33	0.95	0.09	
Other benthos	2.09	13.4	2.50	12.50	0.44	0.20	2.43E-05
Bacteria	2.00	1.72	11.1	170.2	0.20	0.07	
Ice algae	1.00	**2.30**	149.5		0.84		
Phytoplankton	1.00	3.71	172.4		0.41		
Detritus	1.00	14.8			0.61		

Table 9. Diet matrix used in the Ecopath balanced model. Values adjusted during model balancing are in bold.

	Prey \ predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
1	Killer whale																											
2	Polar bear																											
3	Narwhal	0.33	0.01																									
4	Bowhead whale	0.15																										
5	Ringed seal	0.10	0.36							0.01																		
6	Other seals	0.07	**0.19**							**0.05**																		
7	Walrus	0.01	0.01																									
8	Seabirds		0.01																									
9	Greenland shark	0.01								0.01																		
10	Greenland halibut			**0.19**			**0.06**			0.03	0.02																	
11	Arctic char		0.01				**0.00**				0.00																	
12	Arctic/Polar cod			0.44		**0.45**	**0.39**		0.10		0.24	0.03			**0.08**		0.02		0.10									
13	Small pelagic fish						**0.09**		0.15								0.02		0.15									
14	Sculpins/Eelpouts					0.10	0.06		0.04		0.05	0.03			0.00		0.01		0.10									
15	Small demersal fish			0.01			0.05		0.03	0.04	0.25	0.03			0.04	0.01	0.03		0.10									
16	Large demersal fish	0.01								0.23	0.18				0.00		0.01											
17	Large crustaceans			0.01		0.06	0.01		0.15	0.01	0.08				0.08	0.01	0.21		0.20									
18	Cephalopods	0.00		0.05			**0.03**		0.02	0.45	0.14				0.03		0.03		0.05									
19	Carnivorous zooplankton				0.48	**0.36**	**0.06**		0.13		0.02	0.37	0.12	0.33	0.34	0.46	0.13	0.13	0.10					0.03	0.05	0.05	0.01	
20	Omnivorous zooplankton				0.15	0.03	0.03		0.17		0.01	0.50	0.46	0.19	0.19	0.25	0.09	0.13	0.10	0.30				0.04	0.04	0.03	0.01	
21	Calanus				0.07				0.02		0.00	0.02	0.42	0.48	0.00	0.04	0.06	0.05	0.10	0.63				0.01	0.01			
22	Microzooplankton																			0.07	0.02	0.02		0.03	0.03	0.05	0.01	
23	Polychaetes						0.02	0.01			0.02	0.01			0.14	0.14	0.08	0.10						0.01	0.10		0.01	
24	Echinoderms							0.05		0.04					0.03	0.01	0.14	0.05						0.01	0.01		0.01	
25	Bivalves						0.02	0.94							0.05	0.01	0.03								0.10		0.01	
26	Other benthos									0.02					0.02	0.07	0.13	0.05						0.10	0.15		0.01	
27	Bacteria																						0.02					
28	Ice algae																				0.66	0.24		0.12	0.08	0.12	0.22	
29	Phytoplankton																	0.05			0.15	0.51	0.48	0.04	0.03	0.05	0.05	
30	Detritus									**0.10**								0.45			0.16	0.23	0.50	0.61	0.41	0.70	0.66	1.00
	Import	**0.33**	**0.42**	**0.30**	0.31		0.17		0.20																			

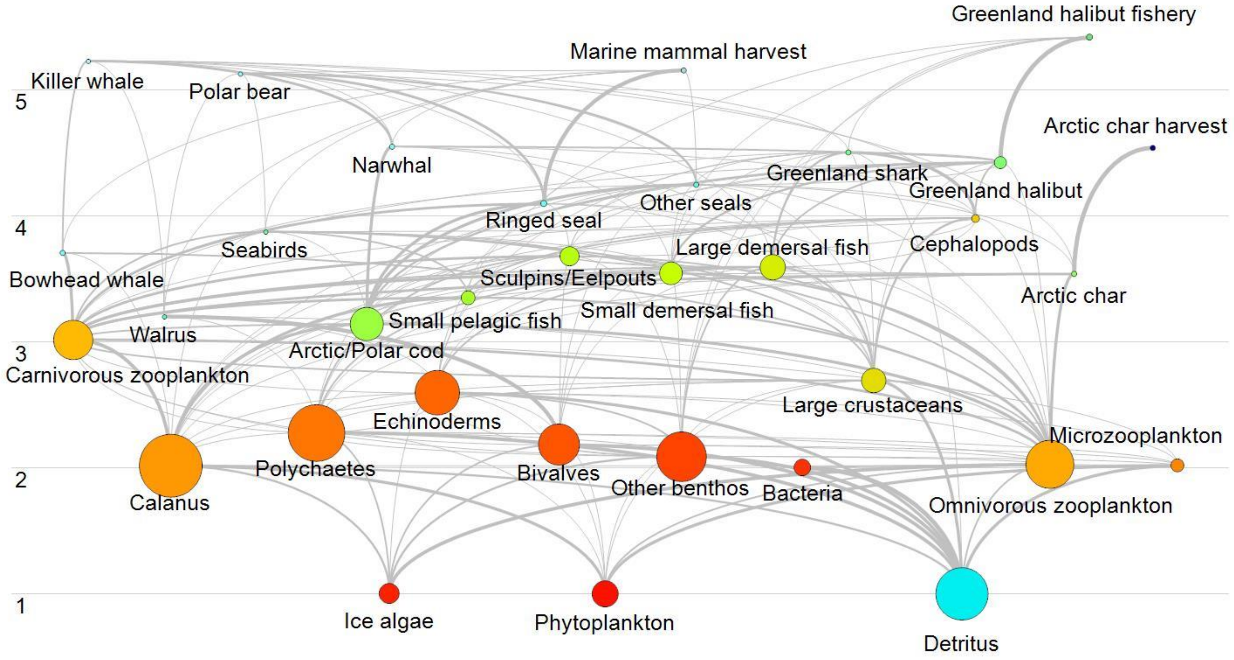


Figure 8. Ecopath flow diagram showing the feeding relationships among species. Thicker links represent larger flows of biomass between groups and larger circles represent groups with relatively larger biomass.

CONCLUSION

The present ecosystem model summarizes the scientific knowledge available regarding the ecology of food web components of the Baffin Bay coast and shelf ecosystem, providing a multidisciplinary effort to further our understanding of this region. As a result, this effort also highlights the existing knowledge gaps. Among the most pressing gaps in scientific knowledge are the biomass of most fish groups for which readily available abundance data are lacking. As for diet composition, there are virtually no local dietary studies for fish and benthos in this ecosystem and as a result we adapted fish diets in the model based on stomach contents for several fish species in other Arctic regions and used qualitative diet reported for benthic species. Additionally, estimates of P/B and Q/B for benthic invertebrates were taken from other Arctic ecosystem models in the absence of system-specific estimates. Despite the importance of ringed seal, Arctic char, and some mollusks like clams for Inuit subsistence harvest (Priest and Usher, 2004), the ecology of these species in the region is not well documented. For example, we did not include clams in a separate functional group due to the lack of data on the harvested species (large-scale abundance, diet composition, etc.). While for ringed seal, the only large-scale abundance estimates existent in the area are extrapolated from polar bear abundance and predation rates (Kingsley, 1998). For other groups, like seabirds, abundance estimates exist, but date from the 1970s and do not comprise all seabird species that frequent the area (Mallory et al., 2019). Another source of uncertainty common to other Arctic ecosystems is related to the sea ice seasonality, especially with regards to marine mammal and seabird migratory species. Our results could be biased by diet studies that have only sampled species in the summer or the breeding season, potentially masking species interactions that may occur only in the winter. Species like narwhal and bowhead whale feed intensely in some areas of their migratory routes, while in other areas they just pass through or feed sporadically (Laidre and Heide-Jørgensen, 2005; Fortune et al., 2020). Yet, for migratory species, weighting the biomass by time spent in the area corrects for this to some extent.

Future work to improve this model will include incorporating traditional ecological knowledge through interviews with Qikiqtarjuammiut hunters and fishers, which will focus on filling gaps on e.g., relative abundance of species in the region, their migration patterns, and temporal trends, if there are any new species in the area, how environmental changes are affecting the species, and which species are most important for local harvest and commercial fisheries. After this the model will be used for co-developing Ecosim scenario guided by Inuit perspectives and concerns in a food security context.

REFERENCES

Acquarone M, Born EW, Speakman JR. 2006. Field Metabolic Rates of Walrus (Odobenus rosmarus) Measured by the Doubly Labeled Water Method. *Aquat Mamm* **32**(3): 363–369. doi: 10.1578/AM.32.3.2006.363

Aitken AE, Fournier J. 1993. Macrobenthos communities of Cambridge, McBeth and Itirbilung fiords, Baffin Island, Northwest Territories, Canada. *Arctic* **46**(1): 60–71. doi: 10.14430/arctic1323

Andersen JM, Wiersma YF, Stenson G, Hammill MO, Joli M, Rosing-Asvid A. 2009. Movement Patterns of Hooded Seals (*Cystophora cristata*) in the Northwest Atlantic Ocean During the Post-Moult and Pre-Breed Seasons. *J Northw Atl Fish Sci* **42**: 1–11. doi: 10.2960/J.v42.m649

Ardyna M, Mundy CJ, Mayot N, Matthes LC, Oziel L, Horvat C, Leu E, Assmy P, Hill V, Matrai PA, et al. 2020. Under-Ice Phytoplankton Blooms: Shedding Light on the " Invisible " Part of Arctic Primary Production. *Front Mar Sci* **7**(November): 1–25. doi: 10.3389/fmars.2020.608032

Arrigo KR, van Dijken GL. 2011. Secular trends in Arctic Ocean net primary production. *J Geophys Res* **116**(C9): C09011. Blackwell Publishing Ltd. doi: 10.1029/2011JC007151

Ashjian CJ, Campbell RG, Welch HE, Butler M, Van Keuren D. 2003. Annual cycle in abundance, distribution, and size in relation to hydrography of important copepod species in the western Arctic Ocean. *Deep Res I* **50**: 1235–1261. doi: 10.1016/S0967-0637(03)00129-8

Atkinson DB, Bowering WR, Parsons DG, Horsted SA, Minet JP. 1982. A Review of the Biology and Fisheries for Roundnose Grenadier, Greenland Halibut and Northern Shrimp in Davis Strait. NAFO Sci. Coun. Studies.

Atkinson EG, Percy JA. 1991. Stomach Content Analysis of Marine Benthic Fish from Arctic Canada. *Can Data Rep Fish Aquat Sci* **840**: 34.

Aumack CF, Juhl AR, Krembs C. 2014. Diatom vertical migration within land-fast Arctic sea ice. *J Mar Syst* **139**: 496–504. doi: 10.1016/j.jmarsys.2014.08.013

Aydin KY, Gaichas S, Ortiz I, Kinzey D, Friday N. 2007. A comparison of the Bering Sea, Gulf of Alaska, and Aleutian Islands large marine ecosystems throug food web modeling. *NOAA Tech Memo NMFS-AFSC no 178*(178): 1–298. doi: 10.1111/j.1365-2435.2010.01760.x

Banas NS, Møller EF, Laidre KL, Simon M, Ellingsen IH, Nielsen TG. 2021. Reconciling Behavioural, Bioenergetic, and Oceanographic Views of Bowhead Whale Predation on Overwintering Copepods at an Arctic Hotspot (Disko Bay, Greenland). *Front Mar Sci* **8**(May): 1–9. doi: 10.3389/fmars.2021.614582

Barlow J, Boveng P. 1991. Modeling age-specific mortality for marine mammal populations. *Mar Mammal Sci* **7**(1): 50–65.

Bech C, Langseth I, Moe B, Fyhn M, Gabrielsen GW. 2002. The energy economy of the arctic-breeding Kittiwake (*Rissa tridactyla*): a review. *Comp Biochem Physiol Part A* **133**: 765–770.

Bednarsek N, Mozina J, Vogt M, O'Brien C, Tarling GA. 2012. The global distribution of pteropods and their contribution to carbonate and carbon biomass in the modern ocean. *Earth Syst Sci Data* **4**: 167–186.

Beverton RJH. 1992. Patterns of reproductive strategy parameters in some marine teleost fishes. *J Fish Biol* **41**: 137–160.

Bouchard C, Mollard S, Suzuki K, Robert D, Fortier L. 2014. Contrasting the early life histories of sympatric Arctic gadids Boreogadus saida and Arctogadus glacialis in the Canadian Beaufort Sea. *Polar Biol* **39**(6): 1005–1022. doi: 10.1007/s00300-014-1617-4

Boveng P, Barlow J. 1991. Modeling age-specific mortality for marine mammal populations. *Mar Mammal Sci* **7**: 50–65.

Bradstreet MSW, Cross WE. 1982. Trophic Relationships at High Arctic Ice Edges. *ARCTIC* **35**(1): 1–12.

Cameron MF, Bengtson JL, Boveng PL, Jansen JK, Kelly BP, Dahle SP, Logerwell EA, Overland JE, Sabine CL, Waring GT, et al. 2010. Status Review of the Bearded Seal (Erignathus barbatus). NOAA Technical Memorandum. Available at www.afsc.noaa.gov. Accessed 2019 Oct 25.

Christensen V, Walters C, Pauly D. 2005. Ecopath with Ecosim: a user's guide Version 5. Fisheries Centre: University of British Columbia.

Christensen V, Walters CJ. 2004. Ecopath with Ecosim: Methods, capabilities and limitations. *Ecol Modell*

172(2–4): 109–139. doi: 10.1016/j.ecolmodel.2003.09.003

Christiansen JS, Hop H, Nilssen EM, Joensen J. 2012. Trophic ecology of sympatric Arctic gadoids, Arctogadus glacialis. *Polar Biol* **35**: 1247–1257. doi: 10.1007/s00300-012-1170-y

Cisneros-Montemayor AM, Zetina-Rejón MJ, Espinosa-Romero MJ, Cisneros-Mata MA, Singh GG, Fernández-Rivera Melo FJ. 2020. Evaluating ecosystem impacts of data-limited artisanal fisheries through ecosystem modelling and traditional fisher knowledge. *Ocean Coast Manag* **195**: 105291. doi: 10.1016/j.ocecoaman.2020.105291

Coll M, Libralato S. 2011. Contributions of food web modelling to the ecosystem approach to marine resource management in the Mediterranean Sea. : 1–29. doi: 10.1111/j.1467-2979.2011.00420.x

Cosandey-Godin A, Krainski ET, Worm B, Flemming JM. 2015. Applying Bayesian spatiotemporal models to fisheries bycatch in the Canadian Arctic. *Can J Aquat Sci* **72**: 186–197.

COSEWIC. 2008. COSEWIC Assessment and Update Status Report on the Killer Whale Orcinus orca in Canada. Available at www.sararegistry.gc.ca/status/status_e.cfm. Accessed 2020 Jan 24.

COSEWIC. 2009. *COSEWIC Assessment and Update Status Report on the Bowhead Whale* Balaena Mysticetus *in Canada*. Ottawa: Committee on the Status of Endangered Wildlife in Canada. Available at www.sararegistry.gc.ca/status/status_e.cfm. Accessed 2020 Aug 6.

COSEWIC. 2017. COSEWIC Assessment and Status Report Atlantic Walrus Odobenus rosmarus rosmarus High Arctic population, Central-Low Arctic population and Nova Scotia-Newfoundland-Gulf of St. Lawrence population in Canada. Ottawa. Available at www.sararegistry.gc.ca/status/status_e.cfm. Accessed 2020 Jan 20.

Deal C, Jin M, Elliott S, Hunke E, Maltrud M, Jeffery N. 2011. Large-scale modeling of primary production and ice algal biomass within arctic sea ice in 1992. *J Geophys Res* **116**: C07004. Blackwell Publishing Ltd. doi: 10.1029/2010JC006409

Delaca TE. 1986. Determination of benthic rhizopod biomass using ATP analysis. *J Foraminifer Res* **16**(4): 285–292. doi: 10.2113/gsjfr.16.4.285

DFO. 2000. Atlantic Walrus. *DFO Sci Stock Status Rep E5-21*(January): 20. Available at https://login.proxy.lib.duke.edu/login?url=https://search.proquest.com/docview/1687669738?accountid=10598%0Ahttp://pm6mt7vg3j.search.serialssolutions.com?ctx_ver=Z39.88-2004&ctx_enc=info:ofi/enc:UTF-8&rfr_id=info:sid/ProQ%3Aasfabiological&rft_val_fmt=info.

DFO. 2011. Identification of Ecologically and Biologically Significant Areas (EBSA) in the Canadian Arctic. *DFO Can Sci Advis Sec Sci Advis* **Rep. 2011/**. Available at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm. Accessed 2020 Mar 17.

DFO. 2015a. Abundance estimates of narwhal stocks in the Canadian High Arctic in 2013. *DFO Can Sci Advis Sec Res Doc 2015/060*, in press.

DFO. 2015b. Updated abundance and harvest advice for the Eastern Canada-West Greenland bowhead whale population. *Can Sci Advis Secr Advis Rep 2015/052*, in press. Available at https://waves-vagues.dfo-mpo.gc.ca/Library/365124.pdf. Accessed 2019 Jul 8.

DFO. 2019. Assessment of Northern Shrimp (Pandalus borealis) and Striped Shrimp (Pandalus montagui) in the Eastern and Western Assessment Zones, February 2019.

DFO F and OC. 2014. Integrated Fishery Management Plan for Greenland Halibut (Reinhardtius hippoglossoides) Northwest Atlantic Fisheries Organization Subarea 0 Effective 2013. Winnipeg. Available at http://www.dfo-mpo.gc.ca/fm-gp/peches-. Accessed 2019 Jul 8.

Dolgov A V. 1994. Some aspects of biology of non-target fish species in the Barents Sea.

Elliott KH, Welcker J, Gaston AJ, Hatch SA, Palace V, Hare JF, Speakman JR, Anderson WG. 2013. Thyroid hormones correlate with resting metabolic rate, not daily energy expenditure, in two charadriiform seabirds. *Biol Open* **2**: 580–586. doi: 10.1242/bio.20134358

Environment and Climate Change Canada, Canadian Wildlife Service (CWS). 2016. Qaqulluit National Wildlife Area. Network of Protected Areas. Available at https://ec.gc.ca/ap-pa/default.asp?lang=En&n=351A0AB4-1. Accessed 2020 Oct 20.

Eriksen E, Benzik AN, Dolgov A V, Skjoldal HR, Vihtakari M, Johannesen E, Prokhorova TA, Keulder-Stenevik F, Prokopchuk I, Strand E. 2020. Diet and trophic structure of fishes in the Barents Sea: The Norwegian-

Russian program “Year of stomachs” 2015-Establishing a baseline. *Prog Oceanogr* **183**: 102262. doi: 10.1016/j.pocean.2019.102262

Ferguson SH, Kingsley MCS, Higdon JW. 2012. Killer whale (Orcinus orca) predation in a multi-prey system. *Popul Ecol* **54**(1): 31–41. Springer Japan. doi: 10.1007/s10144-011-0284-3

Ferguson SH, Zhu X, Young BG, Yurkowski DJ, Thiemann GW, Fisk AT, Muir DCG. 2018. Geographic variation in ringed seal (*Pusa hispida*) growth rate and body size. *Can J Zool* **96**(7): 649–659. doi: 10.1139/cjz-2017-0213

Finley KJ, Bradstreet MSW, Miller GW. 1990. Summer feeding ecology of harp seals (Phoca groenlandica) in relation to arctic cod (Boreogadus saida) in the Canadian high arctic. *Polar Biol* **10**: 609–618. doi: 10.1007/BF00239372

Finley KJ, Evans CR. 1983. Summer Diet of the Bearded Seal (*Erignathus barbatus*) in the Canadian High Arctic. *Arctic* **36**(1): 82–89. doi: 10.14430/arctic2246

Finley KJ, Gibb EJ. 1982. Summer diet of the narwhal (*Monodon monoceros*) in Pond Inlet, northern Baffin Island. *Can J Zool* **60**: 3353–3363. Available at www.nrcresearchpress.com. Accessed 2019 Apr 25.

Fisher K 1, Stewart REA. 1997. Summer foods of Atlantic walrus, *Odobenus rosmarus rosmarus,* in northern Foxe Basin, Northwest Territories. *Can J Zool* **75**: 1166–1175. Available at www.nrcresearchpress.com. Accessed 2020 Jan 20.

Ford JKB. 2002. Killer Whale, *Orcinus orca*. In: Perrin WF, Wursig B, Thewissen JGM, editors. *Encyclopedia of Marine Mammals*. San Diego, CA, USA: Academic Press. p. 669–676.

Forest A, Galindo V, Darnis G, Pineault S, Lalande C, Tremblay JÉ, Fortier L. 2011. Carbon biomass, elemental ratios (C:N) and stable isotopic composition (δ13C, δ15N) of dominant calanoid copepods during the winter-to-summer transition in the Amundsen Gulf (Arctic Ocean). *J Plankton Res* **33**(1): 161–178. doi: 10.1093/plankt/fbq103

Fortune SME, Young BG, Ferguson SH. 2020. Age- and sex-specific movement, behaviour and habitat-use patterns of bowhead whales (Balaena mysticetus) in the Eastern Canadian Arctic. *Polar Biol* **43**: 1725–1744. doi: 10.1007/s00300-020-02739-7

Frederiksen M, Descamps S, Erikstad KE, Gaston AJ, Gilchrist HG, Grémillet D, Johansen KL, Kolbeinsson Y, Linnebjerg JF, Mallory ML, et al. 2016. Migration and wintering of a declining seabird, the thick-billed murre Uria lomvia, on an ocean basin scale: Conservation implications. *Biol Conserv* **200**: 26–35. doi: 10.1016/j.biocon.2016.05.011

Frederiksen M, Falk K, Per Huffeldt N, Johansen K, Labansen A, Linnebjerg J, Merkel F, Mosbech A. 2014. *Seabird Baseline Studies in Baffin Bay 2008-2013 Colony-Based Fieldwork at Kippaku and Apparsuit, NW Greenland*. doi: 10.13140/2.1.4549.5046

Froese R, Binohlan C. 2000. Empirical relationships to estimate asymptotic length, length at first maturity and length at maximum yield per recruit in fishes, with a simple method to evaluate length frequency data. *J Fish Biol* **56**(4): 758–773. doi: 10.1006/jfbi.1999.1194

Froese R, Pauley D. 2008. Fishbase [WWW Document}. Available at www.fishbase.org.

Fu C, Quinn II TJ, Shirley Fu TC. 2001. The role of sex change, growth and mortality in Pandalus population dynamics and management. *ICES J Mar Sci* **58**: 607–621. doi: 10.1006/jmsc.2001.1050

Furness RW, Monaghan P. 1987. Seabird Feeding Ecology. In: *Seabird Ecology*. Boston, MA: Springer US. p. 23–34. doi: 10.1007/978-1-4613-2093-7_3

Gaichas SK, Aydin KY, Francis RC. 2010. Using food web model results to inform stock assessment estimates of mortality and production for ecosystem-based fisheries management. **1506**: 1490–1506. doi: 10.1139/F10-071

Galicia MP, Thiemann GW, Dyck MG, Ferguson SH. 2015. Characterization of polar bear (Ursus maritimus) diets in the Canadian High Arctic. *Polar Biol* **38**: 1983–1992. doi: 10.1007/s00300-015-1757-1

Garde E, Hansen SH, Ditlevsen S, Tvermosegaard KB, Hansen J, Harding KC, Heide-Jørgensen MP. 2015. Life history parameters of narwhals (Monodon monoceros) from Greenland. *J Mammal* **96**(4): 866–879. doi: 10.1093/jmammal/gyv110

Gardiner K, Dick TA. 2010. Arctic cephalopod distributions and their associated predators. *Polar Res* **29**(2): 209–227. doi: 10.1111/j.1751-8369.2010.00146.x

Gaston A, Elliott K. 2014. Seabird diet changes in northern Hudson Bay, 1981-2013, reflect the availability of schooling prey. *Mar Ecol Prog Ser* **513**: 211–223. doi: 10.3354/meps10945

Gaston AJ, Bradstreet MS. 1993. Intercolony differences in the summer diet of Thick-billed Murres in the eastern Canadian Arctic. *Can J Zool* **71**: 1831–1840. Available at www.nrcresearchpress.com. Accessed 2019 Jul 16.

Gaston AJ, Hipfner M. 1998. The effect of ice conditions in northern Hudson Bay on breeding by Thick-billed Murres (Uria lomvia). *Can J Zool* **76**: 480–492. Available at http://www.nrcresearchpress.com/doi/pdf/10.1139/z97-222. Accessed 2017 Nov 22.

Gaston AJ, Mallory ML, Gilchrist HG. 2012. Populations and trends of Canadian Arctic seabirds. *Polar Biol* **35**(8): 1221–1232. doi: 10.1007/s00300-012-1168-5

George JC, Bada J, Zeh J, Scott L, Brown SE, O'Hara T, Suydam R. 1999. Age and growth estimates of bowhead whales (Balaena mysticetus) via aspartic acid racemization. *Can J Zool* **77**: 571–580.

Giraldo C, Stasko A, Walkusz W, Majewski A, Rosenberg B, Power M, Swanson H, Reist JD. 2018. Feeding of Greenland halibut (*Reinhardtius hippoglossoides*) in the Canadian Beaufort Sea. *J Mar Syst* **183**: 32–41. doi: 10.1016/j.jmarsys.2018.03.009

Golikov A V., Ceia FR, Sabirov RM, Belyaev AN, Blicher ME, Arboe NH, Zakharov D V., Xavier JC. 2019. Food spectrum and trophic position of an Arctic cephalopod, *Rossia palpebrosa* (Sepiolida), inferred by stomach contents and stable isotope (δ13C and δ15N) analyses. *Mar Ecol Prog Ser* **632**: 131–144. doi: 10.3354/meps13152

Government of Nunavut. 2010. Nunavut coastal resources inventory, Qikiqtarjuaq. Qikiqtarjuaq. Available at https://www.gov.nu.ca/sites/default/files/ncri_qikiqtarjuaq_en_0.pdf. Accessed 2019 Jul 3.

Government of Nunavut. 2014. Nunavut coastal resources inventory, Clyde River. Clyde River. Available at https://www.gov.nu.ca/sites/default/files/ncri_clyde_river_en.pdf. Accessed 2019 Jul 3.

Grossi SM, Sullivan CW. 1985. Sea ice microbial communities V. The vertical zonation of diatoms in an Antarctic fast ice community. *J Phycol* **21**: 401–409. Available at https://onlinelibrary-wiley-com.ezproxy.lib.uconn.edu/doi/pdfdirect/10.1111/j.0022-3646.1985.00401.x. Accessed 2021 Jul 30.

Guénette S, Christensen V, Pauly D. 2001. Fisheries Impacts on North Atlantic Ecosystems: Models and Analyses. Vancouver, BC.

Guénette S, Heymans SJJ, Christensen V, Trites AW. 2005. Ecosystem Models of the Aleutian Islands and Southeast Alaska Show that Steller Sea Lions are Impacted by Killer Whale Predation when Sea Lion Numbers are Low. *Proc Fourth Glacier Bay Sci Symp*: 2000–2004.

Hammill MO, Mosnier A, Gosselin J-F, Higdon JW, Stewart DB, Doniol-Valcroze T, Ferguson SH, Dunn JB. 2016. Estimating abundance and total allowable removals for walrus in the Hudson Bay-Davis Strait and south and east Hudson Bay stocks during September 2014. Available at http://www.dfo-mpo.gc.ca/csas-sccs/. Accessed 2020 Jan 20.

Hammill MO, Stenson G. 2006. Abundance of Northwest Atlantic hooded seals (1960-2005). Available at http://www.dfo-mpo.gc.ca/csas/. Accessed 2020 Jan 30.

Hammill MO, Stenson GB. 2000. Estimated Prey Consumption by Harp seals (*Phoca groenlandica*), Hooded seals (*Cystophora cristata*), Grey seals (*Halichoerus grypus*) and Harbour seals (*Phoca vitulina*) in Atlantic Canada. *J Northw Atl Fish Sci* **26**: 1–23. Available at http://journal.nafo.int. Accessed 2019 Jul 16.

Hammill MO, Stenson GB, Doniol-Valcroze T, Mosnier A. 2015. Conservation of northwest Atlantic harp seals: Past success, future uncertainty? *Biol Conserv* **192**: 181–191. Elsevier Ltd. doi: 10.1016/j.biocon.2015.09.016

Hammill MO, Stenson GB, Mosnier A, Doniol-Valcroze T. 2014. Abundance Estimates of Northwest Atlantic Harp seals and Management advice for 2014. Available at http://www.dfo-mpo.gc.ca/csas-sccs/. Accessed 2020 Jan 31.

Harrison WG, Plait T, Irwin B. 1982. Primary production and nutrient assimilation by natural phytoplankton populations of the Eastern Canadian Arctic. *Can J Fish Aquat Sci* **39**: 335–345. Available at www.nrcresearchpress.com. Accessed 2020 Apr 6.

Harter BB, Elliott KH, Divoky GJ, Davoren, Gail K. 2013. Arctic cod (Boreogadus saida) as prey: fish length-energetics relationships in the Beaufort Sea and Hudson Bay. *Arctic* **66**(2): 191–196. Available at http://linkinghub.elsevier.com/retrieve/pii/S007966111500107X.

Hatch SA. 1993. *Ecology and Population Status of Northern Fulmats Fulmarus Glacialis of the North Pacific*. Canadian Wildlife Service, editor. The status, ecology, and conservation of marine birds of the north Pacific. Spec. Publ. Ottawa, ON.

Heide-Jørgensen MP, Laidre K, Fossette S, Rasmussen MH, Nielsen NH, Hansen RG. 2014. Abundance of walruses in Eastern Baffin Bay and Davis Strait. *NAMMCO Sci Publ* **9**: 159. doi: 10.7557/3.2606

Heide-Jørgensen MP, Laidre KL, Jensen M V., Dueck L, Postma LD. 2006. Dissolving stock discreteness with satellite tracking: bowhead whales in Baffin Bay. *Mar Mammal Sci* **22**(1): 34–45.

Heide-Jørgensen MP, Laidre KL, Wiig Ø, Jensen M V, Dueck L, Maiers LD, Schmidt HC, Hobbs RC. 2003. From Greenland to Canada in Ten Days: Tracks of Bowhead Whales, Balaena mysticetus, across Baffin Bay. ARCTIC. Available at http://pubs.aina.ucalgary.ca/arctic/Arctic56-1-21.pdf. Accessed 2019 Apr 20.

Heide-Jorgensen MP, Lassen H, Teilrnann I, Davis RA. 1993. An Index of the Relative Abundance of Wintering Belugas *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, off West Greenland. *Can J Fish Aquat Sci* **50**: 2323–2335.

Higdon J. 2007. Status of knowledge on Killer Whales (*Orcinus orca*) in the Canadian Arctic. Available at http://www.dfo-mpo.gc.ca/csas/. Accessed 2019 Aug 12.

Higdon JW, Hauser DDW, Ferguson SH. 2012. Killer whales (Orcinus orca) in the Canadian Arctic: Distribution, prey items, group sizes, and seasonality. *Mar Mammal Sci* **28**(2): 93–109. doi: 10.1111/j.1748-7692.2011.00489.x

Higdon JW, Westdal KH, Ferguson SH. 2014. Distribution and abundance of killer whales (Orcinus orca) in Nunavut, Canada—an Inuit knowledge survey. *J Mar Biol Assoc United Kingdom* **94**(06): 1293–1304. doi: 10.1017/S0025315413000921

Hirst AG, Bunker AJ. 2003. Growth of marine planktonic copepods: Global rates and patterns in relation to chlorophyll a, temperature, and body weight. *Limnol Oceanogr* **48**(5): 1988–2010. doi: 10.3354/meps279161

Hobson KA, Fisk A, Karnovsky N, Holst M, Gagnon JM, Fortier M. 2002. A stable isotope (δ13C, δ15N) model for the North Water food web: Implications for evaluating trophodynamics and the flow of energy and contaminants. *Deep Res Part II Top Stud Oceanogr* **49**(22–23): 5131–5150. doi: 10.1016/S0967-0645(02)00182-0

Hobson KA, Welch HE. 1992. Determination of trophic relationships within a high Arctic marine food web using δ13C and δ15N analysis. *Mar Ecol Prog Ser* **84**(1): 9–18. doi: 10.3354/meps084009

Hoekstra PF, O'Hara TM, Fisk AT, Borgå K, Solomon KR, Muir DCG. 2003. Trophic transfer of persistent organochlorine contaminants (OCs) within an Arctic marine food web from the southern Beaufort-Chukchi Seas. *Environ Pollut* **124**(3): 509–522. doi: 10.1016/S0269-7491(02)00482-7

Holst M, Stirling I, Hobson K a. 2001. Diet of ringed seals (*Phoca hispida*) on the east and west sides of the North Water Polynya, northern Baffin Bay. *Mar Mammal Sci* **17**(4): 888–908. doi: 10.1111/j.1748-7692.2001.tb01304.x

Hoover C, Pitcher T, Christensen V. 2013. Effects of hunting, fishing and climate change on the Hudson Bay marine ecosystem: I . Re-creating past changes 1970 – 2009. *Ecol Modell* **264**: 130–142. Elsevier B.V. doi: 10.1016/j.ecolmodel.2013.02.005

Hopcroft RR, Clarke C, Nelson RJ, Raskoff KA. 2005. Zooplankton communities of the Arctic's Canada Basin: The contribution by smaller taxa. *Polar Biol* **28**(3): 198–206. doi: 10.1007/s00300-004-0680-7

Hopkins CC, Grotnes PE, Eliassen J-E. 1989. Organization of a fjord community at 70° North: The pelagic food web in Balsfjord, northern Norway. *Rapp Proces-verbaux des Réunions Cons Int pour l'Éxploration la Mer* **188**: 146–153. Available at https://www.researchgate.net/publication/283679004. Accessed 2020 Jun 18.

Hunt GL, Kato H, McKinnell SM, Organization NPMS. 2000. Predation by marine birds and mammals in the subarctic North Pacific Ocean. *PICES Sci Rep* **14**(14): 165.

Hurtubise J. 2016. Evolution of subsistence and commercial Inuit fisheries in the Territory of Nunavut, Canada: Research and summation of landings, quotas, gear type, significance, use and status of hunted marine species. (Marine Affairs Program Technical Report #14). doi: Available at Marine Affairs Program: http://www.dal.ca/faculty/ science/marine-affairs-program/research/research-news/map-technical-series-reports.html

Hussey NE, Orr J, Fisk AT, Hedges KJ, Ferguson SH, Barkley AN. 2018. Mark report satellite tags (mrPATs) to detail large-scale horizontal movements of deep water species: First results for the Greenland shark (Somniosus microcephalus). *Deep Res Part I* **134**: 32–40. doi: 10.1016/j.dsr.2018.03.002

Janjua MY, Tallman RF, Hedges KJ, Martin Z. 2015. An initial mass balance model of the Western Baffin Bay Coastal and Shelf Ecosystem. Final Project Report Cansubmitted to DFO-ACCASP (unpublished). : v + 43.

Jørgensen OA, Hvingel C, Møller PR, Treble MA. 2005. Identification and mapping of bottom fish assemblages in Davis Strait and southern Baffin Bay. *Can J Fish Aquat Sci* **62**(8): 1833–1852. doi: 10.1139/f05-101

Jørgensen OA, Hvingel C, Treble MA. 2011. Identification and Mapping of Bottom Fish Assemblages in Northern Baffin Bay. *J Northwest Atl Fish Sci* **43**: 65–79. doi: 10.2960/J.v43.m666

Jørgensen OA, Treble MA. 2016. Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 + Division 1A Offshore + Divisions 1B-1F. Available at www.nafo.int. Accessed 2020 Nov 2.

Kang S-H, Kang J-S, Lee S, Chung KH, Kim D, Park MG. 2001. Antarctic phytoplankton assemblages: the marginal ice zone of the northwestern Weddell Sea. *J Plankton Res* **23**(4): 333–352.

Kapel FO. 2000. Feeding habits of harp and hooded seals in Greenland waters. *NAMMCO Sci Publ* **2**: 50–64. Available at https://pdfs.semanticscholar.org/704c/0ce5e0e36da863aa467f0826466e5da89422.pdf?_ga=2.24067834.1758305980.1556212669-1972508834.1553615072. Accessed 2019 Apr 25.

Karnovsky N, Hobson K, Iverson S, Hunt G. 2008. Seasonal changes in diets of seabirds in the North Water Polynya: a multiple-indicator approach. *Mar Ecol Prog Ser* **357**: 291–299. doi: 10.3354/meps07295

Kelly BP, Badajos OH, Kunnasranta M, Moran JR, Martinez-Bakker M, Wartzok D, Boveng P. 2010. Seasonal home ranges and fidelity to breeding sites among ringed seals. *Polar Biol* **33**(8): 1095–1109. doi: 10.1007/s00300-010-0796-x

Kingsley MCS. 1998. The numbers of ringed seals (Phoca hispida) in Baffin Bay and associated waters. *NAMMCO Sci Publ* **I**: 181–196.

Kiørboe T. 2013. Zooplankton body composition. *Limnol Oceanogr* **58**(5): 1843–1850. doi: 10.4319/lo.2013.58.5.1843

Laidre K, Heide-Jørgensen M, Nielsen T. 2007. Role of the bowhead whale as a predator in West Greenland. *Mar Ecol Prog Ser* **346**: 285–297. doi: 10.3354/meps06995

Laidre KL, Heide-Jørgensen MP. 2005. Winter Feeding Intensity of narwhals (*Monodon monoceros*). *Mar Mammal Sci* **21**(January): 45–57.

Laidre KL, Heide-Jørgensen MP, Jørgensen OA, Treble MA. 2004. Deep-ocean predation by a high Arctic cetacean. *ICES J Mar Sci* **61**: 430–440. doi: 10.1016/j.icesjms.2004.02.002

Leblanc M, Gauthier S, Garbus SE, Mosbech A, Fortier L. 2019. The co-distribution of Arctic cod and its seabird predators across the marginal ice zone in Baffin Bay. *Elem Sci Anthr* **7**: 1–18.

Van Leeuwe MA, Tedesco L, Arrigo KR, Assmy P, Campbell K, Meiners KM, Rintala JM, Selz V, Thomas DN, Stefels J. 2018. Microalgal community structure and primary production in Arctic and Antarctic sea ice: A synthesis. *Elementa* **6**(4): 1–25. doi: 10.1525/elementa.267

Lefort KJ, Garroway CJ, Ferguson SH. 2020. Killer whale abundance and predicted narwhal consumption in the Canadian Arctic. *Glob Chang Biol* **26**(8): 4276–4283. doi: 10.1111/gcb.15152

Lefort KJ, Matthews CJD, Higdon JW, Petersen SD, Westdal KH, Garroway CJ, Ferguson SH. 2020. A review of Canadian Arctic killer whale (Orcinus orca) ecology. *Can J Zool* **98**: 245–253. doi: 10.1139/cjz-2019-0207

Link JS. 2010. Adding rigor to ecological network models by evaluating a set of pre-balance diagnostics : A plea for PREBAL. *Ecol Modell* **221**: 1580–1591. doi: 10.1016/j.ecolmodel.2010.03.012

Liu H, Hopcroft RR. 2008. Growth and development of Pseudocalanus spp. in the northern Gulf of Alaska. *J Plankton Res* **30**(8): 923–935. doi: 10.1093/plankt/fbn046

Lunn NJ, Stirling I, Nowicki SN. 1997. Distribution and abundance of ringed (Phoca hispida) and bearded seals (Erignathus barbatus) in western Hudson Bay. *Can J Fish Aquat Sci*(54): 914–921. Available at https://www.nrcresearchpress.com/doi/pdf/10.1139/f96-346. Accessed 2019 Apr 9.

MacNeil MA, McMeans BC, Hussey NE, Vecsei P, Svavarsson J, Kovacs KM, Lydersen C, Treble MA, Skomal GB, Ramsey M, et al. 2012. Biology of the Greenland shark Somniosus microcephalus. *J Fish Biol* **80**(5):

991–1018. doi: 10.1111/j.1095-8649.2012.03257.x

Madsen SD, Nielsen TG, Hansen BW. 2001. Annual population development and production by Calanus finmarchicus, C. glacialis and C. hyperboreus in Disko Bay, western Greenland. *Mar Biol* **139**(1): 75–93. doi: 10.1007/s002270100552

Mallory M, Karnovsky N, Gaston A, Hobson K, Provencher J, Forbes M, Hunt G, Byers T, Dick T. 2010. Temporal and spatial patterns in the diet of northern fulmars Fulmarus glacialis in the Canadian High Arctic. *Aquat Biol* **10**(2): 181–191. doi: 10.3354/ab00277

Mallory ML. 2006. The northern fulmar (Fulmarus glacialis) in Arctic Canada: Ecology, threats, and what it tells us about marine environmental conditions. *Environ Rev* **14**(3): 187–216. doi: 10.1139/A06-003

Mallory ML, Akearok JA, Edwards DB, O'Donovan K, Gilbert CD. 2008. Autumn migration and wintering of northern fulmars (Fulmarus glacialis) from the Canadian high Arctic. *Polar Biol* **31**(6): 745–750. doi: 10.1007/s00300-008-0417-0

Mallory ML, Forbes MR. 2013. Behavioural and energetic constraints of reproduction: Distinguishing breeding from non-breeding northern fulmars at their colony. *Ecoscience* **20**(1): 48–54. doi: 10.2980/20-1-3552

Mallory ML, Gaston AJ, Gilchrist HG. 2009. Sources of Breeding Season Mortality in Canadian Arctic Seabirds. *ARCTIC* **62**(3): 333–341.

Mallory ML, Gaston AJ, Provencher JF, Wong SNP, Anderson C, Elliott KH, Gilchrist HG, Janssen M, Lazarus T, Patterson A, et al. 2019. Identifying key marine habitat sites for seabirds and sea ducks in the Canadian Arctic. *Environ Rev* **27**(2): 215–240. doi: 10.1139/er-2018-0067

Maps F, Record NR, Pershing AJ. 2014. A metabolic approach to dormancy in pelagic copepods helps explaining inter-and intra-specific variability in life-history strategies. *J Plankton Res* **36**(1): 18–30. doi: 10.1093/plankt/fbt100

Massicotte P, Amiraux R, Amyot M-P, Archambault P. 2020. Green Edge ice camp campaigns: understanding the processes controlling the under-ice Arctic phytoplankton spring bloom. *Earth Syst Sci Data* **12**: 151–176.

Massicotte P, Amiraux R, Amyot M-P, Archambault P, Ardyna M, Arnaud L, Artigue L, Aubry C, Ayotte P, Bécu G, et al. 2019. The Green Edge initiative: understanding the processes controlling the under-ice Arctic phytoplankton spring bloom. SEANOE. Copernicus GmbH. doi: 10.5194/essd-2019-160

Matley JK, Fisk AT, Dick TA. 2013. The foraging ecology of Arctic cod (*Boreogadus saida*) during open water (July–August) in Allen Bay, Arctic Canada. *Mar Biol* **160**: 2993–3004. doi: 10.1007/s00227-013-2289-2

Matthews CJD, Breed GA, Leblanc B, Ferguson SH, Estes JA. 2020. Killer whale presence drives bowhead whale selection for sea ice in Arctic seascapes of fear. *PNAS* **117**(12): 6590–6598. PNAS. doi: 10.1073/pnas.1911761117/-/DCSupplemental

Matthews CJD, Ferguson SH. 2015. Seasonal foraging behaviour of eastern Canada-West Greenland bowhead whales: An assessment of isotopic cycles along baleen. *Mar Ecol Prog Ser* **522**(April): 269–286. doi: 10.3354/meps11145

Mckinney M a., Iverson SJ, Fisk AT, Sonne C, Rigét FF, Letcher RJ, Arts MT, Born EW, Rosing-Asvid A, Dietz R. 2013. Global change effects on the long-term feeding ecology and contaminant exposures of East Greenland polar bears. *Glob Chang Biol* **19**: 2360–2372. doi: 10.1111/gcb.12241

Mclaren PL. 1982. Spring Migration and Habitat Use by Seabirds in Eastern Lancaster Sound and Western Baffin Bay. *Arctic* **35**(1): 88–111.

Mecklenburg CW, Lynghammer A, Johannesen E, Byrkjedal I, Christiansen JS, Dolgov A V, Karamushko O V, Mecklenburg TA, Møller PR, Steinke D, et al. 2018. Marine fishes of the Arctic region. *Conserv Arct Flora Fauna, Akureyri, Iceland ISBN ISBN 978-9935-431-69-1*, in press. Akureyri, Iceland.

Mecklenburg CW, Møller PR, Steinke D. 2011. Biodiversity of arctic marine fishes: taxonomy and zoogeography. *Mar Biodivers* **41**: 109–140. doi: 10.1007/s12526-010-0070-z

Menden-Deuer S, Lessard EJ. 2000. Carbon to volume relationships for dinoflagellates, diatoms, and other protist plankton. *Limnol Oceanogr* **45**(3): 569–579. doi: 10.4319/lo.2000.45.3.0569

Merkel F, Barry T. 2008. Seabird harvest in the Arctic. Available at http://www.caff.is. Accessed 2020 Mar 16.

Moles A. 1999. Parasitism, feeding rate, and hydrocarbon uptake of pink shrimp Pandalus borealis fed a crude oil contaminated diet. *Bull Environ Contam Toxicol* **62**(3): 259–265. doi: 10.1007/s001289900868

Moloney CL, Field JG. 1989. General allometric equations for rates of nutrient uptake, ingestion, and respiration in plankton organisms. *Limnol Oceanogr* **34**(7): 1290–1299. doi: 10.4319/lo.1989.34.7.1290

Mumm N. 1991. Zur sommerlichen Verteilung des Mesozooplanktons im Nansen-Becken, Norpolarmeer. *Berichte zur Polarforsch* **92**: 146.

NAMMCO. 2016. Report of the NAMMCO working group on coastal seals.

NAMMCO. 2018. Report of the NAMMCO Global Review of Monodontids. 13-16 March 2017. Hillerød, Denmark. Available at https://nammco.no/topics/sc-working-group-reports/.

Nanang D. 2020. Greenland halibut - Northwest Atlantic Fisheries Organization Subarea 0. DFO. Available at https://www.dfo-mpo.gc.ca/fisheries-peches/ifmp-gmp/groundfish-poisson-fond/2019/halibut-fletan-eng.htm#toc1. Accessed 2020 Oct 20.

Nielsen J, Christiansen JS, Grønkjær P, Bushnell P, Steffensen JF, Kiilerich HO, Præbel K, Hedeholm R. 2019. Greenland Shark (Somniosus microcephalus) Stomach Contents and Stable Isotope Values Reveal an Ontogenetic Dietary Shift. *Front Mar Sci* **6**(April). doi: 10.3389/fmars.2019.00125

Nielsen J, Hedeholm RB, Heinemeier J, Bushnell PG, Christiansen JS, Olsen J, Ramsey CB, Brill RW, Simon M, Steffensen KF, et al. 2016. Eye lens radiocarbon reveals centuries of longevity in the Greenland shark (Somniosus microcephalus). **353**(6300).

Nielsen NH, Rekdal SL, Laidre KL, Borchers D, Heide-Jørgensen MP, Bachmann L, Fossette S, Wiig Ø, Hansen RG, Tervo O. 2014. Trends in bowhead whales in West Greenland: Aerial surveys vs . genetic capture-recapture analyses . *Mar Mammal Sci* **31**(1): 133–154. doi: 10.1111/mms.12150

Nunavik Marine Regional Wildlife Board (NMRWB). 2018. Nunavik Inuit knowledge and Observations of Polar Bears: Polar bears of the Southern Hudson Bay sub-population. Project conducted and report prepared for the NMRWB by Basterfield, M., Breton- Honeyman, K., Furgal, C., Rae, J. and M. O'Connor. : xiv + 73 pp. Available at http://marefateadyan.nashriyat.ir/node/150.

Nunavut Department of Environment Fisheries and Sealing Division. 2018. *Common Fishes of Nunavut.* Inhabit Media Incorporated.

Ochoa-Acuña HG, Mcnab BK, Miller EH. 2008. Seasonal energetics of northern phocid seals. *Comp Biochem Physiol Part A* **152**: 341–350. doi: 10.1016/j.cbpa.2008.11.008

Ogloff WR, Ferguson SH, Fisk AT, Marcoux M, Hussey NE, Jaworenko A, Yurkowski DJ. 2021. Long-distance movements and associated diving behaviour of ringed seals (*Pusa hispida*) in the eastern Canadian Arctic. *Arct Sci* **00**: 1–18. doi: 10.1139/as-2019-0042

Orr D, Veitch PJ, Sullivan DJ. 2006. Northern shrimp (Pandalus borealis) off Baffin Island, Labrador and northeastern Newfoundland. Canadian Science Advisory Secretariat. St. Jonh`s.

Orr DC, Bowering WR. 1997. A multivariate analysis of food and feeding trends among Greenland halibut (Reinhardtius hippoglossoides) sampled in Davis Strait, during 1986. *ICES J Mar Sci* **54**: 819–829.

Overholtz W, Link J. 2009. A simulation model to explore the response of the Gulf of Maine food web to large-scale environmental and ecological changes. *Ecol Modell* **220**: 2491–2502. doi: 10.1016/j.ecolmodel.2009.06.034

Oziel L, Massicotte P, Randelhoff A, Ferland J, Vladoiu A, Lacour L, Galindo V, Lambert-Girard S, Dumont D, Cuypers Y, et al. 2019. Environmental factors influencing the seasonal dynamics of spring algal blooms in and beneath sea ice in western Baffin Bay. *Elem Sci Anth* **7**(1): 34. doi: 10.1525/elementa.372

Pabi S, van Dijken GL, Arrigo KR. 2008. Primary production in the Arctic Ocean, 1998-2006. *J Geophys Res Ocean* **113**: 1–22. doi: 10.1029/2007JC004578

Pagano AM, Durner GM, Rode KD, Atwood TC, Atkinson SN, Peacock E, Costa DP, Owen MA, Williams TM. 2018. High-energy, high-fat lifestyle challenges an Arctic apex predator, the polar bear. Science. Available at http://science.sciencemag.org/. Accessed 2021 Jun 11.

Palomares MLD, Pauly D. 1998. Predicting food consumption of fish populations as functions of mortality,food type, morphometrics, temperature and salinity. *Mar Freshw Res* **49**: 447–453.

Pauly D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. *J du Cons Int pour l'Exploration la Mer* **39**(3): 175–192. doi: 10.1093/icesjms/39.2.175

Pedersen SA, Zeller D. 2001. A mass balance model for the West Greenland marine ecosystem. *Fish Res*: 111–127.

Pomerleau C, Lesage V, Ferguson SH, Winkler G, Petersen SD, Higdon JW. 2012. Prey assemblage isotopic variability as a tool for assessing diet and the spatial distribution of bowhead whale Balaena mysticetus foraging in the Canadian eastern Arctic. *Mar Ecol Prog Ser* **469**: 161–174. doi: 10.3354/meps10004

Priest H, Usher PJ. 2004. The Nunavut wildlife harvest study. Available at http://cyber.usask.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=fih&AN=ASTI62983&site=ehost-live.

Randelhoff A, Oziel L, Massicotte P, Bécu G, Galí M, Lacour L, Dumont D, Vladoiu A, Marec C, Bruyant F, et al. 2019. The evolution of light and vertical mixing across a phytoplankton ice-edge bloom. *Elem Sci Anth* **7**(1): 20. doi: 10.1525/elementa.357

Reeves RR. 1998. Distribution, abundance and biology of ringed seals (Phoca hispida): an overview. *NAMMCO Sci Publ* **1**: 9–45. doi: 10.7557/3.2979

Reeves RR, Wenzel GW, Kingsley MCS. 1998. Catch history of ringed seals (*Phoca hispida*) in Canada. *NAMMCO Sci Publ* **1**: 100–129. Available at https://www.researchgate.net/profile/George_Wenzel/publication/280210976_Catch_history_of_ringed_seals_Phoca_hispida_in_Canada/links/56aa22c708aeaeb4cefae8bd/Catch-history-of-ringed-seals-Phoca-hispida-in-Canada.pdf. Accessed 2019 Apr 24.

Richard PR, Treble MA, Leblanc B. 2014. Assessment of the winter range of Baffin Bay narwhals. Doc. 2013/069. Available at http://www.dfo-mpo.gc.ca/csas-sccs/. Accessed 2019 May 20.

Sabatini M, Kiørboe T. 1994. Egg production, growth and development of the cyclopoid copepod Oithona similis. *J Plankton Res* **16**(10): 1329–1351. doi: 10.1093/plankt/16.10.1329

Saint-Béat B, Fath BD, Aubry C, Colombet J, Dinasquet J, Fortier L, Galindo V, Grondin P-L, Joux F, Lalande C, et al. 2020. Contrasting pelagic ecosystem functioning in eastern and western Baffin Bay revealed by trophic network modeling. *Elem Sci Anth* **8**: 1–24. doi: 10.1525/elementa.397

Sakshaug E. 1997. Biomass and productivity distributions and their variability in the Barents Sea. *ICES J Mar Sci* **54**: 341–350.

Sameoto DD. 1980. Relationships between stomach contents and vertical migration in Meganyctiphanes norvegica, *Thysanoessa raschii* and *T. inermis* (Crustacea Euphausiacea). *J Plankton Res* **2**(2): 129–143.

Schreiber EA, Burger J. 2001. *Biology of Marine Birds*. Biology of Marine Birds. doi: 10.1201/9781420036305

Shumway SE, Perkins HC, Schick DF, Stickney AP. 1985. Synopsis of biological data on the pink shrimp, Pandalus borealis Kroyer, 1838. NOAA Technical Report NMFS 30 FAO Fisheries Synopsis No. 144.

Sifred TD. 2005. Assessment of a Clam Fishery near Qikiqtarjuaq, Nunavut.

Spares AD, Stokesbury MJW, O'Dor RK, Dick TA. 2012. Temperature, salinity and prey availability shape the marine migration of Arctic char, Salvelinus alpinus, in a macrotidal estuary. *Mar Biol* **159**: 1633–1646. doi: 10.1007/s00227-012-1949-y

Stewart RE, Born EW, Dietz R, Ryan AK. 2013. Estimates of Minimum Population Size for Walrus near Southeast Baffin Island, Nunavut. *NAMMCO Sci Publ* **9**: 141. doi: 10.7557/3.2615

Stirling I. 2002. Polar Bears and Seals in the Eastern Beaufort Sea and Amundsen Gulf: A Synthesis of Population Trends and Ecological Relationships over Three Decades. *ARCTIC* **55**: 59–76.

Stirling I, Parkinson CL. 2006. Possible effects of climate warming on selected populations of polar bears (Ursus maritimus) in the Canadian Arctic. *Arctic* **59**(3): 261–275. doi: 10.14430/arctic312

Strathmann R. 1967. Estimating the organic carbon content of phytoplankton from cell volume or plasma volume. *Limnol Oceanogr* **12**(3): 411–418.

Sweetman CJ, Sutton TT, Vecchione M, Latour RJ. 2014. Diet composition of Bathylagus euryops (Osmeriformes: Bathylagidae) along the northern Mid-Atlantic Ridge. *Deep Sea Res Part I* **92**: 107–114. doi: 10.1016/j.dsr.2014.06.010

SWG. 2016. Re-Assessment of the Baffin Bay and Kane Basin Polar Bear Subpopulations: Final Report to the Canada-Greenland Joint Commission on Polar Bear. *Sci Work Gr to Canada-greenl Jt Comm Polar Bear*(Joint Commission on Polar Bear): x + 636 pp.

Tang CCL, Ross CK, Yao T, Petrie B, Detracey BM, Dunlap E. 2004. The circulation, water masses and sea-ice of Baffin Bay. *Prog Oceanogr* **63**: 183–228. doi: 10.1016/j.pocean.2004.09.005

Taylor M, Lee J. 1995. Distribution and abundance of Canadian polar bear populations: A management perspective. *Arctic* **48**(2): 147–154. doi: 10.14430/arctic1236

Taylor MK, Akeeagok Seeglook, Andriashek Dennis, Barbour W, Born EW, Calvert Wendy, Dean Cluff H, Ferguson Steve, Laake Jeff, Rosing-Asvid Aqqalu, et al. 2001. Delineating Canadian and Greenland polar bear (Ursus maritimus) populations by cluster analysis of movements. *Can J Zool* **79**: 690–709. doi: 10.1139/cjz-79-4-690

Thiemann GW, Iverson SJ, Stirling I, Obbard ME. 2011. Individual patterns of prey selection and dietary specialization in an Arctic marine carnivore. *Oikos* **000**: 001–010. doi: 10.1111/j.1600-0706.2011.19277.x

Thomson DH. 1982. Marine benthos in the eastern Canadian High Arctic: multivariate analyses of standing crop and community structure. *Arctic* **35**(1): 61–74. doi: 10.1016/0198-0254(82)90310-7

Tomczak MT, Heymans JJ, Yletyinen J, Niiranen S, Otto SA, Blenckner T. 2013. Ecological Network Indicators of Ecosystem Status and Change in the Baltic Sea. *PlosOne* **8**(10): 1–11. doi: 10.1371/journal.pone.0075439

Treble MA. 2011. Report on Greenland Halibut caught during the 2010 Trawl Survey in NAFO Division 0A.

Treble MA. 2017. Report on Greenland halibut caught during the 2016 trawl survey in Divisions 0A and 0B.

Treble MA. 2020. Report on Greenland halibut caught during the 2019 trawl survey in Division 0A. NAFO SCR Doc. 20/007REV.

Treble MA, Nogueira A. 2020. Assessment of the Greenland Halibut Stock Component in NAFO Subarea 0 + 1 (Offshore). Available at www.nafo.int. Accessed 2020 Nov 2.

Trites A, Capuliband E, Christensenb V. 1995. Diet composition and trophic levels of marine mammals. *ICES J Mar Sci* **55**: 467–481.

Trites AW, Pauly D. 1998. Estimating mean body masses of marine mammals from maximum body lengths. *Can J Zool* **76**: 886–896. Available at http://www.marinemammal.org/wp-content/pdfs/TritesPauly1998-bodymass.pdf. Accessed 2018 May 30.

Uye S. 1982. Length-weight relationships of important zooplankton from the inland Sea of Japan. *J Oceanogr Soc Japan* **38**: 149–158.

Vézina AF, Platt T. 1988. Food web dynamics in the ocean. I. Best-estimates of flow networks using inverse methods. *Mar Ecol Prog Ser* **42**: 269–287.

Walsh P. 2008. Winter Longline Fishing in Scott inlet/Sam Fjord, Baffin Island. Harvester program to assist with the creation of a Community based Greenland Halibut fishery, Clyde River. doi: 10.13140/RG.2.2.26815.76966

Walters C, Christensen V, Pauly D. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance assessments. *Rev Fish Biol Fish* **7**: 139–172.

Wang J, Mysak LA, Grant Ingram R. 1994. Interannual variability of sea-ice cover in Hudson bay, Baffin bay and the Labrador sea. *Atmosphere-Ocean* **32**: 2. doi: 10.1080/07055900.1994.9649505

Welcker J, Moe B, Bech C, Fyhn M, Schultner J, Speakman JR, Gabrielsen GW. 2010. Evidence for an intrinsic energetic ceiling in free-ranging kittiwakes Rissa tridactyla. *J Anim Ecol* **79**: 205–213. doi: 10.1111/j.1365-2656.2009.01626.x

Wheeland L, Devine B. 2018. Bycatch of Greenland Shark (Somniosus microcephalus) from inshore exploratory fisheries adjacent to NAFO Division 0.

Whitehouse G Andy, Aydin K, Essington TE. 2014. A trophic mass balance model of the eastern Chukchi Sea with comparisons to other high-latitude systems. *Polar Biol*, in press. doi: 10.1007/s00300-014-1490-1

Whitehouse G. Andy, Aydin K, Essington TE, Hunt GL. 2014. A trophic mass balance model of the eastern Chukchi Sea with comparisons to other high-latitude systems. *Polar Biol* **37**(7): 911–939. doi: 10.1007/s00300-014-1490-1

Wiig Ø, Heide-Jørgensen MP, Lindqvist C, Laidre KL, Postma LD, Dueck L, Palsbøll PJ, Bachmann L. 2011. Recaptures of genotyped bowhead whales Balaena mysticetus in eastern Canada and West Greenland. *Endanger Species Res* **14**: 235–242. doi: 10.3354/esr00365

Williams TM, Peter-Heide Jørgensen M, Pagano AM, Bryce CM. 2020. Hunters versus hunted: New perspectives on the energetic costs of survival at the top of the food chain. *Funct Ecol* **34**(10): 2015–2029. Blackwell Publishing Ltd. doi: 10.1111/1365-2435.13649

Xavier JC, Cherel Y, Allcock L, Rosa R, Sabirov RM, Blicher ME, Golikov A V. 2018. A review on the biodiversity, distribution and trophic role of cephalopods in the Arctic and Antarctic marine ecosystems under a changing ocean. *Mar Biol* **165**: 93. doi: 10.1007/s00227-018-3352-9

Yano K, Stevens JD, Compagno LJV. 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. *J Fish Biol* **70**(2): 374–390. doi: 10.1111/j.1095-8649.2007.01308.x

Young BG, Higdon JW, Ferguson SH. 2011. Killer whale (Orcinus orca) photo-identification in the eastern Canadian Arctic. *Polar Res* **30**(SUPPL.1): 1–7. doi: 10.3402/polar.v30i0.7203

Yurkowski DJ, Ferguson SH, Semeniuk CAD, Brown TM, Muir DCG, Fisk AT. 2016. Spatial and temporal variation of an ice-adapted predator’s feeding ecology in a changing Arctic marine ecosystem. *Oecologia* **180**: 631–644. doi: 10.1007/s00442-015-3384-5

APPENDIX A: MARINE MAMMAL SURVIVAL EQUATIONS

Mortality for marine mammal functional groups was calculated based on life history information and longevity from (Boveng and Barlow, 1991). Estimates of longevity $L(x)$ were made using equation A.1 to estimate the probability of survivorship from birth to age x, with information from equations A.2, where $L_j(x)$ is the mortality due to juvenile factors, A.3 representing $L_c(x)$ or the constant mortality experienced by all age classes, and A.4 where $L_s(x)$ is the mortality due to senescent factors. Longevity (**Ω**) is used as the maximum recorded age of each species.

Flexibility in the survivorship curve is determined by constant parameters: a_1, a_2, a_3, b_1, and b_3 (Table A.1), which are based on species specific life history traits. However, when species specific information was not available, a surrogate representing similar life mortality throughout their life span was used as a replacement. For *Ringed seal*, *Other seals* and *Walrus* groups, northern fur seal was used as a surrogate, representing high mortality for young age classes and decreasing mortality as seals age. Human survivorship was used for *Polar bear* and *Killer whale*, as there are few to zero predators, lowering juvenile mortality (compared to other surrogates). *Narwhal* and *Bowhead whale* survivorship was calculated using monkey and human survivorship parameters with the monkey life history parameters having a slightly higher juvenile mortality. The natural mortality used in the model was taken as mortality averaged over all ages up to a maximum age (longevity) and was calculated as 1- the survivorship.

$A.1$

$$L(x) = L_j(x) * L_c(x) * L_s(x)$$

$A.2$

$$L_j(x) = exp\ [\ (-\ a_1/b_1) * 1 - exp\ (-b * x/\Omega)]$$

$A.3$

$$\mathrm{L_c(x) = exp\ [-a_2 *\ x/\Omega]}$$

$\mathrm{A.4}$

$$\mathrm{L_s(x) = exp\ (a_3/b_3) * 1 - exp\ (b_3 * x/\Omega)}$$

Table A1. Survivorship curve parameters based on life histories of fur seals, monkeys, and humans as provided in Boveng and Barlow (1991: Table 2).

Species group	**a_1**	**a_2**	**a_3**	**b_1**	**b_3**
Northern Fur Seal	14.343	0.171	0.0121	10.259	6.6878
Old World Monkeys	30.430	0.000	0.7276	206.72	2.3188
Human (female)	40.409	0.4772	0.0047	310.36	8.0290

APPENDIX B: ZOOPLANKTON CONVERSION EQUATIONS

Table B1. Weight-length relationships for zooplankton species. Relationships are given in dry weight (DW), carbon (C), ash-free dry weight (AFWD) to length (L).

Species	Weight-length relationship	Source
Calanus glacialis	$C_{\mu g} = 4.742 \text{ x } L_{mm}^{3.452}$	(Forest et al., 2011)
Calanus hyperboreus	$DW_{mg} = 0.003 \text{ x } L_{mm}^{3.718}$	(Ashjian et al., 2003)
Calanus finmarchicus	$C_{mg} = 0.0048 \text{ x } L_{mm}^{3.5687}$	(Madsen et al., 2001)
Boroecia maxima	$AFDW_{mg} = 0.0228 \text{ x } L_{mm}^{2.3698}$	(Mumm, 1991)
Discoconchoecia elegans	$AFDW_{mg} = 0.0228 \text{ x } L_{mm}^{2.3698}$	(Mumm, 1991)
Heterostylites major	$\log(C_{\mu g}) = 3.07 \text{ x } \log(L_{\mu m})-8.37$	(Uye, 1982)
Limacina helicina	$DW_{mg} = 0.137 \text{ x } L_{mm}^{1.5005}$	(Bednarsek et al., 2012)
Metridia longa	$C_{mg} = 7.498 \text{ x } L_{mm}^{3.225}$	(Forest et al., 2011)
Microcalanus	$\log(C_{\mu g}) = 3.07 \text{ x } \log(L_{\mu m})-8.37$	(Uye, 1982)
Oithona similis	$C_{\mu g} = 9.4676 \text{ x } 10^{-7} \text{ x } L_{\mu m}^{2.16}$	(Sabatini and Kiørboe, 1994)
Oncaea notopus	$\log(AFDW_{\mu g}) = 3.16 \text{ x } \log(L_{\mu m}) - 8.18$	(Hopcroft et al., 2005)
Pseudocalanus spp.	$\log_{10}(Dw_{\mu g}) = -7.62 + 2.85 \text{ x } \log_{10}(L_{\mu m})$	(Liu and Hopcroft, 2008)
Spinocalanus longicornis	$\log(C_{\mu g}) = 3.07 \text{ x } \log(L_{\mu m})-8.37$	(Uye, 1982)
Triconia borealis	$C_{\mu g} = 9.4676 \text{ x } 10^{-7} \text{ x } L_{\mu m}^{2.16}$	(Sabatini and Kiørboe, 1994)
Aglantha digitale	$DW_{mg} = 0.00194 \text{ x } L_{mm}^{3.05}$	(Hopcroft et al., 2005)
Eukrohnia hamata	$DW_{mg} = 0.00032 \text{ x } L_{mm}^{3.00}$	(Hopcroft et al., 2005)
Gaetanus tenuispinus	$AFDW_{mg} = 0.0089 \text{ x } L_{mm}^{3.4119}$	(Mumm, 1991)
Heterorhabdus norvegicus	$AFDW_{mg} = 0.0031 \text{ x } L_{mm}^{4.7164}$	(Mumm, 1991)
Paraeuchaeta spp.	$AFDW_{mg} = 0.0075 \text{ x } L_{mm}^{3.274}$	(Mumm, 1991)
Themisto abyssorum	$DW_{\mu g} = 0.0049 \text{ x } L_{mm}^{2.957}$	(Hopcroft et al., 2005)

Table B2. Conversion factors for zooplankton weight estimates from Kiørboe (2013). Conversions between dry weight (DW), carbon (C), ash-free dry weight (AFWD) and wet weight (WW).

	DW (% WW)	AFDW (% dry)	C (% DW)	C (% WW)
Copepods	16.2 ± 2.4	7.6 ± 1.8	48 ± 1.4	9.95 ± 1.49
All crustaceans	18.3 ± 1.9	11.5 ± 2.4	43.5 ± 1.3	9.61 ± 0.01
Amphipods	23.9 ± 9.0	20.7 ± 6.7	34.5 ± 3.2	8.41 ± 1.38
Pteropods	23.0 ± 19.4	30.9 ± 93.1	28.9 ± 4.8	5.3 ± 5.5
Cnidarians*	4.1 ± 0.3	52.4 ± 6.4	13.2 ± 2.1	0.48 ± 0.13

*the only cnidarian sampled was *A. digitale*. Compared to other zooplankton species, a larger portion of Cnidarians' body mass is water. When converting carbon to wet weight, the biomass value for *A. digitale* was unreasonably large and therefore we assumed the same conversion factor as for all crustaceans instead, which produced more ecologically sound results.

Table B3. Formulas used in Saint-Béat et al. (2020) to calculate ingestion and growth rated in zooplankton functional groups.

	Life stage	**Consumption**	**Production***	**Source**
All species	all	$\text{pgC day}^{-1} = 63{*}\text{pgC}^{-0.25}$		(Moloney and Field, 1989)
Broadcaster spawners [a]	adults		$\log_{10}\text{growth} = 0.0125{*}T - 0.230{*}(\log_{10}BW)+0.729{*}(\log_{10}Chla)-1.348$	(Hirst and Bunker, 2003)
	juveniles		$\log_{10}\text{growth} = -0.0143{*}T - 0.363{*}(\log_{10}BW)+0.135{*}(\log_{10}Chla)-0.105$	(Hirst and Bunker, 2003)
Sac spawners [b]	all		$\log_{10}\text{growth} = 0.0182{*}T+0.193{*}(\log_{10}BW)+0.195{*}(\log_{10}Chla)-1.591$	(Hirst and Bunker, 2003)
Other [c]			$\text{pgC day}^{-1} = 14{*}\text{pgC}^{-0.25}$	(Moloney and Field, 1989)

*Weight specific fecundity growth (day^{-1}), temperature (T, °C), body weight (BW, $\mu\text{gC ind}^{-1}$), and total chla concentration ($\mu\text{gChl L}^{-1}$)

[a] *C. finmarchicus, C. glacialis, C. hyperboreus, G. tenuispinus, H. norvegicus, H. major, M. longa, Microcalanus, S. longicornis*

[b] *O. similis, O. notopus, Paraeuchaeta spp., Pseudocalanus spp., T. borealis*

[c] *T. abyssorum, L. helicina, E. hamata, D. elegans, A. digitale, B. Maxima*

APPENDIX C: PEDIGREE QUALITATIVE SCALE IN ECOPATH

Table C1. Options included in the Ecopath software for defining data pedigree.

	Pedigree	CI (%)
Biomass		
Estimated by Ecopath	1	± 80
From other model	2	± 80
Guesstimate	3	± 80
Approximate or indirect method	4	± 50
Sampling/locally, low precision	5	± 30
Sampling/locally, high precision	6	± 10
Production/Biomass & Consumption/Biomass		
Estimated by Ecopath	1	± 80
Guesstimate	2	± 70
From other model	3	± 60
Empirical relationship	4	± 50
Similar species, similar system, low precision	5	± 40
Similar species, same system, low precision	6	± 30
Same species, similar system, high precision	7	± 20
Same species, same system, high precision	8	± 10
Diet composition		
General knowledge of related group/species	1	± 80
From other model	2	± 80
General knowledge for same group/species	4	± 60
Qualitative diet composition study	5	± 50
Quantitative but limited diet composition study	5	± 30
Quantitative, detailed, diet composition study	6	± 10
Landings		
Guesstimate	1	± 70
From other model	2	± 70
FAO statistics	3	± 80
National statistics	4	± 50
Local study, low precision/incomplete	5	± 30
Local study, high precision/complete	6	± 10

APPENDIX D: REPORTED TROPHIC LEVELS FOR MARINE MAMMALS AND FISH

Table D1. Trophic levels reported for marine mammal and seabird species present in the West Baffin Bay coastal and shelf ecosystem.

Functional group	Species	Scientific name	Trophic level	Source
Killer whale	Killer whale	*Orcinus orca*	4.5	(Trites et al., 1995)
Polar bear	Polar bear	*Ursus maritimus*	5.1; 5.5	(Hobson and Welch, 1992; Hobson et al., 2002)
Narwhal	Narwhal	*Monodon monoceros*	3.7; 4.1	(Hobson and Welch, 1992; Hobson et al., 2002)
Bowhead whale	Bowhead whale	*Balaena mysticetus*	3.4; 2.8 ± 0.1	(Hobson et al., 2002; Hoekstra et al., 2003)
Ringed seal	Ringed seal	*Pusa hispida*	4.1; 4.4 & 4.6	(Hobson and Welch, 1992; Hobson et al., 2002)
Other seals	Bearded seal	*Erignathus barbatus*	4.0; 4.3	(Hobson and Welch, 1992; Hobson et al., 2002)
	Harp seal	*Pagophilus groenlandicus*	3.8	(Trites et al., 1995)
	Hooded seal	*Cystophora cristata*	4.2	(Trites et al., 1995)
Walrus	Atlantic walrus	*Odobenus rosmarus rosmarus*	2.9; 3.2	(Hobson and Welch, 1992; Hobson et al., 2002)
Seabirds	Black-legged kittiwake	*Rissa tridactyla*	4.0; 3.9	(Hobson and Welch, 1992; Hobson et al., 2002)
	Northern fulmar	*Fulmarus glacialis*	3.9; 4.0	(Hobson and Welch, 1992; Hobson et al., 2002)
	Thick-billed murre	*Uria lomvia*	4.1; 4.0	(Hobson and Welch, 1992; Hobson et al., 2002)

Table D2. Trophic levels reported for fish species present in the West Baffin Bay coastal and shelf ecosystem from fishbase.org (based on results from literature).

Functional group	**Species**	**Scientific name**	**Trophic level (±SE)**
Greenland shark	Greenland shark	*Somniosus microcephalus*	4.4 ± 0.57
Greenland halibut	Greenland halibut	*Reinhardtius hippoglossoides*	4.4 ± 0.14
Arctic char	Arctic char	*Salvelinus alpinus*	4.4 ± 0.51 *3.1 ± 0.1
Arctic/Polar cod	Polar cod	*Arctogadus glacialis*	3.3 ± 0.33
	Arctic cod	*Boreogadus saida*	3.1 ± 0.11
Small pelagic fish	Goiter blacksmelt	*Bathylagus euryops*	3.3 ± 0.38
	Glacier lanternfish	*Benthosema glaciale*	3.0 ± 0.29
Sculpins/eelpouts	Atlantic hookhear sculpin	*Artediellus atlanticus*	3.4 ± 0.44
	Bigeye sculpin	*Triglops nybelini*	3.3 ± 0.22
	Ribbed sculpin	*Triglops pingelii*	3.4 ± 0.26
	Polar sculpin	*Cottunculus microps*	4.1 ± 0.22
	Doubleline eelpout	*Lycodes eudipleurostictus*	3.5 ± 0.50
	Arctic eelpout	*Lycodes reticulatus*	3.5 ± 0.53
	Pale eelpout	*Lycodes pallidus*	3.1 ± 0.36
Small demersal fish	Atlantic poacher	*Leptagonus decagonus*	3.2 ± 0.30
	Atlantic spiny lumpsucker	*Eumicrotremus spinosus*	3.5 ± 0.49
	Sea tadpole	*Careproctus reinhardti*	3.8 ± 0.58
	Gelatinous seasnail	*Liparis fabricci*	3.3 ± 0.42
	Arctic flounder	*Liopsetta glacialis or Pleuronectes glacialis*	3.4 ± 0.06
Large demersal fish	Roughhead grenadier	*Macrourus berglax*	3.6 ± 0.53
	Deepwater redfish	*Sebastes mentella*	4.1 ± 0.66
	Spotted Wolffish	*Anarhichas minor*	3.6 ± 0.51
	Arctic skate	*Amblyraja hyperborea*	4.3 ± 0.54
	Thorney skate	*Amblyraja radiata*	4.2 ± 0.27

*Value reported for Arctic char in the Beaufort-Chukchi Sea (Hoekstra et al., 2003)

Table D3. Trophic levels reported for invertebrate species present in the West Baffin Bay coastal and shelf ecosystem.

Functional group	**Species**	**Trophic level (±SE)**	**Source**
Large crustaceans	*Pandalus* sp.	3.4	(Hobson et al., 2002)
Cephalopods	*Rossia palpebrosa*	3.6 ± 0.1	(Golikov et al., 2019)
Carnivorous zooplankton	*Aglantha digitale*	2.3	(Hobson and Welch, 1992)
	Themisto abyssorum	2.6	(Hobson et al., 2002)
Omnivorous zooplankton	*Metridia longa*	2.5	(Hobson et al., 2002)
Calanus copepods	*Calanus hyperboreus*	2.0	(Hobson and Welch, 1992)
	Calanus glacialis	2.3	(Hobson et al., 2002)
Polychaetes	*Lumbrineris* sp.	3.6	(Hobson et al., 2002)
	Phyllodoce mucosa	3.2	(Hobson et al., 2002)
	Phascolosoma eremeta	3.1	(Hobson et al., 2002)
Echinoderms	*Crossaster papposus*	3.8	(Hobson and Welch, 1992)
	Leptasterias sp.	2.6	(Hobson and Welch, 1992)
Bivalves	*Mya truncata*	2.1	(Hobson and Welch, 1992)
	Astarte elliptica	2.2	(Hobson et al., 2002)
	Serripes groenlandica	1.9	(Hobson and Welch, 1992)
	Buccinum sp.	2.9	(Hobson and Welch, 1992)
Other benthos	*Mertensia ovum*	3.2	(Hobson and Welch, 1992)
	Anemone urticina	3.3	(Hobson and Welch, 1992)