MASS-BALANCE MODELS OF THE NEWFOUNDLAND AND LABRADOR SHELF ECOSYSTEM FOR 1985-1987 AND 2013-2015

Jamie C. Tam and Alida Bundy

Fisheries and Oceans Canada
Ocean Ecosystem Sciences Division
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth, NS
B2Y 4A2

2019

Canadian Technical Report of Fisheries and Aquatic Sciences 3328

Fisheries and Oceans Canada   Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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

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

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

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

Rapport technique canadien des sciences halieutiques et aquatiques

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

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

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

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

Canadian Technical Report
Fisheries and Aquatic Sciences 3328

2019

Mass-balance models of the Newfoundland and Labrador Shelf ecosystem for 1985-1987 and 2013-2015

Jamie C. Tam and Alida Bundy

Fisheries and Oceans Canada
Bedford Institute of Oceanography
Ocean Ecosystem Sciences Division
1 Challenger Dr.
Dartmouth, NS. B2Y 4A2

© Her Majesty the Queen in Right of Canada, 2019.

Cat. No. Fs97-6/3328E-PDF ISBN 978-0-660-32111-0 ISSN 1488-5379

Correct citation for this publication:

Tam, J.C. and Bundy, A. 2019. Mass-balance models of the Newfoundland and Labrador Shelf ecosystem for 1985-1987 and 2013-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3328: vii + 78 p.

TABLE OF CONTENTS

List of Tables

List of Figures

Abstract

Tam, J.C. and Bundy, A. 2019. Mass-balance models of the Newfoundland and Labrador Shelf ecosystem for 1985-1987 and 2013-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3328: vii + 78 p.

The CoArc project (A Transatlantic Innovation Arena for Sustainable Development in the Arctic) is an initiative funded by the Norwegian Ministry of Foreign Affairs bringing together scientists from Norway and Canada to explore innovative methods for marine management in the Arctic and sub-Arctic. The CoArc project aims to develop better management tools for Arctic and sub-Arctic marine ecosystems. Work plan 1 (WP1) of CoArc is focused on a transatlantic synthesis of ecosystem understanding and to that end, has selected two large ecosystems in Canada and Norway for comparative purposes. One goal of the CoArc WP1 project is to develop mass-balance ecosystem models for the 1985-1987 and 2013-2015 periods in the NL Shelf synthesizing information on biomass, production, consumption and diets of major species groups. These time periods were selected due to their relatively constant biomasses for major commercial species and represent periods of stability in both the NL Shelf and Barents Sea. The 1985-1987 model represents the period prior to the groundfish collapse in the NL Shelf (which occurred in the early 1990s), where groundfish abundances were relatively high. The 2013-2015 model represents a period of relative increase compared to the 1985-1987 period in commercial invertebrate stocks in the NL Shelf and the establishment of associated harvesting of resources for groups such as shrimp and snow crab. During these time periods, the Barents Sea experienced an inverse pattern with low groundfish in the mid-1980s and an increase in groundfish in the 2010s. This report focuses on the development of the mass-balance ecosystem models for the NL Shelf as part of WP1.

Résumé

Tam, J.C. and Bundy, A. 2019. Mass-balance models of the Newfoundland and Labrador Shelf ecosystem for 1985-1987 and 2013-2015. Can. Tech. Rep. Fish. Aquat. Sci. 3328: vii + 78 p.

Le projet CoArc (*A Transatlantic Innovation Arena for Sustainable Development in the Arctic*, centre d'innovation transatlantique pour le développement durable dans l'Arctique) est une initiative financée par le ministère norvégien des Affaires étrangères, et il réunit des scientifiques de la Norvège et du Canada qui étudient des méthodes novatrices de gestion marine dans les régions arctiques et subarctiques. Le projet CoArc vise à mettre au point de meilleurs outils de gestion pour les écosystèmes marins arctiques et subarctiques. Le plan de travail 1 (WP1) du projet CoArc est axé sur la compréhension d'une synthèse transatlantique des écosystèmes, qui passe par la sélection de deux grands écosystèmes du Canada et de la Norvège et par la comparaison de ceux-ci. L'un des objectifs du WP1 du projet CoArc est d'élaborer des modèles écosystémiques de bilan massique du plateau continental de Terre-Neuve-et-Labrador pour les périodes de 1985 à 1987 et de 2013 4 2015, en vue d'une synthèse de l'information sur la biomasse, la production, la consommation et les régimes alimentaires des principaux groupes d'espèces. Ces périodes ont été choisies en raison de leur biomasse relativement constante concernant les principales espèces commerciales, et elles constituent des périodes de stabilité sur le plateau continental de T.-N.-L. et dans la mer de Barents. Le modèle pour la période de 1985 à 1987 représente la période précédant |'effondrement des stocks de poisson de fond sur le plateau continental de T.-N.-L. (qui a eu lieu au début des années 1990), soit une période où les poissons de fond étaient relativement abondants. Le modèle pour la période de 2013 à 2015 concerne une période d'accroissement relatif, par rapport à la période de 1985 41987, si l'on songe aux stocks commerciaux d'invertébrés sur le plateau continental de T.-N.-L. et à la mise en place de pratiques pour la pêche de groupe d'espèces, comme la crevette et le crabe des neiges. Au cours de ces périodes, la mer de Barents a connu une tendance inverse : les poissons de fond y étaient peu abondants au milieu des années 1980, puis leur population s'est accrue dans les années 2010. Le présent rapport porte sur l'élaboration des modèles écosystémiques de bilan massique du plateau continental de Terre-Neuve-et-Labrador et fait partie du WPI.

Introduction

Ecosystem modeling tools are advisable to collate, synthesize and predict ecosystem dynamics related to cumulative impacts (Korpinen and Andersen 2016), indirect effects (Crain et al. 2008), emergent properties (Link et al. 2015) and ecosystem-level reference points (Tam et al. 2017). Ecosystem models are important tools for collating, understanding and predicting key features of marine ecosystems and can provide a basis for ecosystem approaches to resource management (Travers et al. 2007; Fulton 2010; Rose et al. 2010; Collie et al. 2014; Tittensor 2017). The most common type of Ecosystem model is Ecopath with Ecosim and Ecospace (Polovina 1984; Walters et al. 1999; Christensen and Walters 2004). Ecopath is a mass-balance model of energy flows in an ecosystem, while Ecosim produces time dynamic simulations of the initial Ecopath model, primarily for fisheries policy exploration. Ecospace allows for the consideration of spatial management by including habitat dependency, migration, fisheries distributions among other spatially explicit parameters.

The models presented here are part of the CoArc project (A Transatlantic Innovation Arena for Sustainable Development in the Arctic), a 4 year joint project between Fisheries and Oceans Canada (DFO) and the Norwegian Ministry of Foreign Affairs. The CoArc project aims to create a transatlantic arena to drive innovation towards creating better tools and technologies to realize ecosystem-based management and the sustainable development of resources in the Arctic and sub-Arctic. The CoArc project is organized into 5 work-packages (WP). WP1 forms the science base on which the innovative solutions, industrial decision tools, and management regulations are based. The basic ecosystem understanding established through WP1 is applied in two case studies: Decision-support tools for operational impacts of petroleum activities (WP2) and Framework for Arctic risk management (WP3). The lasting legacy of CoArc is developed in WP4: A sustainable transatlantic arena. WP5 is a project management work package to address project logistics, operational routines, dissemination and reporting requirements.

WP1 of CoArc is focused on a transatlantic synthesis of ecosystem understanding and, to that end, has selected two large ecosystems in Canada and Norway for comparative purposes. Both are exposed to a range of stressors, including climatic change and anthropogenic factors such as fisheries and industrial activities. In Canada, the Newfoundland and Labrador (NL) Shelf is a representative sub-Arctic/Arctic ecosystem with a complex, recorded history of shifts in the proportion of species assemblages and in commercial fishing over the last 50 years. Through the 1970s and 1980s a prosperous groundfish fishery took place butwas brought to a halt by the collapse of groundfish in the early 1990s (Hutchings and Myers 1994). The following time period, though the 2000s and 2010s, experienced an increase in shellfish resources and a shift to shellfish as the major fishery (Lilly et al. 2000). Conversely, the Barents Sea, Norway had low groundfish stocks in the 1980s and have seen increased abundances of groundfish in the 2010s. Thus, model time periods of 1985-1987 and 2013-2015 were selected for both ecosystems for the development of representative mass-balance models. This reports documents the development of Ecopath models for the NL Shelf.

The 1985-1987 NL Shelf Ecopath model was based on a previously constructed model by Bundy et al. (2000) for North Atlantic Fisheries Organization (NAFO) divisions 2J3KLNO which represents approximately 495 000 km^2 (Figure 1). The study area is the southern third of the Labrador Shelf, the Northeast Newfoundland Shelf and the Grand Bank from the coast out to the 1000m isobaths and is referred hereafter as the Newfoundland and Labrador Shelf (NL Shelf). The choice of the study area aimed to encompass stock boundaries of most major commercial species and appropriately represents the NL Shelf, while at the same time fitting within the boundaries of the NAFO Divisions.

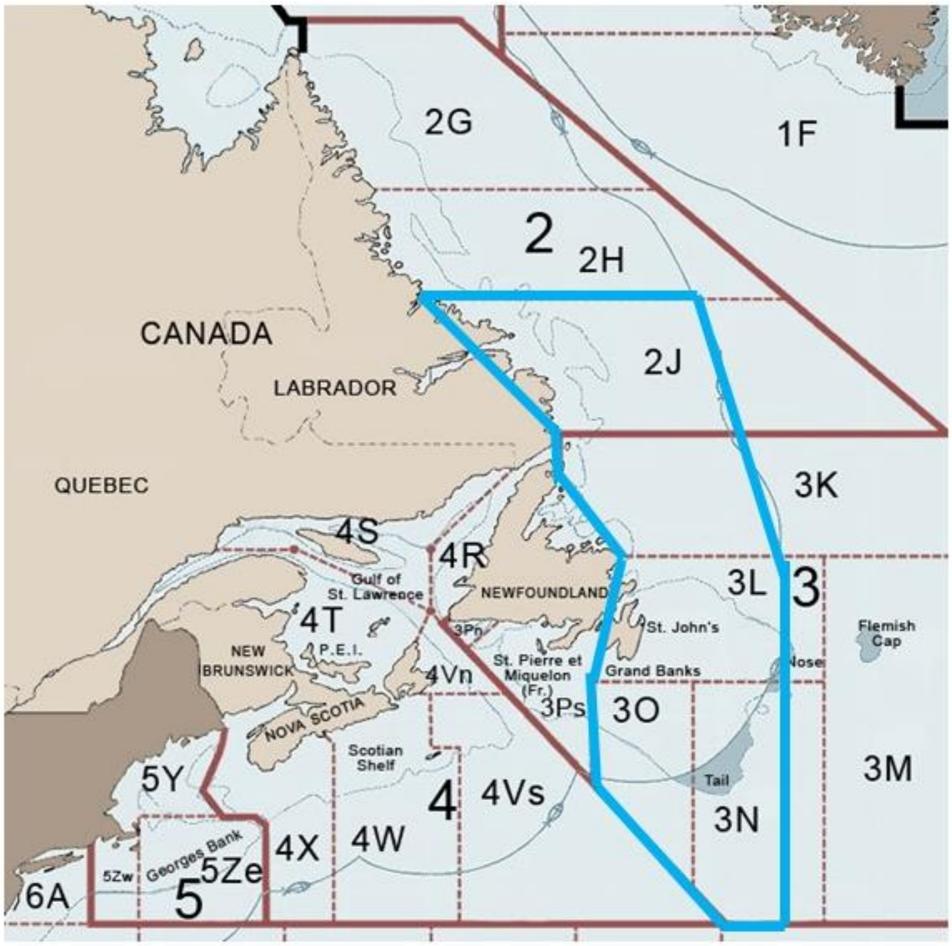

Figure 1. Map of the Newfoundland and Labrador (NL) Shelf model area, NAFO divisions 2J3KLNO from the coast out to the solid blue line.

In order to ensure the comparability with the BS Ecopath models, mutual agreement on the model structure was necessary and subsequent changes from the past Ecopath model were made. Changes to the current models (Table 1) from the past mass-balance ecosystem model of the NL Shelf include greater representation of higher trophic and lower trophic groups. This means the inclusion of both whale and seabird functional groups as well as a wider distinction between invertebrate, zooplankton and phytoplankton groups. This model also includes representative groups for the microbial loop, which represents an important trophic pathway that is not often represented in ecosystem models. Further studies of these models will include comparisons between models and concurrent simulations to compare the NL Shelf to a similarly constructed model from the Barents Sea.

Model structure

The model structure (Table 1) was determined for both the NL Shelf and Barents Sea for the 1985-1987 and 2013-2015 time periods through consultations with experts from each region. The model structure reflects important species and functional groups that represent both regions that can also be used to compare ecosystems. A previous mass balance model of the NL Shelf for the 1985-1987 period developed by Bundy et al. (2000) was used as a starting point for this work, and adjusted to the model structure in Table 1.

Table 1. Model structure of the current Ecopath models for the Newfoundland and Labrador Shelf and the Barents Sea ecosystems.

	Whale Groups		**Fish Groups cont.**		**Microbial Loop**
1	Whale fish eater	21	American plaice > 35	44	Bacteria
2	Whale zooplankton eater	22	Am plaice <= 35	45	Heterotrophic nanoflagellates
3	Whale squid eater	23	Thorny skate		**Phytoplankton**
4	Whale mammal eater	24	Haddock	46	Large phytoplankton
5	Whale Minke	25	Other Large benthivorous fish	47	Small phytoplankton
	Seal Groups	26	Yellowtail flounder		**Detritus**
6	Seal Harp	27	Witch flounder	48	Detritus
7	Seal Hooded	28	Other Medium benthivorous fish		
8	Seal other	29	Small benthivorous fish		
	Seabird Groups	30	Herring		
9	Seabird piscivore	31	Sandlance		
10	Seabird planktivore	32	Capelin		
11	Seabird benthivore	33	Other planktivorous fish		
	Fish Groups		**Invertebrate Groups**		
12	Greenland shark	34	Squid		
13	Atlantic Cod > 35 cm	35	Shrimp		
14	Atlantic Cod <= 35 cm	36	Snow crab		
15	Greenland halibut	37	Predatory invertebrates		
16	Silver hake/ Pollock	38	Deposit feeding invertebrates		
17	Other piscivorous fish	39	Suspension feeding invertebrates		
18	Redfish	40	Macrozooplankton		
19	Arctic cod	41	Large mesozooplankton		
20	Other plank-piscivorous fish	42	Small mesozooplankton		
		43	Microzooplankton		

Methods

Modelling framework

Ecopath with Ecosim and Ecospace (EwE) is a modelling framework (Pauly et al. 2000) representing the whole biological system. The Ecopath model provides a mass-balance snapshot of the resources in an ecosystem and their interactions represented by trophically linked functional groupings for a particular time period. These functional groupings can be a single species or a group of species, which may be divided into two or more stanzas that represent ontogenetic stages for a particular species, creating multistanza groups. For example, cod are split into two size groups, ≤ 35 cm and > 35 cm (Table 1).

The core routine of Ecopath is derived from the Ecopath program of Polovina (1984), modified to include a biomass accumulation term that removed the steady state assumption. The Ecopath equation describes how the production term for each group can be split:

Production = catches + predation mortality + biomass accumulation + net migration + other mortality

or, more formally,

$$P_i = Y_i + B_i M2_i + E_i + BA_i + P_i(1 - EE_i)$$

[Eq 1]

where P_i is the total annual production rate of (i), Y_i is the total fishery annual catch rate of (i), $M2_i$ is the total predation rate for group (i), B_i the biomass of the group, E_i the net migration rate (emigration - immigration), BA_i is the biomass accumulation rate for (i), while $M0_i = P_i \,.\, (1-EE_i)$ is the 'other mortality' rate for (i) where EE_i is the ecotrophic efficiency (the fraction of the production that is used in the system).

The EE is estimated from

$$EE_i = \frac{Y_i + B_i M2_i + E_i + BA_i}{P_i}$$

[Eq. 2]

And the Ecopath master equation can be expressed as:

$$B_i \cdot (P/B)_i - (P/B)_i \cdot B_i \cdot (1 - EE_i) - Y_i - E_i - BA_i - \sum_{j=1}^{n} B_j \cdot (Q/B)_j \cdot DC_{ji} = 0$$

[Eq 3]

Where $(P/B)_i$ is the production to biomass ratio of functional group i, B_j is the biomass of consumers or predators j, $(Q/B)_j$ is the consumption per unit biomass of j and DC_{ji} is the fraction of i in the diet j.

In an Ecopath model, the energy input and output of all living groups must be balanced. To account for other flows outside of production 'missing' parameters are estimated to ensure mass balance between the groups energy flow:

Consumption=production + respiration +unassimilated food

Or

$$Q_i = P_i + R_i + Q_i * GS_i$$

[Eq 4]

Where R_i and GS_i are the respiration and the proportion of food that is not assimilated.

For multistanza functional groups, where age structure is defined, the Ecopath model uses estimates of total mortality (Z), B and Q/B for the leading stanza group (the main age group input parameter used in the population model by Ecopath) and Z for the other stanza groups. In addition, estimates for the growth parameter K of the von Bertalanffy growth function, the starting age in months of each stanza and the ratio between the average weight at maturity and the asymptotic weight must be entered. The B of the other stanzas are then estimated by Ecopath using a population model that calculates biomass and Q/B of the other stanzas based on the following assumptions: (1) body growth for the species or group follows a von Bertalanffy growth curve with weight proportional to length cubed, (2) the species population has had a relatively stable mortality and recruitment rate for at least a few years with a stable age-size distribution, (3) Q/B estimates for other stanza groups are estimated based on the assumption that feeding rates vary with age as the 2/3 power of body weight.

This approach is thoroughly documented in scientific literature (Christensen and Pauly 2008; Walters et al. 2010) and has been used and described in DFO technical reports (Bundy et al. 2000, Araujo and Bundy 2011).

Description of input parameters

Biomass

For whale groups in the 1985-1987 model, biomass was estimated using data from a previous Ecopath model by Bundy et al. (2000) for the NL Shelf, with updated information supplemented from Lawson and Gosselin (2009). For the 2013-2015 model, estimates were generated using sightings data from Lawson and Gosselin (2009) and scaled to the NL Shelf study are of this project.

Seal group biomass for both 1985-1987 and 2013-2015 model were generated from seal population models by Buren and Stenson (unpubl. data).

Seabird biomasses were estimated from data provided Bill Montevecchi (Memorial University, Newfoundland) in Bundy et al (2000) for the 1985-1987 model and by Canadian Wildlife Service's Eastern Canada Seabirds at Sea survey (Gjerdrum et al. 2008, 2012a, 2012b) for the 2013-2015 model and scaled to the NL Shelf study area of this project.

Fish group biomass estimates were derived from Fisheries and Oceans Canada Stratified Random Research Vessel (RV) surveys for the Northwest Atlantic Fisheries Centre (NAFC) from 1985-2016 with information on functional groupings provided by Mariano Koen-Alonso (Pers. Comm. April 2017, NAFC). In 1995, the sampling gear for DFO RV surveys in NL was changed from an Engel to a

Campelen trawl. In order to make the data consistent between the two gear types two methods were developed. Method (1) scaling factors developed by Koen-Alonso (unpubl. data, April 2017, NAFC) for specific functional groupings (piscivores, plank-piscivores, planktivores, large benthivores, medium benthivores, small benthivores) were applied to functional groups for the 1985-1987 model. While these methods produced realistic scaling factors for some functional groups, for specific species this was not the case. Thus, Method (2) was developed using averaged biomass estimates for each species from the 1993-1994 period (Engel) and compared to the average biomass estimates for the 1996-1997 period (Campelen). The biomass estimates from the 1996-1997 period were then divided by the biomass estimates for the 1993-1994 period and the resulting scaling factor was applied to the biomass estimates for the 1985-1987 period. The 2013-2015 model used biomass estimates derived from the Campelen survey for that time period.

For the functional groups with multi-stanzas, (Atlantic cod and American plaice) biomass data were provided by Paul Regular (unpubl. data, April 2017, NAFC) for the NAFO 2J3KLNO divisions from stock assessment models (see specific functional groups for details) for the years 1985-2017.

Biomass estimates for important commercial invertebrates, Shrimp (*Pandalus* sp) and Snow crab (*Chionoecetes opilio*), were estimated from the original values in Bundy et al. (2000) for the 1985-1987 model. These estimates were modified given expert opinion and from information in more recent stock assessment models. The 2013-2015 model used stock assessment values from that time period (DFO 2016a, 2017a, 2018a, 2019)

Due to the lack of available invertebrate data from the 1985-1987 period, biomass estimates were derived primarily from the environmental assessments performed by Mobile Oil Canada as part of the Hibernia Development project. Data were also used from Bundy et al. (2000). Biomass values for the 2013-2015 model were calculated from the NEREUS project benthic grab samples provided by Kent Gilkinson (DFO 2012) which aimed to compliment RV survey from 2008-2010 and to provide better information about benthic invertebrates. The project area of the NEREUS grab sampling had a lower spatial coverage (158 grab samples in the NAFO 3LNO divisions) compared to the RV survey. Preliminary analyses indicated that proportion of benthic invertebrate predators, suspension feeders and deposit feeders were similar between NEREUS and the RV survey with some differences between the two sampling programs. The estimated biomass density of all benthic invertebrates from the NEREUS program was much higher than the total biomass density of benthic invertebrates sampled by the RV survey, however, the grab sample did not capture larger crustaceans (such as lobster) which are known to be in the region. Therefore, in order to estimate an aggregate biomass of benthic invertebrates from the NEREUS and RV surveys, the following steps were followed: (i) the total biomass density of benthic invertebrates estimated from the NEREUS project represented total biomass density of benthic invertebrates excluding larger crustaceans. (i) Proportions for each functional group were based on the proportions averaged over the NEREUS Survey and the RV survey (iii) biomass density of larger crustaceans was estimated from the RV Survey data.

The estimated biomass for macrozooplankton was estimated by Ecopath. Large mesozooplankton, small mesozooplankton and microzooplankton were derived from Head and Pepin (2009) and Pepin et al. (2011) data from the Atlantic Zone Monitoring (AZMP) program for the Newfoundland and Labrador Region. The data were supplied for areas within the NL Shelf study area for this project.

Bacteria and heterotrophic nanoflagellates (HNAN) biomass estimates were calculated from particulate organic carbon (POC) values derived from the AZMP provided by Pierre Pepin (Pers Comm. October 2018, NAFC). Specific details can be found in the background information for these functional groups.

Large and small phytoplankton biomass for the 1985-1987 period were estimated from Bundy et al. 2000 with data provided by Carla Caverhill from the Coastal Zone Color Scanner (CZCS) program. Phytoplankton biomasses for the 2013-2015 model were estimated from satellite images for 2013-2015 period. Large and small phytoplankton were determined through further analysis to differentiate large and small phytoplankton from satellite images (Liu et al. 2018). Specific details can be found in the background information for these functional groups.

Growth and maturity parameters for multistanza groups

Generally, size/age at maturity information for both Atlantic cod and American plaice for the 2J3KLNO period are available through stock assessments for both the 1985-1987 and 2013-2015 periods. For K parameters, these data were determined from published studies or, when empirical studies were unavailable, on fishbase (Froese and Pauly 2013) for all or part of the NL Shelf.

Production to Biomass and total mortality parameters

Christensen and Pauly (1993) define production as the total amount of tissue elaborated in the population or community of the study area during a given time period. This production is measured as the total biomass lost due to death and emigration for that time period. Total mortality (Z), under the condition assumed for the construction of mass-balance models, is a general approximation for production over biomass (Allen 1971). i.e., P/B=Z=M+F. For the majority of groups, P/B estimates were derived from previously published studies or calculated from estimates of natural mortality and fishing morality (where applicable), i.e., calculated as the sum of natural mortality and fishing mortality. Natural mortality was estimated using the Hoenig (1983) equation for mortality:

$$\ln(M) = 1.46 - 1.01 * \ln(Age_{\max}) \text{ for fish groups}$$

[Eq 5]

$$\ln(M) = 0.941 - 0.873 * \ln(Age_{\max}) \text{ for marine mammals}$$

[Eq 6]

Where M is the mortality and Age_{max} is maximum age for a given species or average maximum age for a group.

For functional groups that were commercially harvested, estimates of fishing mortality (F) were added to M to obtain an estimate of Z (and used as P/B ratio). F was calculated using catch data divided by the estimated biomass for a given functional group.

For multistanza groups estimates of total mortality are required to be entered for each stanza. For these groups where published estimates of fishing mortality (F) are available, that was added to the estimates for natural mortality (M) from published stock assessments or reports for the model region.

Consumption to biomass ratio

Estimates of consumption to biomass were generally derived from stomach content data for major commercial fish from the RV survey and provided by Mariano Koen-Alonso for 1985-2015 (Pers Comm. April 2017, NAFC). Where stomach content data were not available, diets from published studies were used.

Diet

Seal diets were derived from stomach contents and reconstructed diets from earlier time periods provided by Garry Stenson and Alejandro Buren (Pers Comm. August 2018, NAFC). Proportional diets for major commercial fish were derived from stomach content data from RV surveys and provided by Mariano Koen-Alonso for 1985-2015 (Pers Comm. April 2017, NAFC). Where diet data were not directly available for the region or time periods, information from published studies were used (see specific functional groups for details).

Landings

For commercial fish species, landings data were calculated from the NAFO 21A database available online (NAFO 2016). This database contains information on annual catches by species, subareas, country and year. Where data were not directly available for time periods or region, data from reports and other published sources were used.

Balancing the model

Initial input data were entered into the Ecopath models. If the models were unbalanced (EE >1 for any functional group) the strategy used to balance the model was to first explore realistic changes to the diet matrix based on the distribution of diet items from the RV survey (where available). Food habits data are generally considered to have large uncertainties due to biases associated with digestion time and sampling sufficiency. If modification of the diet matrix did not reduce EE < 1, then biomass, production or consumption rates were changed. The magnitudes of the changes were based on the degree of confidence in the data input based on expert opinion, which was highest for the main commercial fish species. These changes were made in an iterative manner and documented in this section.

Estimates of input parameters

Table 2. Basic inputs and model estimates for balanced the NL Shelf 1985-1987 model. Dark grey cells denote multistanza groups, while light grey cells denote values estimated by Ecopath.

	Group name	TL	B (t/km²)	Z (/year)	P/B (/year)	Q/B (/year)	EE	P/Q	Landings
1	Whale fish eater	4.312	0.141		0.129	5.387	0.000	0.024	0.000
2	Whale zp eater	3.694	0.028		0.055	3.468	0.148	0.016	0.000
3	Whale squid eater	4.597	0.057		0.078	5.498	0.000	0.014	0.000
4	Whale mammal eater	5.266	0.000		0.084	8.100	0.000	0.010	0.000
5	Whale Minke	4.332	0.022		0.089	5.380	0.078	0.017	0.000
6	Seal Harp	4.425	0.100		0.149	16.782	0.265	0.009	0.003
7	Seal Hooded	5.007	0.028		0.115	18.225	0.211	0.006	0.000
8	Seal other	4.756	0.010		0.128	13.000	0.068	0.010	0.000
9	Seabird piscivore	4.330	0.010		0.250	119.416	0.031	0.002	0.000
10	Seabird planktivore	3.348	0.002		0.150	64.605	0.000	0.002	0.000
11	Seabird benthivore	3.631	0.000		0.130	45.291	0.000	0.003	0.000
12	Greenland shark	5.250	0.012		0.010	0.125	0.000	0.080	0.000
13	Cod> 35 cm	4.314	3.576	0.651		1.615	0.319	0.403	0.603
14	Cod<= 35 cm	3.749	0.958	0.600		3.605	0.753	0.166	0.000
15	Greenland halibut	4.596	0.436		0.719	2.900	0.999	0.248	0.035
16	Silver hake/ Saithe	4.245	0.017		0.530	4.100	0.246	0.129	0.002
17	Other pisc	4.221	0.200		0.505	2.775	0.467	0.182	0.024
18	Redfish	3.808	1.800		0.330	2.000	0.879	0.165	0.162
19	Arctic cod	3.592	2.729		0.400	2.630	0.740	0.152	0.000
20	Other plank-pisc	3.335	0.039		0.350	2.500	0.976	0.140	0.000
21	AmPlaice > 35	3.783	0.990	0.540		2.000	0.776	0.270	0.110
22	AmPLaice <= 35	3.752	3.332	0.630		3.972	0.287	0.159	0.025
23	Thorny skate	4.072	0.540		0.286	1.918	0.762	0.149	0.038
24	Haddock	3.509	0.092		0.297	2.080	0.588	0.143	0.008
25	Other L benth	3.433	0.424		0.200	1.333	0.998	0.150	0.001
26	Yellowtail flounder	3.655	0.589		0.386	3.600	0.885	0.107	0.041
27	Witch flounder	3.584	0.230		0.257	2.599	0.802	0.099	0.025
28	Other M benth	3.612	0.693		0.300	2.000	0.969	0.150	0.011
29	Other S benth	3.373	1.527		0.421	2.000	0.950	0.211	0.000
30	Herring	3.709	0.136		1.150	3.148	0.950	0.365	0.019
31	Sandlance	3.466	2.391		1.150	7.670	0.950	0.150	0.000
32	Capelin	3.400	13.766		1.150	4.300	0.601	0.267	0.126
33	Other plank	2.836	1.247		1.150	4.190	0.950	0.274	0.001
34	Squid	3.606	0.365		3.400	13.200	0.443	0.258	0.000
35	Shrimp	2.389	0.876		1.700	11.333	0.771	0.150	0.000
36	Snow crab	3.302	0.180		0.460	3.067	0.896	0.150	0.014
37	Predatory invert	2.648	12.473		1.310	8.733	0.710	0.150	0.003
38	Deposit feeding invert	2.000	60.934		1.500	10.000	0.635	0.150	0.000
39	Suspension feeding invert	2.481	99.293		0.556	3.707	0.328	0.150	0.000
40	Macro ZP	2.626	11.275		3.430	19.500	0.950	0.176	0.000
41	Large meso ZP	2.436	20.500		8.400	28.000	0.978	0.300	0.000
42	Small meso ZP	2.050	6.500		31.610	105.367	0.937	0.300	0.000
43	Micro ZP	2.256	5.600		72.000	240.000	0.714	0.300	0.000
44	Bacteria	2.000	4.400		50.445	135.000	0.990	0.374	0.000
45	HNAN	2.538	0.505		73.000	187.920	0.924	0.388	0.000
46	Phytoplankton L	1.000	11.723		93.100		0.600		0.000
47	Phytoplankton S	1.000	17.656		93.100		0.800		0.000
48	Detritus	1.000	1.000				0.821		0.000

Table 3. Basic inputs and model estimates for the balanced NL Shelf 2013-2015 model. Dark grey cells denote multistanza groups, while light grey cells denote values estimated by Ecopath.

	Group name	TL	B (t/km²)	Z (/year)	P/B (/year)	Q/B (/year)	EE	P/Q	Landings
1	Whale fish eater	4.284	0.265		0.055	5.394	0.000	0.010	0.000
2	Whale zp eater	3.692	0.028		0.054	3.468	0.151	0.016	0.000
3	Whale squid eater	4.589	0.066		0.073	5.498	0.000	0.013	0.000
4	Whale mammal eater	5.092	0.000		0.084	8.100	0.000	0.010	0.000
5	Whale Minke	4.149	0.040		0.089	5.380	0.043	0.017	0.000
6	Seal Harp	4.092	0.320		0.149	17.643	0.324	0.008	0.015
7	Seal Hooded	4.933	0.038		0.115	18.332	0.131	0.006	0.000
8	Seal other	4.700	0.015		0.128	13.000	0.034	0.010	0.000
9	Seabird piscivore	4.253	0.007		0.250	119.410	0.607	0.002	0.001
10	Seabird planktivore	3.348	0.006		0.150	64.605	0.000	0.002	0.000
11	Seabird benthivore	3.632	0.002		0.130	45.291	0.000	0.003	0.000
12	Greenland shark	5.144	0.009		0.010	0.125	0.000	0.080	0.000
13	Cod> 35 cm	4.287	0.760	0.307		1.615	0.932	0.190	0.011
14	Cod<= 35 cm	3.756	0.038	0.302		4.433	0.374	0.068	0.000
15	Greenland halibut	4.399	0.690		0.644	2.900	0.888	0.222	0.027
16	Silver hake/ Saithe	4.258	0.163		0.401	4.100	0.741	0.098	0.001
17	Other pisc	4.213	0.101		0.455	2.525	0.678	0.180	0.007
18	Redfish	3.806	2.130		0.330	2.000	0.717	0.165	0.031
19	Arctic cod	3.590	2.729		0.400	2.633	0.569	0.152	0.000
20	Other plank-pisc	3.335	0.028		0.350	2.500	0.670	0.140	0.000
21	AmPlaice > 35	3.820	0.239	0.600		2.000	0.986	0.300	0.003
22	AmPLaice <= 35	3.865	1.349	0.753		4.236	0.624	0.178	0.000
23	Thorny skate	4.021	0.305		0.286	2.174	0.590	0.132	0.008
24	Haddock	3.494	0.072		0.214	2.080	0.283	0.103	0.000
25	Other L benth	3.433	0.250		0.200	1.333	0.793	0.150	0.000
26	Yellowtail flounder	3.654	1.666		0.364	3.600	0.821	0.101	0.017
27	Witch flounder	3.584	0.065		0.233	2.599	0.753	0.090	0.001
28	Other M benth	3.612	0.469		0.300	2.000	0.950	0.150	0.001
29	Other S benth	3.386	1.154		0.421	3.148	0.950	0.134	0.000
30	Herring	3.707	0.920		1.150	4.000	0.950	0.288	0.010
31	Sandlance	3.450	2.790		1.150	7.670	0.950	0.150	0.000
32	Capelin	3.390	4.970		1.150	4.300	0.999	0.267	0.048
33	Other plank	2.832	2.195		1.150	4.190	0.950	0.274	0.000
34	Squid	3.612	0.365		3.400	13.200	0.748	0.258	0.000
35	Shrimp	2.389	2.440		1.700	11.333	0.763	0.150	0.014
36	Snow crab	3.303	0.330		0.460	3.067	0.992	0.150	0.089
37	Predatory invert	2.648	30.856		1.310	11.000	0.336	0.119	0.107
38	Deposit feeding invert	2.000	121.815		1.500	10.000	0.953	0.150	0.001
39	Suspension feeding invert	2.481	77.329		0.556	3.707	0.906	0.150	0.001
40	Macro ZP	2.626	7.845		3.430	19.500	0.950	0.176	0.000
41	Large meso ZP	2.436	13.804		8.400	28.000	0.983	0.300	0.000
42	Small meso ZP	2.050	5.534		31.610	105.367	0.779	0.300	0.000
43	Micro ZP	2.256	5.360		72.000	240.000	0.627	0.300	0.000
44	Bacteria	2.000	5.200		50.445	135.000	0.833	0.374	0.000
45	HNAN	2.538	0.600		73.000	187.920	0.698	0.388	0.000
46	Phytoplankton L	1.000	11.433		103.270		0.413		0.000
47	Phytoplankton S	1.000	13.067		103.270		0.855		0.000
48	Detritus	1.000	1.000				0.000		0.000

Table 4. Diet composition for the 1985-1987 model

	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
1	Whale fish eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Whale zp eater	0.000	0.000	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Whale squid eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Whale mammal eater	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Whale Minke	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Seal Harp	0.000	0.000	0.000	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	Seal Hooded	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.220	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Seal other	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Seabird piscivore	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Seabird planktivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	Seabird benthivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Greenland shark	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	Cod> 35 cm	0.000	0.000	0.000	0.000	0.000	0.024	0.191	0.031	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.000
14	Cod<= 35 cm	0.001	0.000	0.027	0.000	0.050	0.010	0.066	0.270	0.005	0.000	0.000	0.020	0.026	0.001	0.090	0.000	0.020	0.000	0.000	0.000	0.004	0.000	0.050
15	Greenland halibut	0.000	0.000	0.000	0.050	0.000	0.000	0.250	0.092	0.000	0.000	0.000	0.180	0.006	0.000	0.080	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
16	Silver hake/ Saithe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
17	Other piscivorous fish	0.000	0.000	0.000	0.050	0.000	0.000	0.016	0.000	0.010	0.000	0.000	0.017	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Redfish	0.000	0.000	0.000	0.000	0.000	0.003	0.033	0.051	0.000	0.000	0.000	0.004	0.000	0.000	0.160	0.010	0.020	0.000	0.000	0.000	0.000	0.000	0.081
19	Arctic cod	0.000	0.000	0.000	0.000	0.000	0.332	0.000	0.011	0.025	0.000	0.000	0.000	0.012	0.003	0.016	0.000	0.020	0.000	0.000	0.000	0.002	0.007	0.001
20	Other plank-pisc fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
21	AmPlaice > 35	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.050	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	AmPLaice <= 35	0.000	0.000	0.010	0.000	0.000	0.020	0.025	0.000	0.000	0.000	0.000	0.000	0.090	0.001	0.003	0.000	0.130	0.000	0.000	0.000	0.000	0.000	0.001
23	Thorny skate	0.000	0.000	0.050	0.000	0.000	0.030	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.010	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
24	Haddock	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.047	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
25	Other L benthivorous fish	0.000	0.000	0.060	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.100	0.010	0.000	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	Yellowtail flounder	0.000	0.000	0.130	0.000	0.000	0.000	0.080	0.020	0.000	0.000	0.000	0.000	0.006	0.000	0.016	0.000	0.010	0.000	0.000	0.000	0.004	0.000	0.007
27	Witch flounder	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
28	Other M benthivorous fish	0.000	0.000	0.027	0.000	0.000	0.022	0.107	0.200	0.000	0.000	0.000	0.054	0.007	0.001	0.006	0.000	0.010	0.000	0.000	0.000	0.001	0.000	0.010
29	Other S benthivorous fish	0.001	0.000	0.000	0.000	0.000	0.058	0.057	0.045	0.035	0.000	0.100	0.050	0.012	0.003	0.002	0.000	0.010	0.000	0.000	0.050	0.004	0.003	0.116
30	Herring	0.000	0.000	0.000	0.000	0.000	0.034	0.000	0.145	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.010	0.000	0.000	0.000
31	Sandlance	0.083	0.080	0.000	0.000	0.000	0.049	0.000	0.060	0.070	0.000	0.000	0.000	0.279	0.014	0.002	0.367	0.020	0.000	0.000	0.010	0.074	0.017	0.130
32	Capelin	0.749	0.080	0.027	0.050	0.750	0.303	0.009	0.019	0.700	0.000	0.000	0.000	0.285	0.137	0.555	0.390	0.500	0.145	0.039	0.010	0.322	0.172	0.080
33	Other planktivorous fish	0.060	0.000	0.039	0.000	0.100	0.000	0.000	0.000	0.156	0.000	0.000	0.000	0.001	0.000	0.004	0.000	0.050	0.212	0.000	0.010	0.000	0.000	0.007
34	Squid	0.023	0.000	0.620	0.050	0.050	0.000	0.126	0.007	0.000	0.000	0.000	0.017	0.002	0.002	0.017	0.000	0.000	0.047	0.000	0.000	0.000	0.000	0.058
35	Shrimp	0.000	0.000	0.000	0.000	0.000	0.084	0.000	0.000	0.000	0.000	0.000	0.000	0.016	0.020	0.009	0.014	0.050	0.086	0.000	0.050	0.004	0.007	0.020
36	Snow crab	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020
37	Predatory invertebrates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.200	0.000	0.077	0.165	0.000	0.010	0.000	0.000	0.000	0.050	0.124	0.201	0.235
38	Deposit feeding invertebrates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.006	0.000	0.000	0.000	0.000	0.000	0.300	0.236	0.030	0.063
39	Suspension feeding invertebrates	0.000	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.000	0.010	0.250	0.040	0.042	0.010	0.000	0.010	0.000	0.000	0.089	0.100	0.184	0.096	0.100
40	Macrozooplankton	0.083	0.520	0.000	0.000	0.050	0.014	0.000	0.001	0.000	0.212	0.250	0.000	0.065	0.633	0.013	0.197	0.080	0.510	0.593	0.310	0.038	0.467	0.014
41	Large mesozooplankton	0.000	0.320	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.444	0.200	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.278	0.100	0.000	0.000	0.004
42	Small mesozooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
43	Microzooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	Bacteria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	Heterotrophic nanoflagellates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	Large Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	Small Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	(1 - Sum)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 4....cont'd diet composition for 1985-1987 model

	Prey \ predator	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	Whale fish eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Whale zp eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Whale squid eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Whale mammal eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Whale Minke	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Seal Harp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	Seal Hooded	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Seal other	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Seabird piscivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Seabird planktivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	Seabird benthivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Greenland shark	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	Cod> 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	Cod<= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	Greenland halibut	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	Silver hake/ Saithe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	Other piscivorous fish	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Redfish	0.000	0.042	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	Other plank-pisc fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	AmPlaice > 35	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	AmPLaice <= 35	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	Thorny skate	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	Haddock	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	Other L benthivorous fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	Yellowtail flounder	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	Witch flounder	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	Other M benthivorous fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	Other S benthivorous fish	0.012	0.033	0.028	0.009	0.079	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	Herring	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	Sandlance	0.050	0.016	0.473	0.000	0.030	0.005	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	Capelin	0.092	0.029	0.004	0.000	0.048	0.021	0.000	0.002	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33	Other planktivorous fish	0.000	0.029	0.000	0.000	0.061	0.003	0.425	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34	Squid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35	Shrimp	0.056	0.013	0.000	0.021	0.010	0.021	0.000	0.000	0.000	0.010	0.046	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	Snow crab	0.021	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	Predatory invertebrates	0.211	0.089	0.000	0.660	0.123	0.226	0.123	0.000	0.005	0.000	0.017	0.100	0.302	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	Deposit feeding invertebrates	0.367	0.440	0.264	0.030	0.184	0.309	0.009	0.182	0.000	0.000	0.025	0.050	0.302	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	Suspension feeding invertebrates	0.142	0.148	0.063	0.278	0.209	0.309	0.000	0.003	0.040	0.040	0.025	0.012	0.126	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	Macrozooplankton	0.000	0.026	0.168	0.000	0.235	0.010	0.427	0.164	0.200	0.000	0.804	0.050	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	Large mesozooplankton	0.036	0.109	0.000	0.001	0.000	0.048	0.016	0.550	0.555	0.359	0.062	0.150	0.024	0.000	0.000	0.050	0.310	0.050	0.000	0.000	0.000	0.000
42	Small mesozooplankton	0.000	0.011	0.000	0.000	0.015	0.048	0.000	0.100	0.200	0.140	0.000	0.150	0.010	0.000	0.000	0.050	0.167	0.200	0.000	0.000	0.000	0.000
43	Microzooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.138	0.000	0.000	0.000	0.200	0.177	0.108	0.000	0.100	0.000	0.000
44	Bacteria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.100	0.000	0.538
45	Heterotrophic nanoflagellates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.020	0.000	0.000
46	Large Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.010	0.000	0.000	0.250	0.107	0.212	0.300	0.150	0.000	0.100
47	Small Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.121	0.000	0.050	0.000	0.000	0.000	0.250	0.107	0.343	0.650	0.400	0.000	0.200
48	Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.101	0.350	1.000	0.200	0.133	0.075	0.000	0.230	1.000	0.162
	Import	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	(1 - Sum)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5. Diet composition for the 2013-2015 model.

	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
1	Whale fish eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Whale zp eater	0.000	0.000	0.000	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Whale squid eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Whale mammal eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Whale Minke	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Seal Harp	0.000	0.000	0.000	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	Seal Hooded	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.220	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Seal other	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Seabird piscivore	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Seabird planktivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	Seabird benthivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Greenland shark	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	Cod> 35 cm	0.000	0.000	0.000	0.000	0.000	0.025	0.080	0.051	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000
14	Cod<= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.020	0.002	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000
15	Greenland halibut	0.000	0.000	0.000	0.050	0.000	0.010	0.316	0.092	0.000	0.000	0.000	0.180	0.014	0.000	0.026	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
16	Silver hake/ Saithe	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.010	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
17	Other piscivorous fish	0.000	0.000	0.000	0.050	0.000	0.000	0.016	0.020	0.010	0.000	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Redfish	0.000	0.000	0.000	0.000	0.000	0.015	0.043	0.081	0.000	0.000	0.000	0.004	0.031	0.000	0.105	0.068	0.020	0.000	0.000	0.000	0.000	0.000	0.012
19	Arctic cod	0.075	0.000	0.000	0.000	0.000	0.074	0.000	0.021	0.049	0.000	0.000	0.000	0.005	0.002	0.011	0.000	0.010	0.000	0.000	0.000	0.007	0.000	0.000
20	Other plank-pisc fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.000	0.010	0.000	0.001	0.000	0.000	0.000	0.000
21	AmPlaice > 35	0.000	0.000	0.010	0.000	0.000	0.020	0.010	0.010	0.000	0.000	0.000	0.013	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	AmPLaice <= 35	0.000	0.000	0.010	0.000	0.000	0.040	0.021	0.020	0.000	0.000	0.000	0.010	0.208	0.011	0.050	0.000	0.120	0.007	0.000	0.000	0.000	0.000	0.000
23	Thorny skate	0.000	0.000	0.050	0.000	0.000	0.003	0.000	0.027	0.000	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
24	Haddock	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.000	0.000	0.000	0.022	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
25	Other L benthivorous fish	0.000	0.000	0.060	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.000	0.002	0.003	0.010	0.000	0.000	0.000	0.000	0.000	0.016
26	Yellowtail flounder	0.000	0.000	0.130	0.000	0.000	0.000	0.270	0.050	0.000	0.000	0.000	0.000	0.075	0.000	0.046	0.000	0.010	0.001	0.000	0.000	0.000	0.007	0.000
27	Witch flounder	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
28	Other M benthivorous fish	0.012	0.000	0.027	0.000	0.000	0.006	0.012	0.080	0.000	0.000	0.000	0.054	0.003	0.007	0.005	0.000	0.010	0.000	0.000	0.000	0.010	0.000	0.020
29	Other S benthivorous fish	0.012	0.000	0.000	0.000	0.000	0.010	0.047	0.045	0.035	0.000	0.100	0.050	0.022	0.003	0.033	0.000	0.010	0.000	0.000	0.050	0.002	0.001	0.028
30	Herring	0.000	0.000	0.000	0.000	0.000	0.162	0.000	0.145	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.010	0.000	0.000	0.000
31	Sandlance	0.241	0.080	0.000	0.000	0.000	0.046	0.035	0.090	0.070	0.000	0.000	0.000	0.120	0.060	0.162	0.367	0.020	0.051	0.000	0.010	0.324	0.133	0.278
32	Capelin	0.400	0.080	0.054	0.050	0.500	0.150	0.009	0.199	0.550	0.000	0.000	0.000	0.224	0.081	0.290	0.333	0.500	0.087	0.039	0.010	0.080	0.204	0.058
33	Other planktivorous fish	0.149	0.000	0.039	0.000	0.250	0.000	0.000	0.020	0.286	0.000	0.000	0.000	0.001	0.000	0.017	0.000	0.050	0.041	0.000	0.010	0.000	0.000	0.000
34	Squid	0.031	0.000	0.620	0.050	0.100	0.000	0.126	0.007	0.000	0.000	0.000	0.017	0.001	0.000	0.100	0.000	0.000	0.070	0.000	0.000	0.000	0.002	0.058
35	Shrimp	0.000	0.000	0.000	0.000	0.000	0.384	0.000	0.000	0.000	0.000	0.000	0.000	0.076	0.058	0.022	0.024	0.050	0.061	0.000	0.050	0.024	0.010	0.081
36	Snow crab	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.010	0.001	0.000	0.000	0.000	0.000	0.000	0.008	0.005	0.020
37	Predatory invertebrates	0.000	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000	0.200	0.000	0.080	0.050	0.000	0.000	0.000	0.000	0.000	0.050	0.099	0.074	0.265
38	Deposit feeding invertebrates	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.000	0.010	0.000	0.000	0.000	0.000	0.300	0.194	0.033	0.004
39	Suspension feeding invertebrates	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.250	0.040	0.018	0.001	0.016	0.000	0.000	0.000	0.089	0.100	0.226	0.176	0.000
40	Macrozooplankton	0.077	0.520	0.000	0.000	0.100	0.000	0.000	0.001	0.000	0.212	0.250	0.000	0.076	0.450	0.097	0.206	0.080	0.681	0.593	0.310	0.025	0.355	0.161
41	Large mesozooplankton	0.000	0.320	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.444	0.200	0.000	0.000	0.117	0.000	0.000	0.000	0.002	0.279	0.100	0.000	0.000	0.000
42	Small mesozooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.333	0.000	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	Microzooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	Bacteria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	Heterotrophic nanoflagellates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	Large Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	Small Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
48	Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Import	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	(1 - Sum)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5…cont'd diet composition for the 2013-2015 model.

	Prey \ predator	24	25	26	27	28	29	30	31	32	33	34	35	36	38	39	40	41	42	43	44	45	46
1	Whale fish eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	Whale zp eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	Whale squid eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	Whale mammal eater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	Whale Minke	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	Seal Harp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	Seal Hooded	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	Seal other	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	Seabird piscivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	Seabird planktivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	Seabird benthivore	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	Greenland shark	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	Cod> 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	Cod<= 35 cm	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	Greenland halibut	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	Silver hake/ Saithe	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	Other piscivorous fish	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	Redfish	0.000	0.042	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	Arctic cod	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	Other plank-pisc fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	AmPlaice > 35	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	AmPLaice <= 35	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	Thorny skate	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	Haddock	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	Other L benthivorous fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	Yellowtail flounder	0.000	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	Witch flounder	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	Other M benthivorous fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	Other S benthivorous fish	0.012	0.033	0.000	0.009	0.079	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	Herring	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
31	Sandlance	0.050	0.016	0.040	0.000	0.030	0.005	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	Capelin	0.092	0.029	0.039	0.000	0.048	0.021	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
33	Other planktivorous fish	0.000	0.029	0.000	0.000	0.061	0.003	0.425	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34	Squid	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35	Shrimp	0.056	0.013	0.000	0.021	0.010	0.021	0.000	0.000	0.000	0.010	0.046	0.000	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	Snow crab	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	Predatory invertebrates	0.232	0.089	0.771	0.660	0.123	0.306	0.123	0.178	0.005	0.000	0.057	0.060	0.302	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
38	Deposit feeding invertebrates	0.367	0.440	0.073	0.030	0.184	0.309	0.009	0.004	0.000	0.000	0.025	0.050	0.302	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39	Suspension feeding invertebrates	0.142	0.148	0.030	0.278	0.209	0.229	0.000	0.002	0.040	0.040	0.025	0.012	0.126	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	Macrozooplankton	0.000	0.026	0.041	0.000	0.235	0.010	0.427	0.170	0.200	0.000	0.801	0.000	0.010	0.000	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000
41	Large mesozooplankton	0.036	0.109	0.007	0.001	0.000	0.048	0.016	0.500	0.530	0.349	0.024	0.050	0.024	0.000	0.000	0.051	0.332	0.050	0.000	0.000	0.000	0.000
42	Small mesozooplankton	0.000	0.011	0.000	0.000	0.015	0.048	0.000	0.144	0.225	0.150	0.000	0.050	0.010	0.000	0.000	0.149	0.035	0.200	0.000	0.000	0.000	0.000
43	Microzooplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.078	0.000	0.000	0.000	0.200	0.077	0.108	0.000	0.100	0.000	0.000
44	Bacteria	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.050	0.100	0.000	0.538
45	Heterotrophic nanoflagellates	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.020	0.000	0.000
46	Large Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.010	0.000	0.000	0.250	0.107	0.212	0.300	0.100	0.000	0.100
47	Small Phytoplankton	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.121	0.000	0.400	0.000	0.000	0.000	0.250	0.107	0.343	0.650	0.100	0.000	0.200
48	Detritus	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.300	0.101	0.400	1.000	0.100	0.333	0.075	0.000	0.580	1.000	0.162
	Import	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	(1 - Sum)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Description of input data for each species or functional group

1. Whales fish eaters

Background

Piscivorous whales are defined as whales that primarily consume fish, with smaller dietary components that are invertebrates. The main piscivorous whales in the region are humpback (*Megaptera noveangliae*), fin (*Balaenoptera physalus*), harbour porpoise (*Phocoena phocoena*), Atlantic white-beaked dolphin (*Lagenorhynchus albitrosis*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*) and common dolphin (*Delphinus delphis*). Many of the species are known to move in and out of the study region (NAFO division 2J3KLNO) during the year, and thus an approximate residency time for piscivorous whales is assumed to be 180 days. It is difficult from observed data from Marine Mammal Surveys (currently two surveys in the region have been conducted 9 years apart) to accurately determine the timing and duration of the time piscivorous whales spend in the area, however, predictable migratory patterns and public sightings can confirm the approximate time spent in the region.

Biomass

Biomass estimates for piscivorous whales (Table 2, 3) were calculated as the number of individuals estimated to be in the study area multiplied by the average body weight and adjusted for the number of days spent in the study area. The biomass estimates for the 1985-87 model are based mainly on findings by Bundy et al. 2000 for humpback whales, fin whales and harbour porpoises. Additional information from Lawson and Gosselin (2009) was used to include white-beaked dolphins and white sided dolphins which are also known to be in the area (Table 6). The estimated biomass for piscivorous whales in the 2013-2015 model is based on the NAISS marine mammal census survey (Table 7; Lawson and Gosselin 2018).

Table 6. Whale fish eater input parameters for the 1985-1987 model.

	number of individuals	mean body weight	biomass t/km2	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	References
humpback	3300	31	0.207	180	0.102	(Barlow and Clapman 1997)
fin	1000	38.5	0.078	180	0.038	(Hay 1982; Mitchell 1974)
harbour porpoise	40	0.05	0.000004	180	0.000002	(Gaskin 1992)
white beaked dolphin	1322	0.04	0.000107	180	0.000053	(Lawson and Gosselin 2009, 2018)
white sided dolphin	1856	0.2	0.000750	180	0.000257	(Lawson and Gosselin 2009, 2018)
common dolphin	827	0.125	0.000145	180	7.0E-05	(Lawson and Gosselin 2009, 2018)
Total			0.285		**0.141**	

Table 7. Whale fish eater input parameters for the 2013-2015 model.

	number of individuals	mean body weight	biomass t/km2	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	References
humpback	6076	31	0.381	180	0.188	(Lawson and Gosselin 2018)
fin	1567	38.5	0.122	180	0.060	(Lawson and Gosselin 2018)
harbour porpoise	35081	0.05	0.00354	180	0.001747	(Lawson and Gosselin 2018)
white beaked dolphin	381987	0.04	0.03087	180	0.015222	(Lawson and Gosselin 2018)
white sided dolphin	2430	0.2	0.00098	180	0.000336	(Lawson and Gosselin 2018)
common dolphin	349721	0.125	0.00015	180	7.0E-05	(Lawson and Gosselin 2018)
Total			0.538		**0.265**	

Production:Biomass
P/B ratios (Table 8) were calculated using Hoenig's (1983) equation for estimating mortality in marine mammals (Eq 6) weighted by the biomass of each group (Table 7)

Maximum age estimates were derived from Trites and Pauly (1998). The calculated P/B estimates were used for both the 1985-1987 and 2013-2015 Ecopath models.

Table 8. Production estimates for Whale fish eaters used for both the 1985-1987 and 2013-2015 models

	Age	Z
humpback	75	0.059
fin	98	0.047
harbour porpoise	13	0.273
white beaked dolphin	30	0.132
white sided dolphin	30	0.132
common dolphin	30	0.132
P/B for group		**0.129**

Consumption:Biomass
Annual consumption by piscivorous whales was calculated assuming a residency time of 180 days in the NL Shelf as in Bundy et al. 2000. Humpbacks and fin whales consumed an estimated 3% of their body weight per day (Lockyer 1981). Total consumption by harbour porpoise, white-beaked dolphin, white-sided dolphin and common dolphin amounted to much less than humpback and fin whales (Table 9; Lien 1985, Pauly et al. 1998). The calculated average Q/B estimate was used for the 1985-1987 model was **5.387 y^{-1}** and **5.394 y^{-1}** 2013-2015 models assuming the percent body weight consumed remained constant.

Table 9. Consumption estimates for Whale fish eaters used for both the 1985-1987 and 2013-2015 models

Species	Consumption (t/km^2) 1985-1987	Consumption (t/km^2) 2013-2015	References
humpback	0.550	0.774	(Lockyer 1981)
Fin	0.207	0.248	(Lockyer 1981)
harbour porpoise	0.000	0.007	(Lien 1985)
white beaked dolphin	2.85E-04	0.064	(Pauly et al. 1998)
white sided dolphin	0.001387	0.001	(Pauly et al. 1998)
common dolphin	0.000378	0.000	(Pauly et al. 1998)
Total	0.760	1.095	
Q/B	**5.387**	**5.394**	

Diet

The diet of piscivorous whales (Table 10) for humpback, fin and harbour porpoise was constructed from information provided by Stenson, Lawson and Bundy in Bundy et al. (2000). Diet proportions for White beaked dolphin, white sided dolphin and common dolphin were taken from Pauly et al. (1998). The diet composition for each whale species was then weighted by the estimated biomass for the model. In some cases, the biomass contribution to the functional group was relatively low, and certain parts of their diet were too small to be considered in the composite diet. For example suspension feeding invertebrates are fed on by white beaked dolphins and white sided dolphins, but due to the relatively low biomass of these species compared to humpbacks or fin whales, suspension feeding invertebrates were not considered part of the overall diet for piscivorous whales.

Table 10. Diets of Whale fish eaters used for both the 1985-1987 and 2013-2015 models

1985-1987	Humback	Fin	Harbour porpoise	White beaked dolphin	White sided dolphin	common dolphin	**Composite diet**
Cod <= 35	0	0	0.125	0.01	0	0	**0.001**
Arctic cod	0	0	0	0.001	0.001	0.001	**0.000**
Large benth fish	0	0	0	0.09	0.1	0.1	**0.000**
Med benth fish	0	0	0	0.2	0.2	0.15	**0.000**
Small benth fish	0	0	0	0.2	0.2	0.2	**0.001**
Capelin	0.75	0.75	0.75	0.1	0.1	0.1	**0.749**
Sandlance	0.083	0.083	0	0	0	0.05	**0.083**
Other plank fish	0.083	0	0.125	0.05	0.05	0.1	**0.06**
Squid	0	0.083	0	0.2	0.25	0.3	**0.023**
Macrozooplankton	0.083	0.083	0	0	0	0	**0.083**
Suspension feeding inverts	0	0	0	0.05	0.1	0	**0.000**
Biomass of predator group	0.102	0.038	1.993E-06	6.057E-06	2.74E-05	0.00007	

2013-2015	Humback	Fin	Harbour porpoise	White beaked dolphin	White sided dolphin	common dolphin	**Composite diet**
Cod <= 35	0	0	0.1	0	0	0	**0.000**
Arctic cod	0	0	0.1	0.1	0.1	0.1	**0.075**
Large benth fish	0	0	0	0.09	0.1	0.1	**0.000**
Med benth fish	0	0	0	0.2	0.2	0.15	**0.012**
Small benth fish	0	0	0	0.2	0.2	0.2	**0.012**
Capelin	0.5	0.5	0.5	0	0	0	**0.400**
Sandlance	0.25	0.25	0.2	0.11	0	0.05	**0.241**
Other plank fish	0.167	0.084	0.2	0.05	0.05	0.1	**0.149**
Squid	0	0.083	0	0.2	0.25	0.3	**0.031**
Macrozooplankton	0.083	0.083	0	0	0	0	**0.077**
Suspension feeding inverts	0	0	0	0.05	0.1	0	**0.003**
Biomass of predator group	0.188	0.060	0.0017475	0.0152224	0.0003362	0.00007	

Balancing the model

Changes to the unbalanced model were made to reflect recently updated biomass estimates from the NAISS marine mammal survey (Lawson and Gosselin 2018). Due to the increase in biomass of piscivorous whales the EE increased for a number of prey items of this group. To correct for this, the diets of piscivorous whales were adjusted to reflect a decrease in capelin consistent with the 2013-2015 time period and the proportion of prey items such as Arctic cod and sandlance were increased.

2. Whales zooplankton eaters

Background

The main zooplankton feeding whales that make up this functional group are sei (*Balaenoptera borealis*) and blue (*Balaenoptera musculus*).

Biomass

Biomass estimates for zooplanktivorous whales (Table 2, 3) were calculated as the number of individuals estimated to be in the study area multiplied by the average body weight and adjusted for the number of days spent in the study area during the 1985-1987 period (Table 11). As values were not updated since these estimates were taken, the same biomass estimates were used for the 2013-2015 model.

Table 11. Biomass estimates for zooplanktivorous whales used for both the 1985-1987 and 2013-2015 models

	number of individuals	mean body weight	biomass (t/km^2)	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	References
sei	1000	14.3	0.029	180	0.014	(Mitchell and Chapman 1977)
blue	250	76.7	0.039	125	0.013	(Mitchell 1974)
Total					**0.028**	

Production:Biomass

P/B ratios (Table 12) for zooplanktivorous whales were calculated using Hoenig's (1983) equation (Eq 6) for estimating mortality in marine mammals and weighted by the biomass of each species.

Maximum age estimates were derived from Trites and Pauly (1998).

Table 12. Production to Biomass ratio estimates for zooplanktivorous whales for both the 1985-1987 and 2013-2015 models.

	Age	Z
sei	69	0.064
blue	100	0.046
P/B for group		**0.055**

Consumption:Biomass

Annual consumption by sei and blue whales (Table 13) was estimated from values in Lien (1985) and was assumed to be the same for both time periods.

Table 13. Consumption to biomass ratio estimates for zooplanktivorous whales for both the 1985-1987 and 2013-2015 models.

Species	Consumption (t/km^2)	References
sei	0.161	(Lien 1985)
blue	0.047	(Lien 1985)
Total	0.208	
Q/B	**3.468**	

Diet
The composite diet for zooplanktivorous whales (Table 4, 5) was constructed from diet information provided by Stenson, Lawson and Bundy in Bundy et al. (2000). In the current models, macrozooplankton refers to Euphausiids, gelatinous zooplankton and amphipods and was considered to be the same as the Large zooplankton functional group in the original model by Bundy et al. (2000). The large mesozooplankton group comprises primarily *Calanus finmarchicus* and other large copepods, and is analogous to the small zooplankton functional group in the original model by Bundy et al. (2000). The diet composition for each whale species was then weighted by the estimated biomass for the model (Table 14).

Table 14. Diet composition for zooplanktivirous whales

Prey/Predator	Sei	Blue	composite diet
Capelin	0.083	0.000	**0.048**
Sandlance	0.083	0.000	**0.048**
Macrozooplankton	0.083	1.000	**0.474**
Large Mesozooplankton	0.750	0.000	**0.430**
Biomass of predator group	0.014	0.011	

Balancing the model

Changes to the unbalanced model were made to reflect recently updated biomass estimates from the NAISS marine mammal survey (Lawson and Gosselin 2018).

3. Whales squid eaters

Background
The main whales that make up this functional group are sperm (*Physeter catodon*) and pilot (*Globicephala melaena*) whales.

Biomass
Biomass estimates for squid eating whales (Tables 2, 3) were calculated as the number of individuals estimated to be in the study area multiplied by the average body weight and adjusted for the number of days spent in the study area during the 1985-1987 period (Table 15). Estimates for pilot whales were updated for the 2013-2015 model (Table 16) , but sperm whale estimates remained the same due to lack of available data.

Table 15. Biomass estimates for squid eating whales for the 1985-1987 period.

	number of individuals	mean body weight	biomass t/km^2	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	References
sperm	1000	45	0.091	180	0.045	(Braham 1984)
pilot	9000	1.4	0.025	180	0.013	(Nelson and Lien 1996)
Total			0.116		**0.058**	

Table 16. Biomass estimates for squid eating whales for the 2013-2015 period.

	number of individuals	mean body weight	biomass t/km2	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	Refs
sperm	1000	45	0.091	180	0.045	(Braham 1984)
pilot	15519.9	1.4	0.044	180	0.022	(Lawson and Gosselin 2018)
Total			0.135		0.066	

Production:Biomass

P/B ratios (Table 17) were calculated using Hoenig's (1983) equation (Eq 6) for estimating mortality in marine mammals and weighted to the biomass of each species.

Maximum age estimates were derived from Trites and Pauly (1998).

Table 17. Production to biomass estimates ratio for squid eating whale for both the 1985-1987 and 2013-2015 model period.

	Age	Z
sperm	69	0.064
pilot	45	0.092
P/B for group		**0.078**

Consumption:Biomass

Annual consumption by squid eating whales was estimated for both sperm and pilot whales to be 3% of their body weight.

Table 18. Annual consumption to biomass ratio estimates by squid eating whales for both the 1985-1987 and 2013-2015 model period.

Species	consumption (t/km^2)	References
sperm	0.242	(Lockyer 1981)
pilot	0.067	(Gaskin 1982, 1992; Stenson 2002)
Total	0.313	
Q/B	**5.498**	

Diet

The composite diet for squid eater whales in the 1985-1987 model (Table 4) was constructed from diet in information provided by Stenson, Lawson and Bundy in Bundy et al. (2000). The diet composition for each whale species was then weighted by the estimated biomass for the model (Table 19). The composite diet for squid eater whales in the 2013-2015 diet were adjusted slightly to reflect the decline in Atlantic cod (Table 5, 20).

Table 19. Diet composition for squid eating whales Biomass estimates for squid eating whales for the 1985-1987 model.

	Sperm	Pilot	composite diet
Cod <= 35	0.021	0.006	**0.027**
American plaice > 35	0.008	0.002	**0.01**
American plaice ≤ 35	0.008	0.002	**0.01**
Thorny skate	0.039	0.011	**0.050**
Large benth fish	0.047	0.013	**0.060**
Yellowtail flounder	0.102	0.028	**0.130**
Other M benth fish	0.021	0.006	**0.027**
Capelin	0.021	0.006	**0.027**
Other plank fish	0.031	0.009	**0.039**
Squid	0.484	0.136	**0.620**
Biomass of predator group	0.045	0.013	

Table 20. Diet composition for squid eating whales Biomass estimates for squid eating whales for the 2013-2015 model.

	Sperm	Pilot	composite diet
American plaice > 35	0.008	0.002	**0.01**
American plaice ≤ 35	0.008	0.002	**0.01**
Thorny skate	0.039	0.011	**0.050**
Large benth fish	0.047	0.013	**0.060**
Yellowtail flounder	0.102	0.028	**0.130**
Other M benth fish	0.021	0.006	**0.027**
Capelin	0.042	0.012	**0.054**
Other plank fish	0.031	0.009	**0.039**
Squid	0.484	0.136	**0.620**
Biomass of predator group	0.045	0.013	

Balancing the model

In the unbalanced 2013-2015 model the consumption of small Atlantic cod (≤ 35 cm) by squid eating whales was higher than the availability of Atlantic cod (≤ 35 cm) . Therefore, cod in the diet of squid eating whales in the 2013-2015 model was removed to reflect the decline in Atlantic cod in the 2013-2015 period compared to the 1985-1987 period.

4. Whales mammal eaters

Background

The main species of mammal eating whale is the killer whale (*Orca orcinus*).

Biomass

The biomass of killer whales (Table 2, 3) was estimated from Lawson et al (2007) in the Newfoundland and Labrador region based on approximately 63 individuals (Table 21). While killer whales are known to be in this region, sightings from marine mammal surveys have been infrequent compared to other whale species.

Table 21. Biomass estimate for killer whales used for both the 1985-1987 and 2013-2015.

	number of individuals	mean body weight	biomass t/km^2	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	References
killer whale	63	3	0.0003818	180	0.000188	(Lawson et al. 2007)

Production:Biomass
P/B ratios for killer whales (Table 22) were calculated using Hoenig's (1983) equation (Eq 6) for estimating mortality (Z) in marine mammals.

Maximum age estimates for killer whales were derived from Trites and Pauly (1998).

Table 22. Production to biomass ratio estimate for killer whales used for both the 1985-1987 and 2013-2015.

	Age	Z
killer whale	50	**0.084**

Consumption:Biomass
Annual consumption by mammal eating whales was estimated to be 754.96 t giving a Q/B of **8.1 yr^{-1}** (Table 23).

Table 23. Consumption to biomass estimate for killer whales used for both the 1985-1987 and 2013-2015.

Species	consumption ($t/km^2/yr$)	References
killer whale	0.0015	(Trites and Pauly 1998)
Q/B	**8.1**	

Diet
The diet composition of killer whale (Table 24) was estimated from studies of killer whale diet for the North Atlantic (Baird and Whitehead 2000; Foote et al. 2009; Lawson and Stevens 2013).

Table 24. Diet composition of killer whales for the 1985-1987 and 2013-2015 period.

	Killer whale
Whale ZP eater	0.150
Minke	0.100
Seabird pisc	0.050
Greenland Halibut	0.050
Other piscivorous fish	0.050
Harp seals	0.400
Hooded seals	0.100
Capelin	0.050
Squid	0.050

Balancing the model

No changes to the input parameters were required to balance the model.

5. Whales Minke

Background
Minke whales (*Balenoptera acutorostrata*) are the focus of this functional group. While minke whales are an important commercial species in the Barents Sea, they are not commercially caught in the NL Shelf.

Biomass
Biomass estimates for minke whales (Table 2, 3) were calculated as the number of individuals estimated to be in the study area multiplied by the average body weight and adjusted for the number of days spent in the study area (Table 25). The biomass estimates for the 1985-87 model are based mainly on findings by Bundy et al. (2000). This estimate for Minke whales was used for both 1985-1987 and 2013-2015 models.

Table 25. Biomass estimate for minke whales used for both the 1985-1987 and 2013-2015.

	number of individuals	mean body weight	biomass t/km2	~ Days spent in 2J3KLNO	Adjustment for time spent in 2J3KLNO	Refs
1985-1987	2573	5.6	0.045	180	0.022	Lawson and Gosselin 2009, 2018
2013-2015	7154	5.6	0.081	180	0.040	Lawson and Gosselin 2018

Production:Biomass
P/B ratios for minke whales (Table 26) were calculated using Hoenig's (1983) equation (Eq 6) for estimating mortality (Z) in marine mammals.

Maximum age estimates were derived from Trites and Pauly (1998).

Table 26. Production to biomass ratio estimate for minke whales used for both the 1985-1987 and 2013-2015.

	Age	Z
minke	47	**0.089**

Consumption:Biomass
The annual consumption by minke whales was estimated to be 74567.38t (Table 27).

Table 27. Consumption to biomass ratio estimate for minke whales used for both the 1985-1987 and 2013-2015.

Species	consumption (t/km^2)	References
minke	0.151	(Lockyer 1981)
Q/B	**5.380**	

Diet
The diet composition for minke whales (Table 28) was derived from Bundy et al. (2000) for the 1985-1987 model and adjustments were made for the 2013-2015 model to reflect a decrease in capelin and Atlantic cod.

Table 28. The diet composition for minke whales used for both the 1985-1987 and 2013-2015 models.

Minke Whale	1985-1987	2013-2015
Cod <= 35	0.050	0.000
Capelin	0.750	0.500
Other plank fish	0.100	0.250
Squid	0.050	0.100
Macrozooplankton	0.050	0.100
Large Mesozooplankton	0.000	0.050

Balancing the model

Changes to the unbalanced model were made to reflect recently updated biomass estimates from the NAISS marine mammal survey (Lawson and Gosselin 2018).

6. Harp Seal

Background

Harp seals (*Pagophilus groenlandica*) are native to the northern Atlantic Ocean and Arctic Ocean. Their distribution ranges from Newfoundland and Labrador to Svalbard, Norway. They are dependent on pack ice for breeding and restricted to regions where pack ice forms seasonally. The largest stock is found in Eastern Canada and in the NL Shelf the main population is comprised of two herds, the Gulf heard (Gulf of St. Lawrence) and the Front herd (Southern Labrador). Unless stated otherwise, data were provided by Alejandro Buren and Garry Stenson (unpubl. data, October 2018, NAFC)

Biomass

The total biomass estimates for harp seals (Table 29) were provided by Alejandro Buren and Garry Stenson (unpubl. data, October 2018, NAFC) using population estimates for the harp seal with an average weight of 80 kg determined from decadal marine mammal surveys.

Table 29. Biomass estimates for harp seals used for both the 1985-1987 and 2013-2015.

Model	biomass (t)	biomass (t/km^2)
1985-1987	49600.39	**0.100**
2013-2015	161182.70	**0.326**

Production:Biomass

It was assumed that the P/B value is equivalent to the total mortality (Allen 1972). The total mortality for harp seals was estimated using Hoenig's (1983) equation (Eq 6) for estimating mortality with an Age_{max} of 26 (Trites and Pauly 1998). The P/B was estimated at **0.149 yr^{-1}**.

Consumption:Biomass

The annual consumption by harp seals was derived from consumption models by Buren and Stenson (unpubl. data, October 2018, NAFC) for the NL Shelf region. The estimated mean annual consumption for harp seals for the 1985-1987 model is 832369.69 t/yr (**Q/B of 16.78 yr^{-1}**), and for the 2013-2015 model is 2843694.25 t/yr (**Q/B of 17.642 yr^{-1}**).

Diet
The diets of harp seals (Table 4, 5) were constructed from stomach content information and models of diet composition. Data were provided by Buren and Stenson (unpubl. data, October 2018, NAFC) with adjustments based on information from prey consumption estimates from Hammill and Stenson (2000) to account for the wider number of functional groups in the Ecopath models compared to the stomach content models provided by Buren and Stenson.

Catch
Estimates of total removals of Harps seals for the NL Shelf region were estimated from Stenson (2014) for the 1985-1987 model to be **0.0031 t/km^2/yr** and for the 2013-2015 model to be **0.01467 t/km^2/yr**.

Balancing the model
In the unbalanced 2013-2015 model, the impact of harp seal diet on Atlantic cod (both ≤ 35cm, >35cm groups) was too large. This was confirmed with the regional pinniped experts Alejandro Buren and Garry Stenson (pers. comm, October 2018, NAFC) and it was agreed that the proportion of Atlantic cod in harp seal diet could plausibly be lower in the 2013-2015 period given the lower availability of Atlantic cod in the study region compared to the 1985-1987 time period. Therefore, the proportion of cod in the diet was changed from 0.05 to 0.00 for Atlantic cod ≤ 35cm and 0.16 to 0.025 for Atlantic cod >35cm.

7. Hooded Seal

Background
Hooded seals (*Cystophora cristata*) are larger than harp seals, but much less abundant in the study area. Hooded seals are found in central and western North Atlantic ranging from Svalbard, Norway to the Gulf of St Lawrence, Canada. They live primarily on drifting pack ice and in deep water in the Arctic ocean and North Atlantic. Unless stated otherwise, data were provided by Alejandro Buren and Garry Stenson (unpubl. Data, October 2018, NAFC)

Biomass
The total biomass estimates for hooded seals (Table 30) were provided by Alejandro Buren and Garry Stenson (unpubl. data, October 2018, NAFC) using population estimates for the hooded seal determined from marine mammal surveys .

Table 30. Biomass estimates for hooded seals used for both the 1985-1987 and 2013-2015.

Model	biomass (t)	biomass (t/km^2)
1985-1987	13613.74	**0.028**
2013-2015	18970.9	**0.038**

Production:Biomass
It was assumed that the P/B value is equivalent to the total mortality (Allen 1972). The total mortality for hooded seals was estimated using Hoenig's (1983) equation (Eq 6) for estimating mortality with an Age_{max} of 35 (Trites and Pauly 1998). The P/B was estimated at **0.115 yr^{-1}**.

Consumption:Biomass
The annual consumption by hooded seals was derived from consumption models by Buren and Stenson (unpubl. data, October 2018, NAFC) for the NL Shelf region. The estimated mean annual consumption for harp seals for the 1985-1987 model is 248155.9 t/yr (**Q/B of 18.23 yr^{-1}**), and for the 2013-2015 model is 347780.8 t/yr (**Q/B of 18.33 yr^{-1}**).

Diet
The diet of hooded seals (Table 4) was constructed from stomach content information and models of diet composition. Data were provided by Buren and Stenson (unpubl. data, October 2018, NAFC) with adjustments based on information from prey consumption estimates from Hammill and Stenson (2000).

Catch
Estimates of total removals of hooded seals for the NL Shelf region were estimated from Stenson (2014) for the 1985-1987 model to be **0.00019 t/km^2/yr**. There were no reported removals of hooded seals during the 2013-2015 periods in the study area.

Balancing the model
No changes to the input parameters were required to balance the model.

8. Other seals

Background
Other seals for the NL model were primarily harbour seals (*Phoca vitulina*) in the NL Shelf. Harbour seals are found along Temperate and Arctic marine coastlines in the Northern Hemisphere. They are common in Norway, the United Kingdom and Canada, with less abundant populations in Greenland and Japan. Unless stated otherwise, data were provided by Alejandro Buren and Garry Stenson (unpubl. Data, October 2018, NAFC)

Biomass
The total biomass estimates for harbour seals (Table 30) were provided by Alejandro Buren and Garry Stenson (unpubl. data, October 2018, NAFC) using population estimates for the harbour seal determined from marine mammal surveys.

Table 31. Biomass estimates for other (Harbour) seals used for both the 1985-1987 and 2013-2015.

Other seals		
Model	biomass (t)	biomass (t/km^2)
1985-1987	4950	**0.01**
2013-2015	7425	**0.015**

Production:Biomass
It was assumed that the P/B value is equivalent to the total mortality (Allen 1972). The total mortality for harbour was estimated using Hoenig's (1983) equation (Eq 6) for estimating mortality with an Age_{max} of 31 (Trites and Pauly 1998). The P/B was estimated at **0.128 yr^{-1}**.

Consumption:Biomass
The annual consumption by harbour seals was derived from consumption models by Buren and Stenson (unpubl. data, October 2018, NAFC) for the NL Shelf region. The estimated mean annual consumption for harbour seals for the 1985-1987 model is 64350 t/yr (**Q/B of 13.00 yr^{-1}**), and for the 2013-2015 model is 475982 t/yr (**Q/B of 13.00 yr^{-1}**).

Diet

The diet of other seals (Table 4) was constructed from stomach content information and models of diet composition. Data were provided by Buren and Stenson (unpubl. data, October 2018, NAFC) with adjustments based on information from prey consumption estimates from Hammill and Stenson (2000).

Balancing the model

No changes to the input parameters were required to balance the model.

9. Seabird piscivores

Background

Piscivorous seabirds (Table 31) were considered as seabirds that spent time in the NL Shelf and ate a diet that was primarily fish. The majority of these seabirds are mainly found in the Arctic with distributions ranging mostly in North America and Europe. The data were provided from yearly seabird surveys that were conducted by Canadian Wildlife Services and provided by Carina Gjerdrum and Sabina Wilhelm.

Table 32. List of piscivorous seabirds in the NL region.

Piscivorous seabirds		
Arctic Tern	Great Shearwater	Pomarine Jaeger
Atlantic Puffin	Great Skua	Razorbill
Audubon's Shearwater	Herring Gull	Red-footed Booby
Black-headed Gull	Iceland Gull	Ring-billed Gull
Black-legged Kittiwake	Iceland Gull/Kumlien's Gull	Ross's Gull
Black Guillemot	Laughing Gull	Sabine's Gull
Black Tern	Leach's Storm-Petrel	Sooty Shearwater
Bonaparte's Gull	Least Tern	South Polar Skua
Caspian Tern	Lesser Black-backed Gull	Thick-billed Murre
Common Murre	Long-tailed Jaeger	Townsend's Shearwater
Common Tern	Manx Shearwater	White-faced Storm-Petrel
Cory's Shearwater	Murre or Razorbill	White-tailed Tropicbird
Double-crested Cormorant	Northern Fulmar	Wilson's Storm Petrel
Glaucous Gull	Northern Gannet	Yelkouan Shearwater
Great Black-backed Gull	Parasitic Jaeger	
Great Cormorant	Pigeon Guillemot	

Biomass

Biomass of piscivorous seabirds in the NL Shelf was estimated from bird census surveys conducted by Canadian Wildlife Services and provided by Carina Gjerdrum and Sabina Wilhelm (Gjerdrum et al. 2008, 2012b). The survey estimates the abundances of seabirds in the NAFO 2GHJ and 3KLNO divisions and were scaled to only include estimates from the 2J3KLNO divisions to remain consistent with the study area. Individual biomass estimates obtained from Bundy et al. (2000) and Warkentin et al. (2013) were applied to the abundance estimates for piscivorous seabirds to obtain an overall biomass estimate. Prior to 2006, the census data were less rigorous, and 1985 values for piscivorous seabirds were based on estimates for piscivorous seabirds found in Bundy et al. (2000), **0.010 t/km^2**. For the 2013-2015 model the estimated biomass for piscivorous seabirds was **0.0071 t/km^2**.

Production:Biomass
Production to biomass of piscivorous seabirds was assumed, as in Bundy et al. (2000), to be **0.25 yr^{-1}**.

Consumption:Biomass
Piscivorous seabird Q/B ratio was estimated from Bundy et al. (2000) to be 54.75 yr^{-1} which was estimated by the model using a P/Q value of 15%. Barrett et al. (2006) estimated a seabird Q/B for the NAFO divisions 2GHJ3KLNMO of **119.41 yr^{-1}** based on a total consumption (80% petrels by number) for the region of 2,248,000 t and an average annual biomass of 18,825 t. As this was the most empirical estimate of consumption available, this Q/B ratio was used for both the 1985-1987 and 2013-2015 period.

Diet
The diet of piscivorous seabirds (Table 33) for the 1985-1987 period was adapted from Bundy et al. (2000). The primary diet items were forage fish such as capelin and other planktonic fish such as myctophids (Table 33). The diet of piscivorous seabirds (Table 33) for the 2013-2015 period were adjusted to reflect the reduction in Atlantic cod and Capelin.

Table 33. Diet proportion of piscivorous seabirds for the 1985-1987 and 2013-2015 models.

Prey item	1985-1987 model	2013-2015 model
Cod<= 35 cm	0.005	0
Other piscivorous fish	0.010	0.010
Arctic cod	0.025	0.045
Other S benthivorous fish	0.035	0.035
Sandlance	0.070	0.070
Capelin	0.700	0.550
Other planktivorous fish	0.156	0.285

Balancing the model
The unbalanced model for the 2013-2015 period (Table 54) had a Q/B ratio for piscivorous seabirds of 54.75 yr-1, which was based on a P/Q of 15% and the same diet as the 1985-1987 model. When this was adjusted to the empirical estimate of 119.41 yr-1, the EE for Atlantic cod<= 35 cm and Capelin increased to >1. To reduce the EEs, the diets of seabirds on Atlantic cod and Capelin were reduced to better reflect the estimated biomasses of Atlantic cod and Capelin in the study region. This resulted in proportionate increases in Arctic cod and other planktivorous fish (Table 33).

10. Seabird zooplanktivores

Background
Zooplanktivorous seabirds were primarily dovekie or little auk (*Alle alle*). Dovkies are a small auk that primarily feed on *Calanus* sp. They are found in the Arctic along the coasts of Greenland, Iceland, Norway, and Eastern Canada. They occur year round in the NL Shelf. They create large colonies on marine cliffsides and nest in crevices.

Biomass
Biomass estimates of dovekies for the NL Shelf were taken from seabird census surveys conducted by the Canadian Wildlife Services and provided by Carina Gjerdrum and Sabina Wilhelm (Gjerdrum et al. 2008, 2012b). The survey estimates the abundances of seabirds in the NL region. Individual biomass estimates

obtained from Montevecchi in Bundy et al (2000) and Warkentin et al. (2013) were applied to the abundance estimates for dovkies to obtain a biomass estimate. The estimated biomass of zooplanktivorous seabirds was **0.00217 t/km^2** for the 1985-1987 period and **0.00561 t/km^2** for the 2013-2015 period.

Production:Biomass
Gabrielsen et al. (1991) noted that dovekie production is low with only one chick per breeding pair. Thus, the P/B ratio was estimated to be **0.15 yr^{-1}** for both models.

Consumption:Biomass
Vermeer (1984) estimated the consumption of a number of auklet species was approximately 17.7% from empirical studies. Thus, the Q/B estimate for zooplanktivorous seabirds was estimated to be **64.605 yr^{-1}**. This estimate was used for both models.

Diet
The diet of dovekies (Table 4, 5) was estimated using diets constructed by Burke et al. (2014) in coastal NL and Harding et al. (2009) in Greenland. Both studies indicated that the primary diet of dovekies consists of *Calanus* spp. (large mesozooplankton), but that they also feed on macrozooplankton (amphipods) and small mesozooplankton (smaller copepods) and occasionally other prey items such as jellyfish (Table 34).

Table 34. The diet composition of zooplanktivorous seabirds for the 1985-1987 and 2013-2015 models.

Prey item	Diet proportion
Suspension feeding invertebrates	0.01
Macrozooplankton	0.212
Large mesozooplankton	0.444
Small mesozooplankton	0.333

Balancing the model
No changes to the input parameters were required to balance the model.

11. Seabird benthivores

Background
Benthivorous seabirds (Table 35) are comprised mainly of eiders and ducks that occur in the NL Shelf. Many of the species occur across North America and Europe, generally in more coastal, inshore areas. The primary species of this group were common eiders which made up 44% of the total abundance and 95% of the total biomass of the group.

Table 35. List of benthivorous seabirds that occur in the NL region.

American Black Duck	Red-breasted Merganser	Family: Ducks, Geese and Swans
American Green-winged Teal	Red-necked Grebe	Family: Loons
Black Scoter	Red-necked Phalarope	Genus: Ducks
Canada Goose	Red-throated Loon	Genus: Eiders
Common Eider	Red Phalarope	Genus: Geese
Common Loon	Surf Scoter	Genus: Goldeneye and Bufflehead
Common Merganser	White-winged Scoter	Genus: Phalaropes

Harlequin Duck	Genus: Scoters
Long-tailed Duck	

Biomass

Biomass of benthivorous seabirds in the NL Shelf was estimated from bird census surveys conducted by the Canadian Wildlife Services and provided by Carina Gjerdrum and Sabina Wilhelm (Gjerdrum et al. 2008, 2012b). The survey estimates the abundances of seabirds in the NL region. Individual biomass estimates obtained from Warkentin et al. (2013) were applied to the abundance estimates for benthivorous seabirds to obtain a biomass estimate. The biomass estimate for the 1985-1987 model was **0.00021 t/km^2** and for the 2013-2015 model was **0.00168 t/km^2**.

Production:Biomass

Mawhinney et al. (1999) found that the total mortality for common eiders in the Bay of Fundy was 13%. The P/B of **0.13 yr^{-1}** was maintained for both the 1985-1987 and 2013-2015 period.

Consumption:Biomass

Q/B ratio for benthivorous seabirds was estimated from a study of eider consumption in the Gulf of St. Lawrence (Guillemette et al. 1996). The Q/B is estimated to be **45.291 yr^{-1}** for both the 1985-1987 and 2013-2015 model.

Diet

The diet of benthivorous seabirds (Table 4, 5) was based on diet and stable isotope analysis for common eiders (Dahl et al. 2003). The functional group eat a variety of benthic and pelagic species including small benthic fish and some species of krill and copepod (Table 36).

Table 36. The diet composition of benthivorous seabirds for the 1985-1987 and 2013-2015 models.

Prey item	Diet proportion
Other S benthivorous fish	0.10
Predatory invertebrates	0.20
Suspension feeding invertebrates	0.25
Macrozooplankton	0.25
Large mesozooplankton	0.20

Balancing the model

No changes to the input parameters were required to balance the model.

12. Greenland Sharks

Background

Greenland shark *(Somniosus microcephalus)* are a large species (approximately 600 cm) of shark that occur in the north Atlantic and are one of the longest living vertebrates with a lifespan of at least 300 years (Nielsen et al. 2016), but thought to be up to 500 years. In the NL Shelf they are not a commercial species.

Biomass

The biomass of Greenland sharks were estimated from the RV survey to be **0.0118 t/km^2** averaged for 1985-1987 (converting Engel to Campelen survey data using Method 1) and **0.0088 t/km^2** for the 2013-2015 period.

Production:Biomass

The P/B was calculated using Hoenig's (1983) equation for estimating the mortality of fish (Eq. 5). As an extremely slow growing species, the maximum age in the equation is from estimates of Greenland shark (Nielsen et al. 2016) aged at approximately 392 years old. Thus the P/B ratio is **0.01 yr^{-1}**.

Consumption:Biomass

Consumption by Greenland sharks was estimated from diet studies from the north Atlantic where stomach contents were examined (Yano et al. 2007; Nielsen et al. 2014). The total annual consumption for Greenland shark in the NL Shelf was 736.31 t in 1985-1987 and 545.29 t in 2013-2015 yielding a Q/B for both models of **0.125 yr^{-1}**.

Diet

The diet of Greenland sharks (Table 4, 5) was taken from Yano et al. (2007) where they studied the stomach contents of 49 Greenland sharks from around the north Atlantic. Greenland shark generally eat a wide variety of food items, however their main diet consists of seals (harp and hooded) and Greenland halibut.

Catch

There was no commercial catch of Greenland shark in the NL Shelf for either time period.

Balancing the model

No changes to the input parameters were required to balance the model.

13 & 14. Atlantic cod (multistanza)

Background

Atlantic cod (*Gadus morhua*) is an iconic species in Atlantic Canada and particularly in Newfoundland and Labrador where it was one of the most important fishery resource for several centuries (Hutchings and Myers 1994). During the 1950s and 1960s, the catches by distant water fleets increased dramatically and stock numbers declined in the mid-1970s with some recovery in the 1980s. The 1985-1987 (pre-groundfish collapse) period and 2013-2015 period reflect times of relative stability in stock size and catches.

For both models, Atlantic cod were split into two groups, the smaller group (≤ 35 cm, age 0-3) and a larger group (> 35 cm, age 3+). The size thresholds for defining each group (35 cm) is approximately the size at which Atlantic cod become more piscivorous and is also the size of first capture in the commercial fishery. Size at 50% maturity for Atlantic cod occurs at approximately 41-42 cm for males and 50-51 cm for females (Shelton et al. 1996); this distinction was not explicitly considered in these models.

Biomass

The biomass of small and large Atlantic cod for the 1985-1987 model (Table 2, 37) and the 2013-2015 model (Table 3, 38) were estimated from RV survey data used for the most recent stock assessment in the NL Shelf. Data were provided by Paul Regular (unpubl data, April 2017, NAFC) of stratified biomass estimates separated into 3 cm bins. Bins were divided at 35 cm and summed to produce biomass estimates for both sizes of Atlantic cod. Since cod are a multistanza group, only the biomass estimate for the leading group (> 35 cm) is entered in the model and the biomass of the ≤ 35 cm group estimated by the population model used in the multistanza routine. See notes on multistanza groups in Methods for further details.

Production:Biomass (Mortality Z)

Total mortality estimates for the 1985-1987 model (Table 2, 37) were taken from Bundy et al. (2000). They used catch curve analysis of RV survey data for the years 1983-1988. The estimates of total mortality (slopes of regression lines fitted to the downward slope of the catch curve) were done for different year combinations. These values were also consistent with model inputs for the most recent stock assessment for northern cod (DFO 2016b).

Total mortality for the 2013-2015 model (Table 3, 38) was estimated from the latest stock assessment model (NCAM) for Atlantic cod in the NL Shelf (DFO 2016b).

Consumption:Biomass

Consumption estimates for Atlantic cod in the literature are highly variable. Values from published studies indicate that Q/B for > 35 cm Atlantic cod could be anywhere from 1.41 yr^{-1} (Pauly 1989) to 6.51 yr^{-1} (Lilly et al 1981). Bundy et al. (2000) used a Q/B estimate of 3.24 yr^{-1} that was a mid-point for the various values that were reported at the time. Araujo and Bundy (2011) used a much lower Q/B estimate for the Scotian Shelf for Atlantic cod of 1.801 yr^{-1} (for 4-6 year Atlantic cod) and 1.326 (for 7+ year Atlantic cod). Here the estimated Q/B was **1.615 yr^{-1}** which is a weighted average based on the values from the Scotian Shelf. The population model used for the multistanza routine uses the estimated biomass from the leading group (for Atlantic cod, this is the >35cm group). See notes on multistanza groups in Methods. The estimated Q/B for Atlantic cod ≤ 35 cm is **3.605 yr^{-1}** in the 1985-1987 model and **4.433 yr^{-1}** in the 2013-2015 model.

Diet

Atlantic cod > 35cm and Atlantic cod ≤ 35cm diets were derived from stomach content data collected during the RV survey in the years 1985-1987 (Table 4) and 2013-2015 (Table 5). Data were provided by Mariano Koen-Alonso (unpubl. data, April 2017, NAFC).

Catch

The average total catch data from the NL Shelf from both the 1985-1987 (Table 2, 37) and 2013-2015 (Table 3, 38) time periods were extracted from the NAFO 21A databases for NAFO Divisions 2J3KLNO (NAFO 2016). To determine catches from both size groups, time series of catch-at-age and weight-at-age were used from the 2016 Atlantic cod assessment for the NAFO Divisions 2J3KL (DFO 2016b) and from the 2015 Atlantic cod Assessments from NAFO divisions 3NO (Rideout et al. 2015).

Table 37. Input parameters for Atlantic cod > 35 cm and ≤ 35 cm for the 1985-1987 model.

Model	Group name	Age, start (months)	Biomass (t/km^2)	Z	Q/B	K (annual)	W_{mat}/W_{inf}	Landings
1985-1987	Cod> 35 cm	36	3.576	0.65	1.615	0.114	0.04	0.603
1985-1987	Cod<= 35 cm	0	0.958	0.60	3.605			2.53E-06

Table 38. Input parameters for Atlantic cod > 35 cm and ≤ 35 cm for the 2013-2015 model.

Model	Group name	Age, start (months)	Biomass (t/km^2)	Z	Q/B	K (annual)	W_{mat}/W_{inf}	Landings
2013-2015	Cod > 35	36	0.760	0.307	1.615	0.114	0.04	0.0105
2013-2015	Cod<=35	0	0.038	0.302	4.433			0.000181

Balancing the model

Initially, in the unbalanced models (Table 53, 54) a Q/B ratio of 3.24 yr^{-1}, based on Bundy et al. (2000) was used for the leading group for Atlantic cod (>35cm). Based on this, the Ecopath multistanza population model calculated a Q/B for cod ≤ 35 cm of 6.697 yr^{-1} for the 1985-1987 model and 8.894 yr^{-1} for the 2013-2015 model. The Q/B for the leading group was adjusted to better align with Q/B estimates for the Scotian Shelf (Araujo and Bundy 2011) for Atlantic Cod. This was in the lower range of estimates found by Bundy et al. (2000).

15. Greenland halibut

Background

Greenland halibut (*Reinharditus hippoglossoides*) is a deep water flatfish found in both the North Atlantic and North Pacific. In the Northwest Atlantic, Greenland halibut are found primarily in the deeper waters from northern Labrador to the Grand Bank, but also occurs on Georges Bank (Bowering 1983).

An inshore gillnet fishery began in the 1960s, and as catches declined in various bays the fishery moved offshore to the deep water channels between the banks. Catches remained around 30000t during the 1970s and gradually declined during the 1980s. In the early 1990s catches rose steeply, reflecting an intense fishery in NAFO Divisions 3LM (Brodie et al. 1997). Catches and abundances declined until the mid-2000s; since then there has been an increase in Greenland halibut abundances to levels nearing the early 1990s (Morgan unpubl data).

Biomass

Biomass estimates for Greenland halibut for both the 1985-1987 model and the 2013-2015 model were provided by Joanne Morgan from the assessment models for the NAFO 2J3KLNO divisions (unpubl.data. May 2018, NAFC). This model provided the biomass estimates from 1975-2015 with an average biomass of **0.436 t/km2** (1985-1987 model) and **0.690 t/km2** (2013-2015 model).

Production:Biomass

P/B was estimated for the 1985-1987 model from calculations as in Bundy et al (2000) where catch curve analysis of numbers at age from the RV survey gave a Z estimate of 0.760 yr^{-1}. This is consistent with the mortality estimates for the latest Greenland halibut stock assessment provided by Joanne Morgan (unpubl. data. May 2018, NAFC) that estimates a total mortality (Z) of 0.52 yr^{-1} for older age classes (average estimate of F for age 5-9 of 0.40 yr^{-1} and a natural mortality estimate of 0.12 yr^{-1}). The Z for smaller age classes of Greenland halibut are estimated to be 0.918 yr^{-1} and thus the weighted average of P/B for the

1985-1987 model is **0.719 yr^{-1}** for the total population of Greenland halibut and is relatively close to the P/B estimate from Bundy et al. (2000). Estimates for the 2013-2015 model were taken from the latest Greenland halibut assessment provided by Joanne Morgan (unpubl. data. May 2018, NAFC) which estimated the F (for age 5-9) to be approximately 0.25 yr^{-1} with a natural mortality estimate of 0.12 yr^{-1}. The Z for smaller age classes were estimated to be 0.918 yr^{-1}. Given this, the biomass weighted estimate for P/B is **0.644 yr^{-1}**.

Consumption:Biomass

Prey consumption by Greenland halibut was calculated from stomach contents collected by the RV survey in 1981, 1982 and 1984 (Bowering and Lilly 1992). The total weight of stomach contents for different size classes of Greenland halibut were used alongside size class estimates of biomass provided by Paul Regular (unpubl. data, April 2017, NAFC) to calculate the biomass estimated consumption per year of Greenland halibut. The Q/B used for both models is **2.90 yr^{-1}**.

Diet

Diets for Greenland Halibut were taken from stomach contents collected by the RV survey between 1985-1985 (Table 4) and 2013-2015 (Table 5) and provided by Mariano Koen-Alonso (Dwyer et al. 2010). Additional information on the diet of Greenland halibut were found in Bowering and Lilly (1992) and Rodriguez-Marin et al. (1995).

Catch

The average total catch data for the NL Shelf (NAFO Divisions 2J3KLNO) for both the 1985-1987 (**0.035 t/km^2/yr**) and 2013-2015 (**0.02668 t/km^2/yr**) time periods were taken from the NAFO 21A databases (NAFO 2016).

Balancing the model

No changes to the input parameters were required to balance the model.

16. Silver hake/Pollock

Background

Two species, silver hake (*Merluccius bilinearis*), also known as whiting, and Pollock (*Pollachius virens*), also known as Pollock, make up this functional group. They are both reasonably large piscivorous fish. Silver hake generally grow to 75 cm and Pollock to 110 cm, but Pollock live longer (Pollock up to 25 years, silver hake up to 12 years) and Pollock reach a higher weight (Pollock up to 32kgs, Silver hake up to 2.3kgs). They are at the northernmost extent of their distribution in the NL Shelf and though both fish species make up important fisheries in more southern distributions, they have not been abundant in Newfoundland and Labrador and there is not a large fishery for them (DFO 2005). Consequently, they were grouped together.

Biomass

The estimated biomass for Silver hake/Pollock in the 1985-1987 model was **0.017 t/km^2/yr** and **0.163 t/km^2/yr** for the 2013-2015 model. Both estimates of Silver hake/Pollock were taken from RV surveys and averaged for the 1985-1987 (converting Engel to Campelen survey data using Method 1) and 2013-2015 periods. Data were provided by Mariano Koen-Alonso (unpubl data. April 2017. NAFC).

Production:Biomass

P/B ratio for Silver hake/Pollock was calculated as the sum of natural mortality and fishing mortality, ie., P/B=Z=F+M. The former (M) was estimated using Hoeing's (1983) equation to estimate mortality in fish (Eq. 5) and the latter (F) was calculated by dividing the catch by biomass, to provide an estimate of total mortality, Z. The P/B ratios of the two species were then biomass weighted and combined to produce a P/B representative of the larger group. The resulting P/B for the 1985-1987 period was **0.53 yr^{-1}** and for the 2013-2015 period was **0.401 yr^{-1}**.

Consumption:Biomass

The Q/B for Silver hake/Pollock was estimated from consumption and diet studies in their more southern distributions (Bowman and Bowman 1980; Garrison and Link 2000a). Garrison and Link (2000) examined 35000 stomach samples from small, medium and large Silver hake in the Northeast US. Based on this, the total Q/B for Silver hake/Pollock, assuming a similar Q/B for Pollock, was estimated to be **4.1 yr^{-1}** for both model periods. .

Diet

Since diets samples were not taken from Silver hake/Pollock during the earlier time periods, the diets of Silver hake/Pollock (Table 4) were estimated from studies completed in the southern distribution range for the 1985-1987 model (Bowman and Bowman 1980). The diets were adjusted to reflect the upper distribution range for the species. For example, Silver hake were shown to consume more Euphausiids in their northern distributions, and consumed more squid in the southern distributional range. For the more recent time period, the diets were estimated from stomach samples taken from the RV survey in the NL Shelf (Table 5). Diet proportion data were provided for the 2013-2015 model by Mariano Koen-Alonso (unpubl. data. April 2017, NAFC).

Catch

Generally the catch of both Silver hake and Pollock were low compared to more southern regions in their distribution (Maritimes Region or Northeast US). Landings data for the 2J3KLNO division were extracted from the NAFO 21A databases (NAFO 2016). The catch for the 1985-1987 model period is **0.00222 $t/km^2/yr$** and for the 2013-2015 period**, 0.00117 $t/km^2/yr$**.

Balancing the model

No changes to the input parameters were required to balance the model.

17. Other piscivorous fish

Background

A number of species made up the group “other piscivorous fish”. This group captures piscivorous fish (Table 39) that were caught in the RV survey that were not isolated as a commercial species or for specific functional roles. The specific ecological designation of each species was developed through feeding studies in the region performed by Marian Koen-Alonso, as detailed in Gaichas et al. (2012) and Dempsey et al. (2017).

Biomass

The estimated biomass was calculated from RV surveys and averaged for the 1985-1987 and 2013-2015 periods (Mariano Koen-Alonso, unpubl data). The estimated biomass for other piscivorous fish in the 1985-1987 model, scaled using Method 1 was **0.200 $t/km^2/yr$** and **0.101 $t/km^2/yr$** for the 2013-2015 model.

Production:Biomass

P/B ratio for other piscivorous fish was calculated using Hoeing's (1983) equation to estimate natural mortality in fish (Eq 5) for Atlantic halibut, black dogfish and white hake. The M for each species was calculated using the maximum age found in published studies or in fishbase (Cargnelli et al. 1999; Jakobsdóttir 2001; Froese and Pauly 2013). The fishing mortality (F) for each time period was calculated by dividing the catch by biomass, which was added to M to estimate total mortality Z. The P/Bs were then biomass weighted and combined to produce a P/B representative of the functional group. The resulting P/B for the 1985-1987 period was **0.505 yr^{-1}** and for the 2013-2015 period was **0.455 yr^{-1}**.

Consumption:Biomass

Specific consumption values for many of the fish that made up the other piscivorous fish group were difficult to obtain for the model area. The Q/B ratio for other piscivorous fish was determined from the consumption and diets of the species that made up the largest proportion of the estimated biomass from the RV survey in 1985-1987 and 2013-2015 which for both model periods was Atlantic halibut, Black dogfish and White hake (which made up ~90% of the group). The final Q/B for other piscivorous fish for the 1985-1987 model is **2.775 yr^{-1}** (Table 40) and **2.525 yr^{-1}** (Table 41) for the 2013-2015 model.

Table 39. List of species or fish groups that make up other piscivorous fish.

Common name	Latin name
Anglers	Lophiformes (Pediculati) (Order)
Barricudinas	Paralepididae
Greenland cod	*Gadus ogac*
Polar cod	*Arctogadus glacialis*
Other gadiformes	Gadiformes (Anacanthini) (Order)
Daggertooth	*Anotopterus pharao*
Other dogfish sharks	Squalidae
Black dogfish	*Centroscyllium fabricii*
Spiny dogfish	*Squalus acanthias*
Boa dragonfish	*Stomias boa ferox*
Other dragonfish	Stomiatidae
Frostfish	*Benthodesmus simonyi*
Longnose greeneye	*Parasudis truculentus*
Gulper	*Saccopharynx ampullaceus*
Other hake	*Merluccius sp.*
Offshore hake	*Merluccius albidus*
White hake	*Urophycis tenuis*
Atlantic halibut	*Hippoglossus hippoglossus*
Lamprey	*Petromyzon marinus*
Shortnose lancetfish	*Alepisaurus brevirostis*
Longnose lancetfish	*Alepisaurus ferox*
Other lancetfish	Alepisauridae (Plagyodontidae)
Blue ling	*Molva brykelange*
Shortfin mako	*Isurus oxyrinchus*
Atlantic salmon	*Salmo salar*
Black scabbardfish	*Aphanopus carbo*
Portuguese shark	*Centroscymnus coelolepis*
Mackerel shark	Lamnidae
Viperfish	*Chauliodus sloani*

Table 40. Consumption to biomass ratio calculated for the 1985-1987 period for other piscivorous fish.

Species	Consumption (t)	Estimated biomass (t)	Q/B (yr^{-1})	References
Atlantic halibut	20551.25	6638		Araujo and Bundy 2011
Black dogfish	6744.29	2714		Jakobsdottir 2000
White hake	3446	1723		Garrison and Link 2006
Total	30741.54	11075	**2.77576**	

Table 41. Consumption to biomass ratio calculated for the 2013-2015 period for other piscivorous fish.

Species	Consumption	Estimated biomass (t)	Q/B (yr^{-1})	References
Atlantic halibut	28813.52	9307		Araujo and Bundy 2011
Black dogfish	9507.41	3826		Jakobsdottir 2000
White hake	19665.59	9833		Garrison and Link 2006
Total	57986.52	22965	**2.525**	

Diet
The diets of other piscivorous fish (Table 4, 5) was determined from the diets of Atlantic halibut (Araujo and Bundy 2011), Black dogfish (Jakobsdottir 2000) and White hake (Garrison and Link 2006). Diet proportions of common prey were biomass weighted and used for the 2013-2015 model. For the 1987-1985 model, the diets proportion of other piscivorous fish on Atlantic cod>35 and on American plaice≤35 was increased slightly to reflect differences in the availability of prey in the model time period.

Catch
Landings data for other piscivorous fish (mainly Atlantic halibut, Black dogfish and White hake) in the 2J3KLNO division was extracted from the NAFO 21A databases (NAFO 2016). The catch for the 1985-1987 model period is **0.024t/km²/yr** and for the 2013-2015 period**, 0.0072t/km²/yr**.

Balancing the model
For the 1987-1985 model, the diets proportion of other piscivorous fish on Atlantic cod>35 was increased slightly (from 0.02 to 0.03) and American plaice increased (from 0.12 to 0.13) to reflect differences in the availability of prey in the model time period. This proportion of the diet was removed from Greenland halibut and Large benthivorous fish.

18. Redfish

Background
Redfish are long-lived, slow growing, semi-pelagic fish that occur at depths of 100-700m. They reach commercial age at approximately 25cm or 8-10 years. Redfish range from New Jersey to Iceland and are commonly found in the northwest Atlantic from Newfoundland and Labrador to Georges Bank (DFO 2018b). They are found on slopes and deep channels at depths of 100-700 m. There are 3 redfish stocks (2J3K, 3LN and 30) within the study area. The stocks consist of a mixture *of Sebastes mentella* and *S. fasciatus.*

Biomass
Thus, for the 1985-1987 model the original estimated biomass density of **1.80 t/km²** for Redfish was used from Bundy et al. (2000). The estimated biomass from the RV survey for the 2013-2015 time period is **2.13 t/km²**. These biomass estimates and trends are consistent with information from recent stock assessments of redfish in southern Newfoundland (DFO 2018b).

Production:Biomass
The P/B ratio of redfish was calculated by Bundy et al. (2000) to be **0.33 yr^{-1}**. This was a calculation based on a natural mortality value of 0.125 added to F determined from the total catch and bycatch estimates from NAFO bulletins divided by biomass for the NL shelf.

Consumption:Biomass
The Q/B ratio for redfish for both models was based on the Bundy et al. (2000) value of **2.00 yr^{-1}**.

Diet

The diet of redfish (Table 4, 5) was calculated from stomach content analysis of samples taken from the RV survey from the years 1985, 1986, 1987 (for the 1985-1987 model) and from 2013, 2014, 2015 (for the 2013-2015 model). The values were provided by Mariano Koen-Alonso (unpubl data. April 2017. NAFC).

Catch

Landings data for redfish in the 2J3KLNO division was extracted from the NAFO 21A databases (NAFO 2016).The catch for the 1985-1987 model period is **0.162t/km^2/yr** and for the 2013-2015 period**, 0.0305t/km^2/yr**.

Balancing the model

The unbalanced 1985-1987 model used a biomass estimate of 1.65 t/km^2. This was increased to 1.80 t/km^2 to match biomass estimates from Bundy et al. (2000).

19. Arctic/polar cod

Background

Arctic cod (*Boreogadus saida*) are semi-demersal and are commonly found in both surface and deep water and feed mainly on pelagic invertebrates. The species is found throughout the northwest Atlantic from the Arctic waters to the St. Lawrence. Arctic cod are considered an important forage species in the NL Shelf linking energy from zooplankton to other fish, mammals and sea birds (Lilly et al. 1994). There is no commercial fishery for Arctic cod. As a result there is no assessment for the species and the information on the species in the region is generally poor.

Biomass

Like other smaller forage fish that are generally pelagic in nature, Arctic cod are generally poorly sampled by RV trawl surveys. Thus to obtain more realistic estimates of total biomass, a scaling factor was used to adjust the RV survey data. A scaling factor of 479.1 developed by Bundy et al. (2000) from acoustic data estimates of biomass for the NL Shelf was applied to Arctic cod biomass from the RV survey. The biomass estimate of Arctic cod from for the 1985-1987 model was **2.7929 t/km^2**. There has not been a recent acoustic survey of Arctic cod to develop similar scaling factors for the species for the 2013-2015. Due to the lack of certainty surrounding Arctic cod biomasses in the NL Shelf region we used the same value of **2.7929 t/km^2** for the 2013-2015 model.

Production:Biomass

The P/B ratio for Arctic cod was based on estimates for total mortality from Bundy et al. (2000). They used an estimated mean mortality of **0.400 yr^{-1}.**

Consumption:Biomass

As in Bundy et al. (2000), it was assumed that ratio between production and consumption is 0.15. The consumption was calculated to be 3552376 t and Q/B was **2.633 yr^{-1}**.

Diet

The diet of Arctic cod (Table 4, 5) was based on the diet constructed by Bundy et al. (2000) and more recent studies by Christiansen et al. (2012). The functional groups from each diet was adjusted to reflect the current model structure and then averaged.

Catch

There was no commercial catch of Arctic cod for either time period.

Balancing the model

The original RV survey estimate for Arctic cod for the 1985-1987 period was 0.00583 t/km^2. This was increased to the value for the Acoustic survey for the 1985-1987 period of 2.7929 t/km^2.

20. Other plank-pisc fish

Background

The other plank-pisc fish group is made up 6 species (Table 42). This group captures fish that feed both on pelagic invertebrates and fish that were caught in the RV survey and were not isolated as a commercial species or for specific functional roles. The specific ecological designation of each species was developed through feeding studies in the region by Marian Koen-Alonso (Gaichas et al. 2012).

Table 42. List of fish groups that make up other plank-pisc fish

Common name	Latin name
Beardfishes	Polymixiidae
Pelican gulper	*Eurypharynx pelecanoides*
Longfin hake	*Urophycis chesteri*
Rockfishes	Scorpaenidae
Scopelosaurus	Scopelosauridae
Seasnail	*Careproctus sp.*

Biomass

The estimated biomass for other plank-pisc fish was derived from RV trawl survey, producing an estimated biomass for the 1985-1987 model of 0.0016 t/km^2. This value was thought to be low due to the gear change from Engel to Campelen in 1995. A scaling factor was used to increase the estimated biomass for the 1985-1987 (converting Engel to Campelen survey data using Method 2). This gave an estimated biomass of **0.039 t/km^2** . The biomass estimate for the 2013-2015 period was **0.027 t/km^2** using RV survey data.

Production:Biomass

For both model time periods the majority of the biomass for other plank-pisc fish was made up of Longfin hake (*Urophycis chesteri*) and Seasnail (*Careproctus* sp.). Information regarding production or total mortality of these fish species was extremely limited. For example, attempts to age Longfin hake through otolith sampling have not been successful (Wenner 1983). Thus, the P/B was assumed to be similar to redfish and Arctic cod (other fish known to be plank-piscivores) and **0.35 yr^{-1}** was used.

Consumption:Biomass

An assumed ratio between production and consumption of 0.15 was used to calculate the consumption of other plank-pisc fish. The consumption was estimated at 25987.5 t giving a Q/B of **2.500 yr^{-1}**.

Diet

The diet of other plank-pisc fish (Table 4, 5) was derived from published studies on diet (Wenner 1983) for the 1985-1987 period and information on diet provided by Mariano Koen-Alonso for the two time periods. Diets from the 1985-1987 period were adjusted to have similar functional groups to the current models and were then averaged.

Catch

There was no commercial catch of other plank-pisc fish in either model time period.

Balancing the model

The unbalanced model for the 1985-1987 (Table 53) period used an RV survey biomass estimate of 0.0016 t/km^2 calculated using Method 1. A scaling factor of 24.23 was developed by comparing 1993-1994 biomass estimates from the RV survey to 1996-1997 biomass estimates from the RV survey (Method 2). This resulted in a biomass estimate of 0.039 t/km^2 for the 1985-1987 period.

21 & 22. American plaice (multistanza)

Background

American plaice (*Hippoglossoides platessoides*) is a commercially important flat fish with a Newfoundland and Labrador population that extends from the waters of south of the Hudson Strait to south of the Grand Banks (Figure 1, primarily in NAFO Divisions 3NO in the NL Shelf, Dwyer et al. 2012). They can reach a size of up to 60 cm.

For both the 1985-1987 and 2013-2015 models, American plaice was split into two groups, a smaller group (ages 0-7, ≤ 35 cm) and a larger group (ages 7+, > 35 cm). The size thresholds for defining each group (35 cm) is the approximate size at maturity for 50% of the population and the size of first capture for American plaice in the commercial fishery.

Biomass

The biomass of small and large American plaice for the 1985-1987 model (Table 43) and 2013-2015 (Table 44) model were estimated from RV survey data used for the most recent stock assessment in the NL Shelf and contributions to NAFO assessments (Dwyer et al. 2012; Morgan et al. 2014). Data were provided by Paul Regular (unpubl data, April 2017, NAFC) of stratified biomass estimates separated into 3 cm bins. Bins were divided at 35 cm and summed to produce biomass estimates for both sizes of American plaice. Since American plaice are a multistanza group, only the biomass estimate for the leading group (> 35 cm) is entered in the model and the biomass of the ≤ 35 cm group estimated by the population model used in the multistanza routine. See notes on multistanza groups in Methods for further details.

Production:Biomass

The total mortality of American plaice >35cm (Table 43) was estimated from a catch curve analysis of Engel to Campelen converted American plaice survey data for the years 1985-1987 (as in Bundy et al. 2000). The total mortality, and therefore P/B estimated from the catch curve for the 1985-1987 model is thus **0.54 yr^{-1}**. For American plaice ≤ 35cm (Table 43) the P/B was calculated by adding the natural mortality (M) to fishing mortality (F). This gives a P/B of **0.63 yr**$^{-1}$.

Total mortality for the 2013-2015 model (Table 44) was estimated from the latest stock assessment model for American plaice in the NL Shelf (Rideout et al. 2011). The P/B ratio estimated for American Plaice > 35cm for the 2013-2015 model is **0.600 yr^{-1}**. For American plaice ≤ 35cm (Table 44) the P/B was calculated by adding the natural mortality (M) to fishing mortality (F). This gives a P/B of **0.753 yr**$^{-1}$.

Consumption:Biomass

Consumption was estimated from daily ration data for American plaice on the tail of the Grand Bank (Zamarro 1992). The diet of American plaice here is comprised mainly of sandlance (*Ammodytus dubius*), brittle stars (Ophiuroids) and capelin (*Mallotus villosus*). Zamarro estimated daily ration using the model of Elliot and Persson (1978). From these data, the mean annual Q/B ratio for the 1985-1987 and 2013-2015 periods for American Plaice > 35 cm were estimated as 1.262 yr^{-1} , however other estimates from the Scotian Shelf and consumption models for the NL Shelf indicated that this value was higher. Thus a value of **2.00 yr^{-1}** was used for both the 1985-1987 and 2013-2015 models (Table 43, 44). The population model used for the multistanza routine uses the estimated biomass from the leading group (for American plaice, this is the > 35cm group). See notes on multistanza groups in Methods. The estimated Q/B for American plaice ≤ 35 cm is **3.972 yr^{-1}** for the 1985-1987 model and **4.236 yr^{-1}** for the 2013-2015 model.

Diet
The diet of American plaice (Table 4, 5) was calculated from stomach content analysis of samples taken from the RV survey from the years 1985, 1986, 1987 (for the 1985-1987 model) and from 2013, 2014, 2015 (for the 2013-2015 model). The values were provided by Mariano Koen-Alonso (unpubl data, April 2017, NAFC).

Catch
The average catch for the period 1985-1987 (Table 43) in 3LNO was 57,931 t (Morgan et al. 1997) and in 2J3K was 1611 t (Brodie et al. 1993, Bundy et al. 2000). Discards from other Newfoundland fisheries and bycatch from the shrimp fishery increased this total to 61,691t. This total was divided between the two size groups of American plaice using commercial biomass-at-length data in Brodie (1986, 1987) for the Canadian fleet and numbers, weight, and length in the commercial catch for the Spanish fleet in 1987 (Brodie 1988).

The landings for the 2013-2015 period (Table 44) were much lower due to a moratorium on commercial catches for American plaice since 1994. Landings data for American Plaice in the 2J3KLNO Division was extracted from the NAFO 21A databases (NAFO 2016) and the average landed value was **0.003242 t/km^2** . Bycatch from the shrimp fishery was 3.3t, 100% of which is thought to be below 31cm, amounting to **0.0000067 t/km^2** (Dwyer et al. 2012).

Table 43. Input parameters for American Plaice > 35 cm and ≤ 35 cm for the 1985-1987 model.

Model	Group name	Age, start (months)	Biomass t/km2	Z	Q/B	K (annual)	Wmat/Winf	Landings
1985-1987	A plaice > 35 cm	84	0.99	0.54	2	0.13	0.06	0.110306
1985-1987	A plaice<= 35 cm	0	3.332	0.63	3.972			2.50E-02

Table 44. Input parameters for American Plaice > 35 cm and ≤ 35 cm for the 2013-2015 model.

Model	Group name	Age, start (months)	Biomass t/km2	Z	Q/B	K (annual)	Wmat/Winf	Landings
2013-2015	A plaice > 35	84	0.239	0.600	2.000	0.13	0.06	0.003242
2013-2015	A plaice<=35	0	1.349	0.753	4.236			6.67E-06

Balancing the model
No changes to the input parameters were required to balance the model.

23. Thorny skate

Background
Thorny skate (*Amblyraja radiata*) is a relatively large skate that can reach up to 110 cm and live up to 30 years. They are widely distributed throughout the NL Shelf, but are most abundant on the southern Grand Bank and off the eastern Scotian Shelf.

Biomass
The biomass of Thorny skate was estimated from RV survey data from the 2J3KLNO area. Biomass estimates for Thorny skate in the 1985-1987 model (converting Engel to Campelen survey data using Method 1) is **0.540 t/km^2**, and **0.304 t/km^2** in the 2013-2015 model.

Production:Biomass
The P/B ratio was estimated from Bundy et al. (2000) who assumed P/B = Z = F + M. Assuming a natural mortality of 0.214, this gives a P/B of **0.286 yr^{-1}**. This value was used for both models.

Consumption:Biomass
As estimates of consumption for the model area were difficult to attain, the consumption rates for thorny skate were estimated from Link and Sosebee (2008) where they examined the stomach contents of Thorny skate in the Northeast US. They developed a time series of consumption rates for Thorny skate. The calculated Q/B for the 1985-1987 model is **1.918 yr^{-1}** which is consistent with estimates from the Eastern Scotian Shelf model of 1.88 (Bundy 2004) and for the 2013-2015 model the Q/B is **2.174 yr^{-1}**.

Diet
The diet of Thorny skate for the 1985-1987 model (Table 4) was determined from Bundy et al (2000) where they used Thorny skate diet as representative of the overall skate group. The stomach content data for the 2013-2015 model time period was taken from the RV surveys for the NL Shelf (Table 5).

Catch
Landings data for Thorny skate in the 2J3KLNO Division, extracted from the NAFO 21A databases (NAFO 2016), were estimated to be **0.0382t/km^2**, and **0.00818 t/km^2** for 1985-1987 and 2013-2015 model time periods respectively.

Balancing the model
No changes to the input parameters were required to balance the model.

24. Haddock

Background
Haddock (*Melanogrammus aeglefinus*) is a member of the cod family, a bottom-dwelling groundfish that occurs on both sides of the Atlantic ranging from southwest Greenland to Cape Hatteras, North Carolina. They are an important commercial species in in the Scotian Shelf, but haddock are not abundant in the NL Shelf.

Biomass
The estimated biomass of haddock was calculated from time series of the RV survey for the NL Shelf. The estimated biomass for the 1985-1987 model (scaling Engel to Campelen survey data using Method 1) is **0.0915 t/km^2** and for the 2013-2015 model is **0.072 t/km^2**.

Production:Biomass
Due to the lack of catch at age data for the region, the P/B ratio was estimated by adding the natural mortality, estimated using Hoenig's (1983) equation for haddock added to the fishing mortality estimated from the total catch from NAFO 21A databases (NAFO 2016) divided by the biomass. The maximum age of haddock for the region was taken from Campana (1997) where they aged haddock from NAFO Divisions 3O and 3Ps. They found that the maximum age for haddock was ~20 years, giving a natural mortality of 0.209 yr^{-1}. The calculated fishing mortality for haddock is 0.088 for the 1985-1987 period and 0.006 for the 2013-2015 period. Thus, the estimated total mortality for the 1985-1985 model is **0.297 yr^{-1}** and for the 2013-2015 model is **0.214 yr^{-1}**.

Consumption:Biomass
Specific consumption data were unavailable for the NL Shelf, we used an estimated Q/B from the NAFO 4X region (Araujo and Bundy 2011) from gastric evacuation models of **2.08 yr^{-1}**. This value was lower than other reported values in the northwest Atlantic that ranged from 3.0 – 12.76 yr^{-1}, but gave a reasonable P/Q ratio. We used the same values for both the 1985-1987 and 2013-2015 models.

Diet
The diet data for haddock (Table 4, 5) was modified from Bundy et al. (2000) and Araujo and Bundy (2011). Both studies generated diet compositions from data for the Scotian Shelf as specific diet data for the NL Shelf is unavailable for haddock. Identical diet data for haddock were used for both the 1985-1987 and 2013-2015 models.

Catch
Values for total catches for haddock were taken from the NAFO 21A databases (NAFO 2016). From landings information dating back from 1953, landings for haddock were highest in the 1950s and early 1960s and remained low through the mid-1960s to the mid-1980s. The stock has been under moratorium since 1993 in NAFO Divisions 2J3KLNO. The average total catch for the 1985-1987 period was **0.0081 $t/km^2/yr$** and for the 2013-2015 period was **0.00043 $t/km^2/yr$**.

Balancing the model
No changes to the input parameters were required to balance the model.

25. Other large benthivorous fish

Background
Several fish make up the other large benthivorous fish group (Table 45). This group captures large benthivorous fish that were caught in the RV survey and were not isolated as a commercial species or for specific functional roles. The specific ecological designation of each species was defined through feeding studies in the region by Marian Koen-Alonso (Gaichas et al. 2012; Dempsey et al. 2017).

Biomass
The estimated biomass of other large benthivorous fish was determined from RV surveys for the NL Shelf. The estimated biomass for the 1985-1987 model for other large benthivores (scaling Engel to Campelen survey data using Method 1) is **0.424 t/km^2** and for the 2013-2015 model is **0.240 t/km^2.**

Production:Biomass
The Production estimates for the group was assumed as in Bundy et al. (2000) and used an assumed natural mortality of 0.2 and added to the average total catch for the model time period. Due to the low commercial catches for any of the species belonging to the group, P/B is **0.2 yr^{-1}** for both time periods.

Consumption:Biomass

The consumption for the species of the other large benthivore group was not easily determined as there was a lack of available data on consumption for these species in the NL Shelf. Here we assumed a production to consumption ratio of 0.15, making the Q/B = **1.333 yr^{-1}** for both time periods.

Diet

The diets from the other large benthivorous group (Table 4, 5) were modified from Bundy et al. (2000) where they averaged the diets of Atlantic wolfish, Ocean pout and Monkfish.

Table 45. List of species that make up the other large benthivorous group.

Common name	Latin name
Monkfish	*Lophius americanus*
Deepwater chimaera	*Hydrolagus affinis*
Knifenose chimaera	*Rhinochimaera atlantica*
Longnose chimaera	*Harriotta raleighana*
Cusk cusk	*Brosme brosme*
Angler deepsea angler	*Ceratius holboelli*
Roughhead grenadier	*Macrourus berglax*
Atlantic hagfish	*Myxine glutinosa*
Ocean pout	*Macrozoarces americanus*
Sea devils	Ceratiidae
Winter skate	*Raja ocellata*
Abyssal skate	*Raja bathyphila*
Arctic skate	*Raja hyperborea*
Barndoor skate	*Raja laevis*
Jensen's skate	*Raja jenseni*
Spinytail skate	*Raja (bathyraja) spinicauda*
White skate	*Raja lintea*
Smoothheads	Alepocephalidae
Atlantic snipe eel	*Nemichthys scolopaceus*
Spiny eels	Notacanthidae
Atlantic sturgeon	*Acipenser oxyrhynchus*
Large tapirfish	*Notacanthus nasus*
Broadhead wolffish	*Anarhichas denticulatus*
Spotted wolffish	*Anarhichas minor*
Striped wolffish	*Anarhichas lupus*
Wrymouth	*Cryptacanthodes maculatus*

Catch

The catch of other large benthivorous fish was low compared to the commercial large benthivores (American plaice, Thorny skate, and haddock). The data for catches was compiled from the NAFO 21A databases (NAFO 2016). The mean total catch for other large benthivores for the 1985-1987 periods was **0.000713 t/km^2/yr**, and for the 2013-2015 period was **0.000413 t/km^2/yr**.

Balancing the model
No changes to the input parameters were required to balance the model.

26. Yellowtail flounder

Background
Yellowtail flounder (*Limanda ferruginea*) is a species of flatfish that is found along the east coast of North America ranging from Newfoundland and Labrador to Chesapeake Bay.

Biomass

The estimated biomass of Yellowtail flounder came from the RV surveys for the NL Shelf, where much of the biomass is found in NAFO Divisions 3LNO. Unadjusted biomass estimates for the 1985-1987 time period from the RV survey appear to be lower than those after 1995. This is thought to be due to Engel gearused in the RV survey prior to 1995 which had a larger mesh size compared to Campelen gear. We used a scaling factor for medium sized benthivores developed by Mariano Koen-Alonso (pers.comm. April 2017, NAFC) of 1.98 (Method 1). Once applied to the data prior to 1995, the biomass trends were similar to those found in the NAFO Scientific Council assessment of Yellowtail flounder for NAFO Divisions 3LNO (Parsons et al. 2013). The estimated biomass for the 1985-1987 model period is **0.589 t/km^2** and for the 2013-2015 period is **1.666 t/km^2**.

Production:Biomass
The P/B ratio was calculated as in Bundy et al. (2000) where they determined that catch curve analysis for flounder were unsuitable. They calculated total mortality as the natural mortality added to the fishing mortality. In the case of Yellowtail flounder for 1985-1987, the natural mortality based on a maximum age of 12 using Hoenig's (1983) equation for fish (Eq 5) is equal to 0.35. The F (catch/biomass) for Yellowtail flounder from the NAFO 21A databases (NAFO 2016) is 0.0357 for the 1985-1987 period and is 0.0146 for the 2013-2015 period. The P/B for 1985-1987 model period is **0.3857 yr^{-1}** and for the 2013-2015 period is **0.364 yr^{-1}**.

Consumption:Biomass
The consumption was estimated as in Bundy et al. (2000) where they used the mean of a range of values found in the literature. The estimate of Q/B for Yellowtail flounder used for both time periods is **3.60 yr^{-1}.**

Diet
The diet for yellowtail flounder (Table 4, 5) was taken from stomach content data from the RV surveys. Data for the 1985-1987 time period was not available, but diet data for yellowtail flounder from 1981-1984 was available and this was used to represent the 1985-1987 time period. The diet data for 2010-2015 was averaged across those years to obtain diet composition. The data were provided by Mariano Koen-Alonso.

Catch
Catch for Yellowtail flounder was taken from the NAFO 21A databases (NAFO 2016). The landings values used were **0.0409 t/km^2/yr** for the 1985-1987 period and **0.0169 t/km^2/yr** for the 2013-2015 period.

Balancing the model
No changes to the input parameters were required to balance the model.

27. Witch flounder

Background
Witch flounder (*Glyptocephalus cynoglossus*) is a species of flatfish that ranges from Newfoundland and Labrador to North Carolina. They typically live at depths of 100-400 m, but have been found as deep as 1600m. They prefer soft substrates such as clay or mud. Witch flounder have a more northern distribution than Yellowtail flounder occurring throughout the NL Shelf. While there was heavy fishing on witch flounder in the 1970s, there has been no directed Canadian fishery since 1994.

Biomass
The estimated biomass of Witch flounder came from the RV surveys for the NL Shelf. For the 1985-1987 model, the values appear to be lower than those beyond 1995. This is thought to be due to Engel gear used for the RV survey prior to 1995 which had a larger mesh size compared to Campelen gear. Because of this, a scaling factor was developed by averaging the biomass estimates from 1996 and 1997 and compared them to 1993 and 1994 (Method 2). This scaling factor was found to be 1.55. The estimated biomass for the 1985-1987 model period is **0.187 t/km^2** and for the 2013-2015 period is **0.065 t/km^2**.

Production:Biomass
The P/B ratio was calculated as in Bundy et al. (2000) where total mortality was calculated as the natural mortality added to the fishing mortality. In the case of Witch flounder for 1985-1987, the natural mortality based on a maximum age of 18 (Bowering 1976) using Hoenig's (1983) equation for fish (Eq 5) is equal to 0.232. The fishing mortality for Witch flounder from the NAFO 21A databases (NAFO 2016) is 0.0248 t/km^2/yr for the 1985-1987 period and is 0.00112 t/km^2/yr for the 2013-2015 period. The P/B for 1985-1987 model period is **0.257 yr^{-1}** and for the 2013-2015 period is **0.233 yr^{-1}**.

Consumption:Biomass
The consumption was estimated as in Bundy et al. (2000) where they used the mean of a range of values found in the literature. The estimate of Q/B for Witch flounder used for both time periods is **2.599 yr^{-1}**.

Diet
The diet for Witch flounder (Table 4, 5) was compiled from (Keats 1990) and Garrison and Link (2000b) for the 1985-1987 model, while stomach content data from recent RV surveys were used to construct the 2013-2015 diet of Witch flounder.

Catch
Catch for Witch flounder was taken from the NAFO 21A database (NAFO 2016). The landings values used were **0.0248 t/km^2/yr** for the 1985-1987 period and **0.00112 t/km^2/yr** for the 2013-2015 period.

Balancing the model
No changes to the input parameters were required to balance the model.

28. Other medium benthivorous fish

Background
A number of fish make up the other medium benthivorous fish group (Table 46). This group captures medium benthivorous fish that were caught in the RV survey and were not isolated as a commercial species or for specific functional roles. The specific ecological designation of each species was defined through feeding studies in the region by Marian Koen-Alonso (Gaichas et al. 2012).

Biomass
The biomass of other medium benthivorous fish from RV surveys was **0.693 t/km^2**, which also included an increase of a 6.798 scaling factor to account for gear change conversion in 1995 from Engel to Campelen (Method 1). For the 2013-2015 model time period the estimated biomass from the RV survey data is **0.470 t/km^2**.

Production:Biomass
Information on the species that made up the other medium benthivorous group in terms of production was limited, thus an estimate for this group for P/B of **0.300 yr^{-1}** was used as in Bundy et al (2000).

Consumption:Biomass
There are no consumption estimates for other medium benthivorous fish, so an estimate of 15% growth efficiency was assumed giving a value of Q/B equal to **2.00 yr^{-1}**.

Diet
There was very little information on the diet of this group. The diet compositions (Table 4, 5) were developed using general information available in (Scott and Scott 1988) and Bundy et al. (2000).

Catch
The catch for this group was composed mainly of Winter flounder, sculpins, lumpfish and grenadier species. The catch information came from the NAFO 21A databases (NAFO 2016). The value for catch for the 1985-1987 model for other medium benthivorous fish is **0.0106 t/km^2/yr** and for the 2013-2015 model is **0.0005 t/km^2/yr**.

Balancing the model
Due to the high uncertainty in the biomass estimates for small benthivores in the RV surveys, an EE of 0.95 was set for small benthivorous fish and for the 1985-1987 model yielding a value of 1.570 t/km^2 and for the 2013-2015 model the value was 1.106 t/km^2.

Table 46. List of species that make up the other medium benthivorous group.

Common name	Latin name
Bigeyes	Priacanthidae
Blennies	*Lumpenus sp.*
Duckbill	*Nessorhamphus ingolfianus*
Arctic eelpout	*Lycodes reticulatus*
Esmark's eelpout	*Lycodes esmarki*
Vahl's eelpout	*Lycodes vahlii*
Green ocean fish doctor	*Gymnelis viridis*
Winter flounder	*Pseudoplueronectes americanus*
Longnose grenadier	*Coelorhynchus carminatus*
Roundnose grenadier	*Coryphaenoides rupestris*
Blue hake	*Antimora rostrata*
Red (Squirrel) hake	*Urophycis chuss*
Halosaurus	Halosauridae
Lipogenys	*Lipogenys gillii*
Longnose	*Synaphobranchus kaupi*
Common lumpfish	*Cyclopterus lumpus*
Mora	*Halargyreus affinis*
Mora	*Halargyreus johnsonii*
Moras	Moridae
Ribbed (Horned) sculpin	*Myoxocephalus sp.*
Fourhorn sculpin	*Myoxocephalus quadricornis*
Longhorn sculpin	*Myoxocephalus octodecemspinosus*
Shorthorn sculpin	*Myoxocephalus scorpius*
Sea raven	*Hemitripterus americanus*
Deepsea Cat shark	*Apristurus profundorum*
Deepwater (Round) skate	*Raja fyllae*
Little skate	*Raja erinacea*
Smooth skate	*Raja senta*
Soft skate	*Raja mollis*
Snake	*Lumpenus lumpretaeformis*
Shortnose snipe eel	*Serrivomer beani*
Snubnose	*Simenchelys parasiticus*
Blue whiting	*Micromesistius poutassou*

29. Small benthivorous fish

Background

A number of fish make up the small benthivorous fish group (Table 47). This group captures all small benthivorous fish that were caught in the RV survey. The specific ecological designation of each species was defined through feeding studies in the region by Marian Koen-Alonso (Gaichas et al. 2012; Dempsey et al. 2017).

Biomass
Generally, the sampling of small benthivores was thought to be relatively poor to larger fish in the RV survey. Thus, the estimated biomass of small benthivorous fish for the 1985-1987 model was **1.527 t/km^2** and for the 2013-2015 model was **1.154 t/km^2** which were both calculated by setting the EE to 0.95 and allowing Ecopath to estimate the biomass.

Production:Biomass
There is little information from the species assemblage that make up the small benthivorous fish to determine production. However, there is some information on the maximum age for some of the species which ranged from approximately 5 to 20 years. With the given information, a weighted average age of 10 was selected giving a natural mortality value of 0.421yr^{-1} using Hoenig's (1983) equation for fish (Eq 6). The catch values for this group were very low for both time periods (for the 1985-1987 model was 0.0000915 t/km^2/yr and for the 2013-2015 model time period was 0.00000202 t/km^2/yr), so the addition of this to the natural mortality values was inconsequential. Thus, a P/B value of **0.421 yr^{-1}** was used for both models.

Consumption:Biomass
There was little information on the consumption by small benthivorous fish. Here we developed a Q/B as in Bundy et al. (2000), which is an approximate value of **2.000 yr^{-1}**. This value was used for both model time periods.

Diet
The diet information was generally difficult to ascertain for the species that make up this group due to lack of research on their specific diets. Thus the diet for small benthivorous fish (Table 4, 5) was developed as in Bundy et al. (2000) with some supplementary information on diet from Chambers and Dick (2005).

Catch
The catch estimate for this group for the 1985-1987 model was **0.0000915 t/km^2/yr** and for the 2013-2015 model time period was **0.00000202 t/km^2/yr**. The catch information came from the NAFO 21A databases (NAFO 2016), with small catches for sculpin, lumpfish and threebeard rockling.

Balancing the model
There was insufficient biomass of small benthivorous fish to meet the consumption requirements of their predators. Since small benthivorous fish are not sampled well by either the Engel or Campelen RV survey gear, an EE of 0.95 was used for small benthivorous fish and the biomass estimated by the Ecopath model resulting in a biomass estimate of **1.570 t/km^2** for the 1985-1987 model and **1.106 t/km^2** for the 2013-2015 model.

Table 47. List of species that make up the small benthivorous fish group

Common name	Latin name
Alfonsino	*Caulolepis longidens*
Aligatorfish	Agonidae
Arctic alligatorfish	*Aspidophoroides olriki*
Common alligatorfish	*Aspidophoroides monopterygius*
Northern alligatorfish	*Agonus decagonus*
Anglemouths	*Cyclothone sp.*
Large Eyed argentine	*Gonostoma sp.*
Gymnast atlantic	*Nansenia groenlandica*
Atlantic batfish	*Xenodermichthys (aleposomus) copei*
Ridgeheads	*Dibranchus atlanticus*
Black swallower	Melamphaidae
Goitre blacksmelt	*Chiasmodon niger*
Blacksmelts	*Bathylagus euryops*
Butterfish	Stromateidae
Sherborn's cardinalfish	*Rhectogramma sherborni*
Pallid deepsea sculpin	*Cottunculus thompsoni*
Polar deepsea sculpin	*Cottunculus microps*
Soft eelpout	*Melanostigma atlanticum*
Fangtooth	*Anoplogaster cornuta*
Notch feelerfish	*Bathypterois dubius*
Rockling fourbeard	*Enchelyopus cimbrius*
Snakeblenny fourline	*Eumesogrammus praecisus*
common grenadier	*Nezumia bairdi*
Roughnose grenadier	*Trachyrhynchus murrayi*
Grenadiers	Macrouridae
Grubby	*Myoxocephalus aeneus*
Gunnels	Pholidae
Hatchetfishes	Sternoptychidae
Hookear Sculpin	Artediellus sp.
Lepidion	*Lepidion (haloporphyrus) eques*
Lightfishes	Gonostomidae
Loosejaw loosejaw	*Malacosteus niger*
Lumpfish	*Eumicrotremus sp.*
Mailed Sculpins	*Triglops sp.*
Atlantic manefish	*Caristius groenlandicus*
Apus platytroctes	*Platytroctes apus*
Arctic sculpin	*Myoxocephalus scorpioides*
Arctic Staghorn sculpin	*Gymnocanthus tricuspis*
Spatulate sculpin	*Icelus spatula*
Sculpins	Cottidae
Warted sea devil	*Cryptosaras couesi*
Seasnails	Liparidae

Table 47…continued

Common name	Latin name
Daubed shanny	*Lumpenus maculatus*
Slimehead slimehead	*Hoplostethus sp.*
Smelts, deepsea	Bathylagidae
Spinyfin	*Diretmus argenteus*
Shortspine tapirfish	*Macdonaldia rostrata*
Threebeard Rockling	*Gaidropsarus sp.*
Twohorn Sculpin	*Icelus sp.*
Wolf Eel	*Lycenchelys sp.*

30. Herring

Background
Herring (*Clupea harengus*) are a small pelagic fish, found across the Atlantic, that grow up to 45 cm. Herring is an important commercial fish south of the NL Shelf. However in the 1970s there was a decline in landings of herring in these southern regions and there was a relative increase in abundance and landings of herring in the NL Shelf.

Biomass
Generally, the biomass of forage fish are underestimated with the gear used for the RV surveys. Due to this lack of certainty of the estimated biomass of Herring in the region, the EE for both models was set to 0.95 calculating the estimated biomass with Ecopath. The estimated biomass for herring in the 1985-1987 model is **0.136 t/km^2** and in the 2013-2015 model is **0.919 t/km^2**.

Production:Biomass
The production to biomass ratio was estimated as in Bundy et al. (2000) where they calculated instantaneous total mortality of planktivorous fish in the study region to be approximately **1.15 yr^{-1}**. This value was used for both time periods.

Consumption:Biomass
The consumption by Herring was estimated from Araujo and Bundy (2011) where they determined consumption using the gastric evacuation model. The range of Q/B for herring was between 2.36 yr^{-1} and 3.935 yr^{-1}. Here we used an average value of **3.1475 yr^{-1}** for both models.

Diet
The diet of herring (Table 4, 5) in the NL Shelf is not well known, however extensive diet studies have been conducted in other regions. Here the diet of herring was determined from the RV surveys for the Scotian Shelf (adapted by Araujo and Bundy 2011) and the US Fall and Spring Surveys (Link and Almeida 2000; Smith and Link 2010).

Catch
The catch of herring was determined from the NAFO 21A databases (NAFO 2016). The catch of herring for the 1985-1987 model was **0.187 t/km^2/yr** and **0.010 t/km^2/yr** for the 2013-2015 model.

Balancing the model
Due to the high uncertainty of the estimated biomass of herring in the region, the EE for both models was set to 0.95 calculating the estimated biomass with Ecopath. The value for the 1985-1987 model was 0.136 t/km^2, for the 2013-2015 model the value was 0.906 t/km^2.

31. Sandlance

Background

Sandlance (*Ammodytes dubius*) are small, semi-demersal, planktivorous fish and can be found from west Greenland to Cape Hatteras. They are a forage species that have a similar role to Capelin and are common on the plateau of the Grand Bank. They occur on sandy and fine gravel substrate. Information about sandlance was provided by Aaron Adamack (pers. comm. April 2017, NAFC).

Biomass

As with other small pelagic fish, the RV survey gear is not particularly good at obtaining an accurate sample for sandlance. In general both Engel and Campelen RV surveys underestimate the abundance and biomass of sandlance. Bundy et al. (2000) estimated a biomass of 1040912 t of sandlance for the NL Shelf which amounts to 2. t/km^2/yr, but used a slightly higher value of **2.391 t/km^2/yr** in the final balanced Ecopath model. Here, we set the EE at 0.95 and allowed Ecopath to calculate the biomass of Sandlance for the 1985-1987 model due to the high uncertainty in the RV survey. We did the same for the 2013-2015 model and used a value of **2.788 t/km^2/yr** .

Production:Biomass

As in Bundy et al. 2000, the P/B ratio estimate from Winters (1983) where they investigated the biological and demographic parameters of sandlance between 1968-1979 on the Grand Bank was used. Winters estimated Z for the period to be 1.15. Thus the P/B used for both models was **1.15 yr^{-1}**.

Consumption:Biomass

In the absence of consumption data by sandlance, the Q/B was estimated as in Bundy et al. (2000) where they estimated a 0.15 ratio between production and consumption. Thus the Q/B was **7.667 yr^{-1}** which was the value used for both models.

Diet

The diet of sandlance (Table 4, 5) was taken from Scott (1973) where they performed frequency and volumetric analysis of food items in 486 stomachs of sandlance across a range of localities and seasons. Copepods made up the majority of the food items, but also include various crustacean larvae and invertebrate eggs.

Catch

Between the 1985-1987 period there was a small amount of reported catch of sandlance amounting to **0.000083 t/km^2/yr**. There was no commercial catch of sandlance during the 2013-2015 time period. Information on catch was calculated from the NAFO 21A databases (NAFO 2016).

Balancing the model

Due to the uncertainty in sandlance biomass estimates with the RV survey, we set the EE at 0.95 and allowed Ecopath to calculate the biomass of Sandlance for the 1985-1987 model due to the high uncertainty in the RV survey, giving an estimated biomass of 2.371 t/km2/yr. This seemed reasonable given past estimates of sandlance for the region. We also set the EE at 0.95 for the 2013-2015 period, the biomass estimate of sandlance used in the model is 1.828 t/km^2/yr.

32. Capelin

Background

Capelin (*Mallotus villosus*) have historically been the dominant pelagic species in the area and the major prey of cod and several species of seabirds and whales. In the early 1990s capelin almost disappeared in NAFO Division 2J, and increased in abundance in areas where it had previously been uncommon (the

Flemish Cap and Scotian Shelf). Capelin in the region has also experienced some phenological changes, arriving later in the inshore for spawning, and has experienced low growth rates (Lilly and Simpson 2000; Mowbray 2002).

Biomass

Although capelin are considered to be the most important forage fish in the NL Shelf, biomass estimates from RV surveys were considered unreliable. Acoustic surveys starting from 1988 were better able to capture the estimated biomass and abundance of capelin and are currently used to estimate capelin biomass for stock assessments. However, the acoustic survey is only conducted for the NAFO Division 3L, whereas capelin are distributed over NAFO Divisions 2J3KLNO. To obtain an approximation of capelin biomass for the whole region, the ratio of the RV survey to the acoustic survey estimates of capelin biomass in NAFO Division 3L was used to prorate the RV Survey biomass of capelin in the other NAFO Divisions, then summed for each model time period. Thus, for the 1985-1987 model, we used an estimated biomass of **13.770 t/km^2** for 1988 as representative of the model period. For the 2013-2015 model, an average biomass estimate of **4.97 t/km^2** based on the acoustic survey from 2013-2015 in NAFO Division 3L. Data were provided by Aaron Adamack (unpubl. data. April 2017, NAFC).

Production:Biomass

The P/B ratio for capelin was estimated as the total mortality (Allen 1971). The survival rates in Shackell et al. 1994 for capelin in the 3L region for the period of 1985-1987 were weighted by sex, age and maturity of the population to obtain a mean survival rate for the population of 31.8% This is equivalent to a mortality rate of approximately **1.15 yr^{-1}**. This value was used for both models.

Consumption:Biomass

While there is some information for capelin diet proportions, the consumption rates for the region were not available. Studies from the Gulf of St. Lawrence (Vesin et al. 1981) and Barents Sea (Ajiad and Pushchaeva 1991) estimated that the rate of consumption is between 1.3 to 5%. Bundy et al. (2000) used a daily consumption rate of 2% with an annual feeding period of 7 months. This is equivalent to a Q/B of **4.3 yr^{-1}**.

Diet

The diet of capelin (Table 4) was compiled from observations on the Grand Bank and Labrador shelf from the 1970s to the early 1990s (Kovalyov 1972; Chan and Carscadden 1973; Gerasimova 1994). More recent diet studies from (Dalpadado and Mowbray 2013) were used to reconstruct capelin diet for the 2013-2015 period (Table 5).

Catch

Catches for capelin were provided by Aaron Adamack (DFO, NAFC) from both inshore and offshore fisheries. The catch from 1985-1987 was **0.126 t/km^2/yr** and from 2013-2015 was **0.048413 t/km^2/yr**.

Balancing the model

The biomass estimates for the unbalanced 2013-2015 model used the average biomass estimated for the time period from the acoustic survey which was 3.823 t/km^2. The estimates of forage fish and particularly capelin in the NL Shelf are known to be poorly sampled (often under sampled), thus it was agreed that the upper limit for capelin estimates from the acoustic survey for the 2013-2015 period were acceptable, and we used the value **4.979 t/km^2** in order to balance the model.

33. Other planktivorous fish

Background

The other planktivorous fish group (Table 48) includes all planktivorous fish that were caught in the RV survey that are not of commercial significance or known to be key trophic species in the study region. The specific ecological designation of each species was defined through feeding studies in the region by Marian Koen-Alonso (Gaichas et al. 2012). While many of the species in this designation are relatively small (e.g. sticklebacks, argentine) basking shark are also included in this group.

Table 48. List of species that make up the other planktivorous fish.

Common name	Latin name
Alewife	*Alosa pseudoharengus*
Atlantic argentine	*Argentina silus*
Striated argentine	*Argentina striata*
Billfish	*Scomberesox saurus*
Black herring	*Bathytroctes sp.*
Lanternfishes	Myctophidae
Atlantic mackerel	*Scomber scombrus*
Whalefishes	Rondeletiidae
Radiated shanny	*Ulvaria subbifurcata*
Basking shark	*Cetorhinus maximus*
Fourspine stickleback	*Apeltes quadracus*
Threespine stickleback	*Gasterosteus aculateus*
Sticklebacks	Gasterosteiformes (Order)

Biomass

From calculations of the RV survey, the estimated biomass of other planktivorous fish for the 1985-1987 period is 0.04 t/km^2, and for the 2013-2015 period is 0.02 t/km^2. However, like the other planktivorous fish, the RV survey estimates of biomass are thought to be undersampled. Thus, for both models the EE was set to 0.95 and the biomass was estimated using the Ecopath model, giving an estimated biomass of **1.247 t/km^2** for the 1985-1987 model and **2.19 t/km^2** for the 2013-2015 period.

Production:Biomass

There was little data for other planktivorous fish with regards to production or total mortality. Thus a P/B ratio similar to the known plankton feeder fish was used for both model time periods of **1.15 yr^{-1}**.

Consumption:Biomas

Consumption information for the species that make up the other planktovorous fish group was generally poor. Consumption rates for the threespine stickleback was shown to be approximately 2.4% of the body weight at 10°C (Rajasilta 1980). Estimates of consumption for basking sharks (Sims 2008) estimate that they consume approximately 30.7 kg/day, but only occur within the NL Shelf during the summer months. Thus, using an approximate consumption of 2.4% body weight for smaller species that may spend 7 months out of the year in the NL Shelf averaged with an estimate for larger fish of 30.7kg per day for 3 months out of the year equals a Q/B of **4.19 yr^{-1}**. This value was used for both model time periods.

Diet
The diet of the other planktivorous group (Table 4, Table 5) was constructed from studies of sticklebacks, stomiatoid, clupeoid and basking sharks (Rajasilta 1980; Mauchline and Gordon 1983; Sims 2008). Generally, copepods (Large mesozooplankton) were the major component of the diets. However other species like amphipods, krill and invertebrate larvae (Macrozooplankton) also made up significant contributions to the overall diets. Due to the sparse data on these species, the same diet was used for both time periods.

Catch
The landings data for this group found in the NAFO 21A databases (NAFO 2016), was **0.0005367t/km^2/yr** for the 1985-1987 period and no commercial catches of any of the other planktivorous fish group were reported for the region in 2013-2015.

Balancing the model
The unbalanced models (Table 53, 54) used estimated biomass of other planktivorous fish for the 1985-1987 period of 0.04 t/km^2, and for the 2013-2015 period of 0.02 t/km^2.

34. Squid

Background
The squid group was primarily made up of the short fin squid (*Illex illecebrosus*), but also consists of various octopus species (*Cirroctopus* sp., *Octopod* sp.) and squid (*Logio* sp.).

Biomass
The biomass estimates for the squid group were from the RV survey, but only for the years between 2006-2011 provided by Mariano Koen-Alonso (unpubl. data. April 2017. NAFC). Bundy et al. (2000) used a combined estimated biomass of squid and myctophids of 0.49 t/km^2 which was higher than the estimates in the current models that have squid as their own functional group. Estimates of biomass for the for both models is **0.365 t/km^2**.

Production:Biomass
Araujo and Bundy (2011) used a P/B estimate of **3.4 yr^{-1}** for squid on the Scotian Shelf. They derived this value from model estimates of natural mortality by Hendrickson and Hart (2006) who estimate that mortality was approximately 0.07 week^{-1}. We used this value for our models.

Consumption:Biomass
Estimates of seasonal consumption off the northeast US were estimated to range seasonally between 0.6 to 19.4 yr^{-1} (Maurer and Bowman 1985). Using this information an annual Q/B of **13.2 yr^{-1}** was used by Araujo and Bundy (2011) for the Scotian Shelf Ecopath model. This value was used in the NL Ecopath models for both the 1985-1987 and 2013-2015 periods.

Diet
The diet data for squid (Table 4, 5) was developed from Dawe (1988) and Dawe et al. (1997) for the inshore Newfoundland region. Supplemental information was also considered for squid diet from Bowman et al. (2000) for the Northeast US region.

Catch
There was a small amount of commercially fished squid during the 1985-1987 period which amounted to **0.00039 t/km^2/yr**. For the 2013-2015 period, the reported catch is lower at **0.00003 t/km^2/yr**. These data were taken from the NAFO 21A databases (NAFO 2016).

Balancing the model

The initial input for the unbalanced models (Table 53, 54) for squid biomass was 0.49 t/km^2 based on information from the original model by Bundy et al. (2000). In light of more current information estimates for the current models were lower. For the 1985-1987 model, the biomass estimate for Squid is 0.365 t/km^2 and for the 2013-2015 model is 0.258 t/km^2.

35. Shrimp

Background

Shrimp (*Pandalus borealis* and other *Pandalus* sp.) in the NL Shelf has seen an increase in both biomass and the commercial fishery. After the groundfish collapse in the late 1980s and early 1990s, there was an increase in shellfish abundance (such as shrimp and snow crab) with a rapid expansion of the fishery. Currently, shrimp (*Pandalus* sp. and particularly *P. borealis*) make up one of the major fisheries in the NL Shelf (DFO 2016c, 2019).

Biomass

There is very little data on the specific biomass of shrimp in the NL Shelf prior to the mid-1990s. Data provided from Mariano Koen-Alonso contain biomasses for shrimp from 2006-2011. Bundy et al. (2000) used an estimated biomass value of 1.46 t/km^2, which was thought to have been too high for the time period given current numbers (Eric Pedersen pers. comm.). The value was lowered to 75% of the value used in the Bundy et al. (2000) Ecopath model. The value used for the 1985-1987 period is **0.876 t/km^2**. The estimated biomass value for the 2013-2015 period was based on expert opinion from Eric Pedersen (pers. comm. May 2018, NAFC) and used information from 2010 and 2011 sample years from the RV survey and was **2.44 t/km^2**.

Production:Biomass

Bundy et al. (2000) found a range of mortality estimates for Northern shrimp from 1.2 to 1.7 yr^{-1} (Hopkins 1988; Hopkins and Nilssen 1990). From current stock assessment models for Northern shrimp, the mortality rates were closer to **1.7 yr^{-1}** (Eric Pedersen, pers comm. May 2018, NAFC).

Consumption:Biomass

The consumption was calculated using a 15% growth efficiency (P/Q). This produces a Q/B ratio for shrimp of **11.33 yr^{-1}.** This value was used for both models.

Diet

The diet of Shrimp (Table 4, Table 5) was largely determined from Bundy et al. (2000) with input from Eric Pedersen (pers comm). Shrimp primarily consumed small invertebrates and zooplankton such as copepods as well as detritus.

Catch

The landings data for Shrimp were taken from the NAFO 21A databases (NAFO 2016). For the 1985-1987 model the shrimp fishery was very small with **0.000004 t/km^2/yr** reported for the 2J3KLNO area. After the collapse of groundfish in the early 1990s, the region experienced a building of shellfish resources. During the 2013-2015 period, the Shrimp catches increased to **0.014 t/km^2/yr**.

Balancing the model

The initial unbalanced model (Table 53) for the 1985-1987 period had a biomass input of 1.46 t/km^2 for shrimp. This was adjusted to 0.876 t/km^2 based on information from current stock assessment models.

36. Snow crab (Queen crab)

Background

Snow crab (*Chionoectes opilio*) are an important commercial species that are found throughout the 2J3KLNO study region. There was a stark buildup of shellfish resources (including Snow crab) in the region post groundfish collapse in the 1990s. Snow crab have a narrow range of temperature preferences, inhabiting mainly cold, deep water. Landings for Snow crab peaked in 1999 (69,100t in 1999 for the whole 2HJ3KLNOP4R region) due to expansion of the fishery to offshore areas. Landings have since gradually declined.

Biomass

The biomass of Snow crab prior to 1995 was poorly sampled by the RV surveys. More recent estimates of snow crab abundance are more comprehensive and include a trap survey beginning in 2004 (Mullowney et al. 2017). Because of the lack of Snow crab data for the 1985-1987 period, estimates of Snow crab came from the 1995-1997 survey years while 2013-2015 model estimates were determined from a combination of exploitable biomass and recruitment biomass from stock assessments that were scaled to the NL Shelf study region (Dawe and Colbourne 2002; DFO 2018a). The estimated biomass for the 1985-1987 model was **0.180 t/km^2** and for the 2013-2015 model was **0.313 t/km^2**.

Production:Biomass

Bundy et al. (2000) estimated production as the catch plus the natural mortality of large crustaceans between 0.1 and 0.3. This gave a range between 0.182-0.382 yr^{-1}. For the Western Scotian Shelf and Bay of Fundy Ecopath models, Araujo and Bundy (2011) estimated that P/B for large crabs (estimated from production of snow crabs in the Gulf of St. Lawrence) was between 0.301-0.654 yr^{-1}. Here we used total mortality estimates from the most recent Snow Crab assessment for the NL Shelf of **0.46 yr^{-1}** (DFO 2017b)**,** which appears to be close to the mean value found for Gulf of St. Lawrence Snow crab. We used this value for both model time periods.

Consumption:Biomass

There was no Q/B estimate for Snow crab. The parameter was estimated based on an assumption that the P/Q ratio for Snow crab is 0.15 for both time period models.

Diet

The diet of Snow crab (Table 4, 5) was determined from Squires and Dawe (2003) where they studied stomach content of Snow crab from the 3K area from crabs collected during the RV survey. Like other large crustaceans, snow crab eat a variety of food items that include both fish and other invertebrates.

Catch

The landings for Snow crab in the 1985-1987 period was relatively low at **0.0144 t/km^2/yr** compared to the 2013-2015 period **at 0.0888 t/km^2/yr**. Data were compiled from the NAFO 21A databases (NAFO 2016).

Balancing the model

The initial unbalanced models (Table 53, 54) used a P/B ratio of 0.38 yr^{-1} which, given light of more current data, were too low. For the current models, the P/B ratio was increased to **0.46 yr^{-1}**. Due to a lack of information on the consumption by snow crab, the assumed P/Q ratio for snow crabs of 0.15 was used, making the estimate of Q/B for the crab to be **3.067 yr^{-1}.**

Invertebrate groups:

37, 38 &39 Predatory invertebrates, Deposit feeding invertebrates, Suspension feeding invertebrates

Background

Predatory invertebrates encompass a wide variety of invertebrates that include lobsters, crabs and other crustaceans.

Deposit feeding invertebrates include urchins, sand dollars, chaetognaths, polychaetes and isopods.

Suspension feeding invertebrates include bivalve molluscs, sea anemones, sponges, brittle/basket stars, ascidians and coral.

The information on invertebrate groups prior to 2006 in the Grand Bank is relatively sparse. In the 1980s and 1990s a number of environmental assessments were performed for localized drilling areas. For the 1985-1987 model period, these assessments were the primary resource for information on the species compositions in the region.

Biomass

The biomass estimates for invertebrate groups for the 1985-1987 period were generated from values calculated from the Hibernia Environmental Impact Assessment (Mobil Oil Canada 1985). These values were compared to the input data from Bundy et al. (2000) for benthic invertebrates, however the species compositions for the current, updated model structure is not the same as in Bundy et al. (2000). More recent assessments of invertebrates from the 2006 RV surveys were also compared to estimates generated from the Hibernia Environmental Impact Assessment (Mobil Oil Canada 1985). For the 2013-2015 model, RV survey data, as well as information from grab sample surveys performed between 2008-2010 (DFO 2012) were used. The biomass inputs used for all invertebrate groups are found in Table 49.

Production:Biomass

Due to the wide variety of species that are included in Predatory invertebrates, the P/B ratio used for both models was taken from Araujo and Bundy (2011) where they estimated a P/B for small crabs to be **1.31 yr^{-1}**.

Bundy et al. (2000) estimated that the P/B for echinoderms and molluscs was 0.6 yr^{-1} while the P/B for miscellaneous meifauna was 2.5 yr^{-1} for the NL Shelf, and Araujo and Bundy (2011) estimated that other arthropods (isopods, mysids) had a P/B of 2.29 yr^{-1} calculated using an equation by Brey (1995, 1999). Here we used the mean of these estimates of **1.5 yr^{-1}** for deposit feeding invertebrates.

The estimated P/B for suspension feeding invertebrates were taken from of the P/B for molluscs of 0.6 yr^{-1} (Bundy et al. 2000) and scallops of 0.75 yr^{-1} (Araujo and Bundy 2011), and sessile benthic invertebrates of 0.34 yr^{-1} (Araujo and Bundy 2011). The P/B was estimated to be the mean of these values at **0.556 yr^{-1}**.

Consumption:Biomass

Consumption data for the invertebrate groups (Table 2, 3) was estimated based on the assumption that the production to consumption ratio (P/Q) is **0.15 yr^{-1}**.

Diet

The diet of the invertebrate groups (Table 4, 5) was based mainly from literature. Predatory inverts were mostly considered crabs (toad crabs, hermit crabs) and lobsters and thus the diet was based on (Carter and Steele 1982).

The diet of deposit feeding invertebrates was based mainly from the sand dollar *Echinarchnius parma* (Hilber and Lawrence 2009).

The diet of suspension feeding invertebrates was based on the diets of brittle stars, scallops and other bivalves (Bayne et al. 1993; Packer et al. 1994, 1999)

Catch
Landings data for the invertebrate groups (Table 49) was from the NAFO 21A databases (NAFO 2016). For predatory invertebrates the landings were mainly from lobsters and various crabs. For Deposit feeding invertebrates, the landings were mainly of sea urchin. Landings of suspension feeding invertebrates were primarily from scallop and other bivalves.

Table 49. Input parameters for the invertebrate groups for the 1985-1987 and 2013-2015 Ecopath models.

Model	Group	Biomass (t/km^2)	P/B (yr^{-1})	Q/B (yr^{-1})	Landings (t/km2/yr)
1985-1987	Predatory	12.472	1.31	11	0.003479
1985-1987	Deposit	60.934	1.5	10	0
1985-1987	Suspension	99.293	0.556	3.707	0.000244
2013-2015	Predatory	20.0	1.31	11	0.107
2013-2015	Deposit	85.0	1.5	10	0.001147
2013-2015	Suspension	61.0	0.57	3.707	0.00096

Balancing the model
Initial biomass input parameters for predatory, deposit and suspension feeding inverts for the 2013-2015 model were 30.856, 121.814 and 77.328 t/km^2 which were found to be too high. As the NEREUS grab samples were taken in only a small area, there was evidence that these data were over representing these groups. Thus, they were reduced to 20.0, 85.0 and 61.0 t/km^{-2}, respectively.

Zooplankton:

40, 41, 42 & 43. Macrozooplankton, Large mesozooplankton, Small mesozooplankton and Microzooplankton

Background
Macrozooplankton consisted of gelatinous zooplankton, non-pandalus shrimp, Euphausiids and Amphipods.

Large mesozooplankton consisted primarily of Large copepods (*Calanus finmarchicus, Calanus hyperboreus, Calanus glacialis,* calanoid nauplii and *Metridia* sp.).

Small mesozooplankton consisted of small copepod species (*Microcalanus* sp., *Oithona atlantica, Oithona similis, Centropages* sp., *Spinocalanus* sp., *Pseudocalanus* sp., *Triconia* sp., *Chiridius gracilis, Arctia* sp., *Paracalanus parvus*).

Microzooplankton are a group of heterotrophic and mixotrophic planktonic organisms. Important contributors to the group are phagotrophic protists such as flagellates, dinoflagellates, ciliates, acantharids, radiolarians, foraminiferans and metazoans such as copepod nauplii, rotiferans and meroplanktonic larvae.

Biomass
The biomass of zooplankton for the 1985-1987 model (Table 50) was estimated from Head and Pepin (2009) and Meyers et al. (1994), who estimated the abundance of zooplankton from the Continuous Plankton Recorder program.

Due to uncertainty in estimating gelatinous zooplankton and other macrozooplankton, the EE for macrozooplankton was set at 0.95 for both model time periods and allowed Ecopath to estimate the biomass for this group (Table 50).

The biomass of mesozooplankton and microzooplankton for the 2013-2015 model (Table 50) was estimated from Pepin et al. (2015) using data from the Atlantic Zone Monitoring Program for the NL region. The data were collected from a network of sampling locations (fixed points, cross shelf and groundfish surveys) that samples the entire study region (NAFO divisions 2J3KLNO). The AZMP sampling began in 1998, data prior to that came from the continuous plankton recorder which has data prior to 1998 (Head and Pepin 2009).

Production:Biomass
The P/B ratio (Table 50) for Macrozooplankton was taken from Bundy et al. (2000), based on the production of Euphausiids.

The P/B for Large mesozooplankton was estimated from McLaren et al. (1989) where they estimated the P/B ratio for *C. finmarchicus* on the Scotian Shelf.

For Small mesozooplankton, the daily production rate was estimated from the empirical equation by (Huntley and Lopez 1992).

$$P = B * 0.0445e^{0.111T}$$

Where P is the daily production rate, B is the estimate biomass, and T is the seawater temperature.

For Microzooplankton, the P/B was taken from Link et al. (2008).

Consumption:Biomass
The Q/B ratio (Table 50) for Macrozooplankton came from (Sameoto 1976) where an estimate of **19.5** $\mathbf{yr^{-1}}$ was based on an average consumption by 3 Euphausiid species in the Gulf of St. Lawrence.

For Large mesozooplankton, Small mesoplankton and microzooplankton we assumed a production to consumption ratio of **0.3** $\mathbf{yr^{-1}}$.

Diet
Macrozooplankton diets (Table 4,5) were based on diet studies for Euphausiids (Saether et al. 1986; Virtue et al. 2000), mysid shrimp (Mauchline 1980) and gelatinous zooplankton (Larson 1987, 1991). Macrozooplankton fed primarily on large mesozooplankton (larger copepods) and detritus, but also a variety of smaller zooplankton and phytoplankton were also found to be part of their diets.

Large and small mesozooplankton diet information was based on data from the EMAX model for the North Eastern US continental shelf (Link et al. 2008) and Sullivan (1980) for small copepod species. These groups primarily feed on phytoplankton.

For microzooplankton the diet was based on Calbet (2008), Schmoker et al. (2013) and Pierce and Turner (1992). Microzooplankton are major consumers of both large and small phytoplankton, but some detritus and bacteria were also included in their diets.

Table 50. Basic estimates for Macrozooplankton, Large mesozooplankton, Small mesozooplankton and Microzooplankton for the 1985-1987 and 2013-2015 Ecopath models.

Model	Group	Biomass (t/km^2)	P/B (yr^{-1})	Q/B (yr^{-1})
1985-1987	Macrozooplankton	11.275	3.430	19.500
1985-1987	Large mesozooplankton	20.500	8.400	28.000
1985-1987	Small mesozooplankton	6.500	31.610	105.367
1985-1987	Microzooplankton	5.600	72.00	240.000
2013-2015	Macrozooplankton	7.845	3.430	19.500
2013-2015	Large mesozooplankton	13.504	8.400	28.000
2013-2015	Small mesozooplankton	5.534	31.610	105.367
2013-2015	Microzooplankton	5.360	72.00	240.000

44 & 45. Bacteria and Heterotrophic nanoflagellates

Background

This group encompasses the main components of the microbial loop for the region. Although the microbial loop in the NL Shelf is not well understood compared to other groups in the Ecopath models, bacteria and heterotrophic nanoflagellates represent an important trophic pathway for dissolved organic matter (dissolved organic carbon, etc.) into the classic food chain.

Biomass

Biomass for both bacteria and heterotrophic nanoflagellates (Table 51) were generated from estimates from Paulsen et al. (2017) from the Icelandic Basin and Iversen and Seuthe (2011) in Svalbard, Norway. Both found generally that bacteria and heterotrophic nanoflagellates made up a percentage of Particulate Organic Carbon (POC) in the water column. POC data were obtained from Pierre Pepin (Unpub. data. October 2018) from the Atlantic Zone Monitoring Program (AZMP) which was implemented in 1998 (Pepin et al. 2005). The mean yearly percentage of Particulate Organic Carbon (POC) in the water column was 2.2% (**4.400 t/km^2**) for bacteria and 0.25 % (**0.505 t/km^2**) for Heterotrophic nanoflagellates for the 1985-1987 model using estimates information from 1998 (earliest information). The mean yearly percentage of Particulate Organic Carbon (POC) in the water column was 2.2% (**5.2 t/km^2**) for bacteria and 0.25 % (**0.60 t/km^2**) for Heterotrophic nanoflagellates for the 2013-2015 model using estimates from those years.

Production:Biomass

The P/B for both bacteria and heterotrophic nanoflagellates (Table 51) were estimated from growth experiments of Bacteria and Heterotrophic nanoflagellates from the Icelandic basin (Paulsen et al. 2017).

Consumption:Biomass

The Q/B ratio for Bacteria and Heterotrophic nanoflagellates (Table 51) were estimated from various published sources (Jurgens and Massana 2008; Iversen and Seuthe 2011; Paulsen et al. 2017). The consumption by bacteria was based on estimates for the entire microbial loop for the Northeast US from the EMAX model (Link et al. 2008).

Rates of bacterivory by Heterotrophic nanoflagellates (Table 51) were calculated from Jurgens and Massana (2008):

$$\log GT = -3.21 + 0.99\ logHNF + 0.028T + 0.55\ logBAC$$

Where GT is the grazing rate (bacteria $mL^{-1}hr^{-1}$), T is temperature (°C), HNF is the heterotrophic nanoflagellate abundance (cells mL^{-1}), and BAC is the bacterial abundance (cells mL^{-1}). The heterotrophic nanoflagellate abundance was estimated from POC values from (Pepin et al. 2005). The resultant grazing rate on bacteria was extrapolated to a yearly value. Estimates of individual biomass of bacteria was estimated from Paulsen et al (2017) and resulted in an estimate of consumption of picoplankton and bacteria by heterotrophic nanoflagellaes.

Diet

The diet of bacteria (Table 4, 5) was unavailable specifically for the NL Shelf. Thus, the diet of bacteria was modified from the EMAX model (Link et al. 2008) and adjusted for the number of functional groups in the current model structure for the 1985-1987 and 2013-2015 Ecopath models for the NL Shelf. The diet of heterotrophic nanoflagellates was determined from grazing rate experiments (Paulsen et al. 2017), and field examinations of interactions between phytoplankton, bacteria and heterogrophic nanoflagellates from Svalbard, Norway (Iversen and Seuthe 2011).

Table 51. Basic estimates for Bacteria and Heterotrophic nanoflagellates (HNAN) from the 1985-1987 and 2013-2015 Ecopath models.

Model	Group	Biomass (t/km2)	P/B (yr-1)	Q/B (yr-1)
1985-1987	Bacteria	4.400	50.445	135.00
1985-1987	HNAN	0.505	73.000	187.92
2013-2015	Bacteria	5.200	50.445	135.00
2013-2015	HNAN	0.600	73.000	187.92

46 & 47. Large and Small phytoplankton

Background

Large and Small phytoplankton are defined by their size structure. Large phytoplankton refer to microplankton (20-200µm), while Small phytoplankton refer to nano and pico-plankton (0.2-20µm). Since the late 1990s, remote sensing and satellite imagery has made obtaining long term phytoplankton (chlorophyll and primary production) information much more accessible than previously when information on phytoplankton biomass was difficult to obtain. For earlier periods there is some information from *in situ* studies from the Continuous Plankton Recorder (Meyers et al. 1994; Jossi et al. 2003) and ship based data from RV surveys. There is also information on ocean colour from the Coastal Zone Color Scanner (CZCS) from 1978-1986.

Biomass

For the 1985-1987 Ecopath model, Bundy et al. (2000) synthesized much of the available information for phytoplankton (as a combined group of Large and Small phytoplankton), using both estimates from *in situ* studies and remote sensing data. However, this was not divided into Large and Small phytoplankton and this data is not available. Therefore, we allowed the model to estimate the biomass of Large and Small phytoplankton by assuming an EE of 0.6 and 0.8, respectively. To confirm that these estimates were meaningful, we compared the total of 29.379 t/km^2 (Table 52) with the aggregated estimate of 26.86 t/km^2 for total phytoplankton from Bundy et al. (2000).

For the 2013-2015 Ecopath model, we used estimates of Large and Small phytoplankton provided by Xiaohan Liu and Emmanual Devred (Bedford Institute of Oceanogaphy) who used an algorithm applied to remote sensing data to gain estimates for Large and Small phytoplankton separately (Liu et al. 2018). To assess the validity of using these values (Table 52), the summed value for Large and Small phytoplankton from the 2013-2015 period was compared to independently derived depth integrated biomass of total phytoplankton from 0-100 m (24.9 t/km^2) obtained from remote sensing data of Chlorophyll a calculated by Carla Caverhill (unpubl. data. March 2017, BIO). These data were converted to phytoplankton biomass using chlorophyll:carbon conversion ratio from Hollibaugh and Booth (1981) and Cloern et al. (1995).

Production:Biomass
For the 1985-1987 model period, primary production estimates were taken from Bundy et al. (2000) where they used information from environmental assessments from the Grand Bank and Labrador region and compared these to CZCS data (Table 52).

The P/B ratio for the 2013-2015 period (Table 52) was determined from yearly primary production estimates provided by Carla Caverhill for the NL Shelf from 1998-2016.

Table 52. Basic estimates for Large and small phytoplankton from the 1985-1987 and 2013-2015 Ecopath models.

Model	Group	Biomass (t/km2)	P/B (yr-1)	EE
1985-1987	L Phytoplankton	11.723	93.1	0.6
1985-1987	S Phytoplankton	17.656	93.1	0.8
2013-2015	L Phytoplankton	11.433	103.27	0.455
2013-2015	S Phytoplankton	13.067	103.27	0.834

Unbalanced models

Table 53. Ecopath model for the 1985-1987 period. Numbers in bold are values that were changed to balance the models.

	Group name	Trophic level	Biomass (t/kmÂ²)	Total mortality (/year)	Production / biomass (computed) (/year)	Consumption / biomass (/year)	Production / consumption	Landings
1	Whale fish eater	4.312	**0.140**		0.129	5.526	0.023	0.000
2	Whale zp eater	3.694	**0.025**		0.055	3.468	0.016	0.000
3	Whale squid eater	4.608	0.057		0.078	5.498	0.014	0.000
4	Whale mammal eater	5.254	0.000		0.084	8.100	0.010	0.000
5	Whale Minke	4.344	**0.028**		0.089	5.380	0.017	0.000
6	Seal Harp	4.400	0.100		0.149	16.782	0.009	0.003
7	Seal Hooded	4.963	0.028		0.115	18.225	0.006	0.000
8	Seal other	4.804	0.010		0.128	13.000	0.010	0.000
9	Seabird piscivore	4.331	0.010		0.250	**54.750**	0.005	0.000
10	Seabird planktivore	3.348	0.002		0.150	64.605	0.002	0.000
11	Seabird benthivore	3.631	0.000		0.130	45.291	0.003	0.000
12	Greenland shark	5.250	0.012		0.008	0.125	0.064	0.000
13	Cod> 35 cm	4.266	3.576	0.651		3.240	0.403	0.603
14	Cod<= 35 cm	3.991	0.958	0.600		**6.697**	0.166	0.000
15	Greenland halibut	4.624	0.436		0.760	2.900	0.262	0.035
16	Silver hake/ Pollock	4.245	0.017		0.400	4.100	0.098	0.002
17	Other pisc	4.221	0.200		0.385	2.775	0.139	0.024
18	Redfish	3.808	**1.650**		0.330	2.000	0.165	0.162
19	Arctic cod	3.592	**0.006**		0.400	2.630	0.152	0.000
20	Other plank-pisc	3.325	**0.002**		0.350	2.500	0.140	0.000
21	AmPlaice > 35	4.227	0.990	0.540		**1.262**	0.428	0.110
22	AmPLaice <= 35	3.741	3.332	0.630		**2.506**	0.251	0.025
23	Thorny skate	4.084	0.540		0.286	1.918	0.149	0.038
24	Haddock	3.509	0.092		0.217	2.080	0.104	0.008
25	Other L benth	3.433	0.424		0.200	1.333	0.150	0.001
26	Yellowtail flounder	3.655	1.550		0.391	3.600	0.109	0.041
27	Witch flounder	3.584	0.230		0.257	2.599	0.099	0.025
28	Other M benth	3.612	0.693		0.300	3.000	0.100	0.011
29	Other S benth	3.373	1.570		0.421	2.000	0.211	0.000
30	Herring	3.709	0.136		1.150	3.148	0.365	0.019
31	Sandlance	3.466	2.391		1.150	7.670	0.150	0.000
32	Capelin	3.400	13.766		1.150	4.300	0.267	0.126
33	Other plank	2.836	**0.040**		1.150	4.190	0.274	0.001
34	Squid	3.606	**0.490**		3.400	13.200	0.258	0.000
35	Shrimp	2.389	**1.460**		1.700	11.333	0.150	0.000
36	Snow crab	3.302	0.180		**0.380**	**3.067**	0.150	0.014
37	Predatory invert	2.648	12.473		1.310	8.733	0.150	0.003
38	Deposit feeding invert	2.000	60.934		1.500	10.000	0.150	0.000
39	Suspension feeding invert	2.481	99.293		0.556	3.707	0.150	0.000
40	Macro ZP	2.626	10.689		3.430	19.500	0.176	0.000
41	Large meso ZP	2.436	20.500		8.400	28.000	0.300	0.000
42	Small meso ZP	2.050	6.500		31.610	105.367	0.300	0.000
43	Micro ZP	2.256	5.600		72.000	240.000	0.300	0.000
44	Bacteria	2.000	4.400		50.445	135.000	0.374	0.000
45	HNAN	2.538	0.505		73.000	187.920	0.388	0.000
46	Phytoplankton L	1.000	12.601		93.100			0.000
47	Phytoplankton S	1.000	19.641		93.100			0.000
48	Detritus	1.000	1.000					0.000

Table 54. Unbalanced model for the 2013-2015 model. Numbers in bold are values that were changed to balance the model.

	Group name	Trophic level	Biomass (t/kmÂ²)	Total mortality (/year)	Production / biomass (computed) (/year)	Consumption / biomass (/year)	Production / consumption	Landings
1	Whale fish eater	4.304	**0.080**		0.129	5.526	0.023	0.000
2	Whale zp eater	3.692	**0.025**		0.055	3.468	0.016	0.000
3	Whale squid eater	4.585	0.054		0.078	5.498	0.014	0.000
4	Whale mammal eater	5.125	0.000		0.084	8.100	0.010	0.000
5	Whale Minke	4.337	**0.011**		0.089	5.380	0.017	0.000
6	Seal Harp	4.125	0.320		0.149	17.643	0.008	0.015
7	Seal Hooded	4.913	0.038		0.115	18.332	0.006	0.000
8	Seal other	4.731	0.015		0.128	13.000	0.010	0.000
9	Seabird piscivore	4.313	0.007		0.250	**54.750**	0.005	0.001
10	Seabird planktivore	3.348	0.006		0.150	64.605	0.002	0.000
11	Seabird benthivore	3.632	0.002		0.130	45.291	0.003	0.000
12	Greenland shark	5.152	0.009		0.008	0.125	0.064	0.000
13	Cod> 35 cm	4.164	0.760	0.307		**3.240**	0.190	0.011
14	Cod<= 35 cm	3.986	0.038	0.302		**8.894**	0.068	0.000
15	Greenland halibut	4.400	0.690		0.644	2.900	0.222	0.027
16	Silver hake/ Pollock	4.258	0.163		0.400	4.100	0.098	0.001
17	Other pisc	4.213	0.073		0.385	2.525	0.152	0.007
18	Redfish	3.805	2.130		0.330	2.000	0.165	0.031
19	Arctic cod	3.591	**0.050**		0.400	2.630	0.152	0.000
20	Other plank-pisc	3.325	0.017		0.350	2.500	0.140	0.000
21	AmPlaice > 35	3.942	0.239	0.600		**1.262**	0.475	0.003
22	AmPLaice <= 35	3.739	1.349	0.753		**2.673**	0.282	0.000
23	Thorny skate	4.021	0.305		0.286	2.174	0.132	0.008
24	Haddock	3.508	0.072		0.209	2.080	0.100	0.000
25	Other L benth	3.433	0.240		0.200	1.333	0.150	0.000
26	Yellowtail flounder	3.654	1.666		0.367	3.600	0.102	0.017
27	Witch flounder	3.584	0.065		0.233	2.599	0.090	0.001
28	Other M benth	3.612	0.385		0.300	3.000	0.100	0.001
29	Other S benth	3.386	1.106		0.421	3.148	0.134	0.000
30	Herring	3.709	0.919		1.150	4.000	0.288	0.010
31	Sandlance	3.450	2.790		1.150	7.670	0.150	0.000
32	Capelin	3.390	**3.823**		1.150	4.300	0.267	0.048
33	Other plank	2.836	**0.020**		1.150	4.190	0.274	0.000
34	Squid	3.606	**0.490**		3.400	13.200	0.258	0.000
35	Shrimp	2.389	2.440		1.700	11.333	0.150	0.014
36	Snow crab	3.303	0.330		**0.380**	**3.067**	0.150	0.089
37	Predatory invert	2.648	30.856		1.310	11.000	0.119	0.107
38	Deposit feeding invert	2.000	121.815		1.500	10.000	0.150	0.001
39	Suspension feeding invert	2.481	77.329		0.556	3.707	0.150	0.001
40	Macro ZP	2.626	5.859		3.430	19.500	0.176	0.000
41	Large meso ZP	2.436	13.504		8.400	28.000	0.300	0.000
42	Small meso ZP	2.050	5.534		31.610	105.367	0.300	0.000
43	Micro ZP	2.256	5.360		72.000	240.000	0.300	0.000
44	Bacteria	2.000	5.200		50.445	135.000	0.374	0.000
45	HNAN	2.538	0.600		73.000	187.920	0.388	0.000
46	Phytoplankton L	1.000	25.876		103.270			0.000
47	Phytoplankton S	1.000	29.572		103.270			0.000
48	Detritus	1.000	1					0.000

References

Ajiad, A.M., and Pushchaeva, T. 1991. The daily feeding dynamics in various length groups of the Barents Sea. 5th PINRO/IMR Symp. (1): 181–192.

Allen, K.R. 1971. Relation between production and biomass. Fish. Res. Board Canada **28**: 1573–1581.

Baird, R.W., and Whitehead, H. 2000. Social organization of mammal-eating killer whales: group stability and dispersal patterns. Can. J. Zool. **78**(12): 2096–2105. doi:10.1139/z00-155.

Barrett, R.T., Chapdelaine, G., Anker-Nilssen, T., Mosbech, A., Montevecchi, W.A., Reid, J.B., and Veit, R.R. 2006. Seabird numbers and prey consumption in the North Atlantic. ICES J. Mar. Sci. **63**(6): 1145–1158. doi:10.1016/j.icesjms.2006.04.004.

Bayne, B.L., Iglesias, J., Hawkins, A.J.S., Navarro, E., Heral, M., and Deslous-Paoli, J.-M. 1993. Feeding behaviour of the mussel, *Mytilus edulis*: responses to variations in quantity and organic content of the seston. J. Mar. Biol. Assoc. United Kingdom **73**: 813–829.

Bowering, W. 1983. Age, growth, and sexual maturity of Greenland Halibut, *Reinhardtius hippoglossoides* (Walbaum), in the Canadian Northwest Atlantic. Fish. Bull. **81**(3): 599–611.

Bowering, W.R. 1976. Distribution, age and growth, and sexual maturity of witch flounder (Glyptocephalus cynoglossus) in Newfoundland waters. J. Fish. Board Canada **33**(7): 1574–1584. doi:10.1139/f76-198.

Bowering, W.R., and Lilly, G.R. 1992. Greenland halibut (Reinhardtius hippoglossoides) off Southern Labrador and Northeastern Newfoundland (Northwest Atlantic) feed primarily on capelin (Mallotus villosus). Netherlands J. Sea Res. **29**(1–3): 211–222. doi:10.1016/0077-7579(92)90021-6.

Bowman, R., and Bowman, E. 1980. Diurnal Variation in the Feeding Intensity and Catchability of Silver Hake Merluccius bilinearis. Can. J. Fish Aquat. Sci. **37**(55984): 1565–1572. doi:10.1139/f80-202.

Bowman, R.E., Stillwell, C.E., Michaels, W.L., and Grosslein, M.D. 2000. Food of the Northwest Atlantic Fishes and two common species of squid. NOAA Tech. Memo. **NMFS-NE-15**.

Braham, H.W. 1984. The status of endangered whales: An overview. Mar. Fish. Rev. **46**(4): 2–6.

Brodie, W.B., Bowering, W.R., Power, D., and Orr, D. 1997. An assessment of Greenland halibut in NAFO subarea 2 and divisions 3KLMNO. NAFO Sci. Counc. Stud. **Doc. 97/52**: 1–37.

Bundy, A. 2004. Mass balance models of the eastern Scotian Shelf before and after the cod collapse and other ecosystem changes. Dep. Fish. Ocean.

Bundy, A., Lilly, G.R., and Shelton, P.A. 2000. A mass balance model of the Newfoundland-Labrador Shelf. St. John's NL.

Burke, C.M., Montevecchi, W.A., Hedd, A., McFarlane-Tranquilla, L.A., Regular, P.M., Robertson, G.J., and Wilhelm, S. 2014. Age-specific variation in trophic niche overlap of Dovekies Alle Alle. Mar. Ornithol. **42**(1): 17–22.

Calbet, A. 2008. The trophic roles of micro zooplankton in marine systems. ICES J. Mar. Sci. **65**: 325–331. Available from https://watermark.silverchair.com/fsn013.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAawwggGoBgkqhkiG9w0BBwagggGZMIIBlQIBADCCAY4GCSqGSIb3DQEHATAeBglghkgBZQMEAS4wEQQMOJhPmfPEU0r7QjsgAgEQgIIBX6bHaNDFIz9lZXk6_xDakaIRPg97wpeA_KkIY0Acjvcf8auu.

Campana, S.E. 1997. Use of radiocarbon from nuclear fallout as a dated marker in the otoliths of haddock Melanogrammus aeglefinus. Mar. Ecol. Prog. Ser. **150**(1–3): 49–56. doi:10.3354/meps150049.

Cargnelli, L.M., Griesbach, S.J., and Morse, W.W. 1999. Atlantic halibut, *Hippoglossus hippoglossus* Life History and Habitat Characteristics. NOAA Tech. Memo. **NMFS-NE-12**: 1–17.

Carter, J.A., and Steele, D.H. 1982. Stomach contents of immature lobsters (*Homarus americanus*) from Placentia Bay, Newfoundland. Can. J. Zool. **60**(3): 337–347. doi:10.1139/z82-045.

Chambers, C.A., and Dick, T.A. 2005. Trophic structure of one deep-sea benthic fish community in the eastern Canadian Arctic: Application of food, parasites and multivariate analysis. Environ. Biol. Fishes **74**(3–4): 365–378. doi:10.1007/s10641-005-2922-0.

Chan, M., and Carscadden, J. 1973. The food and feeding of capelln (*Mallotus villosus*) In the Labrador area during Autumn 1973. Int. Comm. Northwest Atl. Fish. Res. Doc. **76/VI/20 S**(3800): 5.

Christensen, V., and Pauly, D. 1993. Trophic models of aquatic ecosystems. *In* 26th edition. Worldfish.

Christensen, V., and Pauly, D. 2008. Ecopath with Ecosim: a user's guide. Fisheries Centre of University of British Columbia, Vancouver.

Christensen, V., and Walters, C.J. 2004. Ecopath with Ecosim : methods, capabilities and limitations. Ecol. Modell. **172**: 109–139. doi:10.1016/j.ecolmodel.2003.09.003.

Christiansen, J.S., Hop, H., Nilssen, E.M., and Joensen, J. 2012. Trophic ecology of sympatric Arctic gadoids, Arctogadus glacialis (Peters, 1872) and Boreogadus saida (Lepechin, 1774), in NE Greenland. Polar Biol. **35**(8): 1247–1257. doi:10.1007/s00300-012-1170-y.

Cloern, J.E., Grenz, C., and Videgar-Lucas, L. 1995. An empirical model of the phytoplankton chlorophyll: carbon ration-the conversion factor between productivity and growth rate. Limnol. Oceanogr. **40**(7): 1313–1321.

Collie, J.S., Botsford, L.W., Hastings, A., Kaplan, I.C., Largier, J.L., Livingston, P.A., Plagányi, É.E., Rose, K.A., Wells, B.K., and Werner, F.E. 2014. Ecosystem models for fisheries management: Finding the sweet spot. Fish Fish.: 1–25. doi:10.1111/faf.12093.

Crain, C.M., Kroeker, K., and Halpern, B.S. 2008. Interactive and cumulative effects of multiple human stressors in marine systems. Ecol. Lett. **11**(12): 1304–1315. doi:10.1111/j.1461-0248.2008.01253.x.

Dahl, T.M., Falk-Petersen, S., Gabrielsen, G.W., Sargent, J.R., Hop, H., and Millar, R.M. 2003. Lipids and stable isotopes in common eider, black-legged kittiwake and northern fulmar: Atrophic study from an Arctic fjord. Mar. Ecol. Prog. Ser. **256**(Johnston 1973): 257–269. doi:10.3354/meps256257.

Dalpadado, P., and Mowbray, F. 2013. Comparative analysis of feeding ecology of capelin from two shelf ecosystems, off Newfoundland and in the Barents Sea. Prog. Oceanogr. **114**: 97–105. Elsevier Ltd. doi:10.1016/j.pocean.2013.05.007.

Dawe, E.G. 1988. Length-weight relationships for short-finned squid in Newfoundland and the effect of diet on condition and growth. Trans. Am. Fish. Soc. **117**(6): 591–599. doi:10.1577/1548-8659(1988)117<0591:LRFSSI>2.3.CO;2.

Dawe, E.G., and Colbourne, E.B. 2002. Distribution and demography of snow crab (Chionoecetes opilio) males on the Newfoundland and Labrador Shelf. Crabs Cold Water Reg. Biol. Manag. Econ. **19**(June 2015): 577–594. doi:10.4027/ccwrbme.2002.42.

Dawe, E.G., Dalley, E.L., and Lidster, W.W. 1997. Fish prey spectrum of short-finned squid (Illex illecebrosus) at Newfoundland. Can. J. Fish. Aquat. Sci. **54**: 200–208. doi:10.1139/f96-155.

Dempsey, D.P., Koen-Alonso, M., Gentleman, W.C., and Pepin, P. 2017. Compilation and discussion of driver, pressure, and state indicators for the Grand Bank ecosystem, Northwest Atlantic. Ecol. Indic. **75**: 331–339. doi:10.1016/j.ecolind.2016.12.011.

DFO. 2005. Stock assessment on subdivision 3Ps Pollock. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/049: 1–21.

DFO. 2012. Results and recommendations from the Ecosystem Research Initiative - Newfoundland and Labrador's Expanded Research on Ecosystem Relevant but Under-Surveyed Splicers. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/058. (December): 15.

DFO. 2016a. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2017/023 (March): 1–22.

DFO. 2016b. Stock assessment of Northern cod (NAFO DIVS. 2J3KL) in 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/026 (May). Available from http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2016/2016_026-eng.pdf.

DFO. 2016c. An assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4-6 and of Striped Shrimp (*Pandalus montagui*) in Shrimp Fishing Area 4 in 2015. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2016/028 (May): 1–25.

DFO. 2017a. An assessment of Northern Shrimp (*Pandalus borealis*) in Shrimp Fishing Areas 4– 6 and of Striped Shrimp (*Pandalus montagui*) in Shrimp Fishing Area 4 in 2016. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. **12**(March).

DFO. 2017b. Assessment of Newfoundland and Labrador Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. **2017/023**.

DFO. 2018a. Assessment of Newfoundland and Labrador (Divisions 2HJ3KLNOP4R) Snow Crab. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2018/024.

DFO. 2018b. Assessment of Redfish stocks in units 1 and 2 in 2017. DFO Can Sci Advis Sec Res Doc 2018/032.

DFO. 2019. Assessment of Northern Shrimp, *Pandalus borealis*, and Striped Shrimp, *Pandalus montagui*, in the Eastern and Western Assessment Zones, February 2019. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2019/011.

Dwyer, K.S., Buren, A., and Koen-Alonso, M. 2010. Greenland halibut diet in the Northwest Atlantic from 1978 to 2003 as an indicator of ecosystem change. J. Sea Res. **64**(4): 436–445. Elsevier B.V. doi:10.1016/j.seares.2010.04.006.

Dwyer, K.S., Morgan, M.J., Maddock Parsons, D., Brodie, W.B., Rideout, R.M., and Healey, B.P. 2012. An Assessment of American plaice in NAFO Div. 3LNO. Nafo: 72. doi:10.1007/s13398-014-0173-7.2.

Elliot, J.M., and Persson, L. 1978. The estimate of daily rates of food consumption for fish. J. Anim. Ecol. **47**: 977–997.

Foote, A.D., Newton, J., Piertney, S.B., Willerslev, E., and Gilbert, M.T.P. 2009. Ecological, morphological and genetic divergence of sympatric North Atlantic killer whale populations. Mol. Ecol. **18**(24): 5207–5217. doi:10.1111/j.1365-294X.2009.04407.x.

Froese, R., and Pauly, D. 2013. FishBase. Available from www.fishbase.org.

Fulton, E.A. 2010. Approaches to end-to-end ecosystem models. J. Mar. Syst. **81**(1–2): 171–183. Elsevier

B.V. doi:10.1016/j.jmarsys.2009.12.012.

Gabrielsen, G.W., Taylor, J.R.E., Konarzewski, M., and Mehlum, F. 1991. Field and Laboratory Metabolism and Thermoregulation in Dovekies (*Alle alle*). Auk **108**(1): 71–78.

Gaichas, S., Gamble, R., Fogarty, M., Benoit, H., Essington, T., Fu, C.H., Koen-Alonso, M., and Link, J.S. 2012. Assembly rules for aggregate-species production models: simulations in support of management strategy evaluation. Mar. Ecol. Prog. Ser. **459**(Watt 1968): 275–+. doi:10.3354/meps09650.

Garrison, L.P., and Link, J.S. 2000a. Diets of five hake species in the northeast United States continental shelf ecosystem. Mar. Ecol. Prog. Ser. **204**: 243–255. doi:10.3354/meps204243.

Garrison, L.P., and Link, J.S. 2000b. Dietary guild structure of the fish community in the Northeast United States continental shelf ecosystem. Mar. Ecol. Prog. Ser. **202**: 231–240. doi:10.3354/meps202231.

Gaskin, D.E. 1982. Ecology of whales and dolphins. *In* FAO. Heinemann, London.

Gaskin, D.E. 1992. Status of the harbour porpoise, Phocoena phocoena, in Canada. Can. F. Nat. **106**: 36–54.

Gerasimova, O. V. 1994. Peculiarities of spring feeding by Capelin (Mallotus villosus) on the Grand Bank in 1987-90. J. Northwest Atl. Fish. Sci. **17**(Table 1): 59–67. doi:10.2960/J.v17.a5.

Gjerdrum, C., Allard, K., and Bolduc, F. 2012a. Pelagic seabird monitoring and reaserch in the northwest Atlantic. Northwest Atl. Fish. Organ. Sci. Counc. Meet. **N6055**: 1–14.

Gjerdrum, C., Fifield, D.A., and Wilhelm, S. 2012b. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms. Atlantic Region.

Gjerdrum, C., Head, E.J.H., and Fifield, D. a. 2008. Monitoring seabirds at sea in Eastern Canada. AZMP Bull. PMZA (7): 52–58.

Guillemette, M., Himmelman, J.H., and Reed, A. 1996. Availability and consumption of food by common eiders wintering in the Gulf of St. Lawrence: evidence of prey depletion. Can. J. Zool. **74**(1): 32–38. doi:10.1139/z96-005.

Hammill, M.O., and Stenson, G.B. 2000. Estimated Prey Consumption by Harp seals (<i>Phoca groenlandica<i/>), Hooded seals (<i>Cystophora cristata<i/>), Grey seals (<i>Halichoerus grypus<i/>) and Harbour seals (<i>Phoca vitulina<i/>) in Atlantic Canada. J. Northwest Atl. Fish. Sci. **26**: 1–23.

Harding, A.M.A., Egevang, C., Walkusz, W., Merkel, F., Blanc, S., and Grémillet, D. 2009. Estimating prey capture rates of a planktivorous seabird, the little auk (Alle alle), using diet, diving behaviour, and energy consumption. Polar Biol. **32**(5): 785–796. doi:10.1007/s00300-009-0581-x.

Head, E., and Pepin, P. 2009. Long-term variability in phytoplankton and zooplankton abundance in the Northwest Atlantic in Continuous Plankton Recorder (CPR) samples. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/063.

Hendrickson, L.C., and Hart, D.R. 2006. An age-based cohort model for estimating the spawning mortality of semelparous cephalopods with an application to per-recruit calculations for the northern shortfin squid, Illex illecebrosus. Fish. Res. **78**(1): 4–13. doi:10.1016/j.fishres.2005.12.005.

Hilber, S., and Lawrence, J.M. 2009. Analysis of Sediment and Gut Contents of the Sand Dollars *Mellita* *tenuis*, *Encope michelini*, and *Encope aberrans* off the Central Florida Gulf Coast. Gulf Mex. Sci. **1**: 74–81.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. **82**: 8.

Hollibaugh, J.T., and Booth, J.A. 1981. Observations on the dynamics and distribution of phytoplankton and primary production on the Grand Banks in the 1980 season. Sect. 4, Gd. Banks Oceanogr. Stud. Final Report, MacLaren Plansearch.

Hopkins, C.C.E. 1988. Energy content and production of the deep-water prawn *Pandalus borealis* as a function of body size/age and season. *In* ICES CM 1988/K:24.

Hopkins, C.C.E., and Nilssen, E.M. 1990. Population biology of the deep-water prawn (<i>Pandalus borealis</>) in Balsfjord, northern Norway: I. abundance, mortality, and growth, 1979-1983. ICES J. Mar. Sci. **47**(2): 148–166. doi:10.1093/icesjms/47.2.148.

Huntley, M.E., and Lopez, D.G. 1992. Temperature-Dependent Production of Marine Copepods : A Global Synthesis. Am. Nat. **140**(2): 201–242.

Hutchings, J.A., and Myers, R.A. 1994. What Can Be Learned from the Collapse of a Renewable Resource? Atlantic Cod, *Gadus morhua*, of Newfoundland and Labrador. Can. J. Fish Aquat. Sci. **51**: 2126–2146.

Iversen, K.R., and Seuthe, L. 2011. Seasonal microbial processes in a high-latitude fjord (Kongsfjorden, Svalbard): I. Heterotrophic bacteria, picoplankton and nanoflagellates. Polar Biol. **34**(5): 731–749. doi:10.1007/s00300-010-0929-2.

Jakobsdóttir, K.B. 2001. Biological aspects of two deep-water squalid sharks: Centroscyllium fabricii (Reinhardt, 1825) and Etmopterus princeps (Collett, 1904) in Icelandic waters. Fish. Res. **51**(2–3): 247–265. doi:10.1016/S0165-7836(01)00250-8.

Jossi, J.W., John, A.W.G., and Sameoto, D. 2003. Continuous plankton recorder sampling off the east coast of North America: history and status. Prog. Oceanogr. **58**: 313–325.

Jurgens, K., and Massana, R. 2008. Protistan grazing on marine bacterioplankton. *In* Microbial Ecology of the Ocean, 2nd edition. *Edited by* D.L. Kirchman. John Wiley & Sons Ltd., Hoboken, New Jersey, USA. p. 403.

Keats, D.W. 1990. Food of winter flounder Pseudopleuronectes americanus in a sea urchin dominated community in eastern Newfoundland. Mar. Ecol. Prog. Ser. **60**(1–2): 13–22. doi:10.3354/meps060013.

Korpinen, S., and Andersen, J.H. 2016. A Global Review of Cumulative Pressure and Impact Assessments in Marine Environments. Front. Mar. Sci. **3**(August): 1–11. doi:10.3389/fmars.2016.00153.

Kovalyov, S.M. 1972. Soviet investigations on capelin on the Grand Bank of Newfoundland in Spring-Summer 1971. ICNAF Res. Doc. **72/102**(2843): 8.

Larson, R.J. 1987. Daily ration and predation by medusae and ctenophores in Saanich Inlet, B.C., Canada. Netherlands J. Sea Res. **21**(1): 35–44.

Larson, R.J. 1991. Diet, prey selection and daily ration of Stomolophus melagris, a filter-feeding scyphomedusa from the NE Gulf of Mexico. Estuar. Coast. Shelf Sci. (32): 511–525.

Lawson, J., and Gosselin, J. 2018. Estimates of cetacean abundance from the 2016 NAISS aerial surveys of eastern Canadian waters, with a comparison to estimates from the 2007 TNASS. SC/25/AE/09 for the NAMMCO Scientific Committee.

Lawson, J.W., Stevens, T., and Snow, D. 2007. Killer whales of Atlantic Canada, with particular reference to the Newfoundland and Labrador Region. Can. Sci. Advis. Secr. **3848**.

Lawson, J.W., and Stevens, T.S. 2013. Historic and current distribution patterns, and minimum abundance of killer whales (*Orcinus orca*) in the north-west Atlantic. J. Mar. Biol. Assoc. United Kingdom **94**(06): 1253–1265. doi:10.1017/S0025315413001409.

Lilly, G.R., Hop, H., Stansbury, D.E., and A, B.C. 1994. Distribution and abundance of polar cod (*Boreogadus saida*) off southern Labrador and eastern Newfoundland. ICES C. 1994/O **6**: 1–21.

Lilly, G.R., Parsons, D.G., and Kulka, D.W. 2000. Was the Increase in Shrimp Biomass on the Northeast Newfoundland Shelf a Consequence of a Release in Predation Pressure from Cod ? **27**.

Lilly, G.R., and Simpson, M. 2000. Distribution and biomass of capelin, Arctic cod and sand lance on the Northeast Newfoundland Shelf and Grand Bank as deduced from bottom-trawl surveys. DFO Can. Sci. Advis. Sec. Res. Doc. 2000/091.

Link, J.S., and Almeida, F.P. 2000. An Overview and History of the Food Web Dynamics Program of the Northeast Fisheries Science Center. Woods Hole, MA.

Link, J.S., Overholtz, W., O'Reilly, J., Green, J., Dow, D., Palka, D., Legault, C., Vitaliano, J., Guida, V., Fogarty, M., Brodziak, J.K.T., Methratta, L., Stockhausen, W., Col, L., and Griswold, C. 2008. The Northeast U.S. continental shelf Energy Modeling and Analysis exercise (EMAX): Ecological network model development and basic ecosystem metrics. J. Mar. Syst. **74**(1–2): 453–474. Elsevier B.V. doi:10.1016/j.jmarsys.2008.03.007.

Link, J.S., Pranovi, F., Libralato, S., Coll, M., Christensen, V., Solidoro, C., and Fulton, E.A. 2015. Emergent Properties Delineate Marine Ecosystem Perturbation and Recovery. Trends Ecol. Evol.: 1–13. Elsevier Ltd. doi:10.1016/j.tree.2015.08.011.

Link, J.S., and Sosebee, K. 2008. Estimates and implications of skate consumption in the northeast US continental shelf ecosystem. North Am. J. Fish. Manag. **28**(3): 649–662. doi:10.1577/M07-100.1.

Liu, X., Devred, E., and Johnson, C. 2018. Remote Sensing of Phytoplankton Size Class in Northwest Atlantic from 1998 to 2016: Bio-Optical Algorithms Comparison and Application. Remote Sens. **10**(7): 1028. doi:10.3390/rs10071028.

Lockyer, C. 1981. Estimates of growth and energy budget for the sperm whale Physeter catodon. FAO Fish. Tech. Pap.

Mauchline, J. 1980. The biology of mysids and euphausiids. Adv. Mar. Biol. **18**: 1–677.

Mauchline, J., and Gordon, J.D.M. 1983. Diets of clupeoid, stomiatoid and salmonoid fish of the Rockall Trough. Mar. Biol. **77**: 67–78.

Maurer, R.O., and Bowman, R.E. 1985. Food consumption of the squids *Illex illecebrosus* and <i>Loligo pealei<i/> off the northeastern United States. NAFO Sci. Counc. Stud. **9**: 117–124.

Mawhinney, K., Diamond, A.W., Kehoe, P., and Benjamin, N. 1999. Status and Productivity of Common Eiders in Relation to Great Black-Backed Gulls and Herring Gulls in the Southern Bay of Fundy and the Northern Gulf of Maine. Waterbirds **22**(2).

McLaren, I.A., Trernblay, M.J., Corkett, C.J., and Roff, C. 1989. Copepod production on the Scotian SHelf based on life-history analyses and Laboratory rearings. Can. J. Fish Aquat. Sci. **46**: 560–583.

Meyers, R.A., Barrowman, N.J., Mertz, G., Gamble, J., and Hunt, H.G. 1994. Analysis of Continuous plankton recorder. Can. Tech. Rep. Fish. Aquat. Sci. **1966**: 1–246.

Mitchell, E. 1974. Present status of northwest Atlantic fin and other whale stocks. *In* The whale problem: A status report. *Edited by* W.E. Schevill. Harvard University Press, Cambridge. pp. 108–169.

Mitchell, E.D., and Chapman, D.G. 1977. Preliminary assessment of stocks of northwest Atlantic sei whales (*Balaenoptera borealis*. Rep. Int. Whal. Com. **1**: 117–120.

Mobil Oil Canada. 1985. Hibernia Development Project: Environmental Impact Statement Vol IIIa Biophysical Assessment. St. John's NL.

Morgan, M.J., Dwyer, K.S., Healy, B.P., and Rideout, R.M. 2014. Stock Assessment of American Plaice (Hippoglossoides Platessoides) stock in NAFO Subdivision 3Ps. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/098: 1–20.

Mowbray, F.K. 2002. Changes in the vertical distribution of capelin (Mallotus villosus) o ff Newfoundland. : 942–949. doi:10.1006/jmsc.2002.1259.

Mullowney, D., Coffey, W., Evans, G., Colbourne, E., Maddock Parsons, D., Fiander, D., Koen-Alonso, M., and Wells, N. 2017. An Assessment of Newfoundland and Labrador Snow Crab (*Chionoecetes opilio*) in 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/032: 1–179.

NAFO. 2016. North Atlantic Fisheries Organization 21A databases. Available from https://www.nafo.int/Data/STATLANT [accessed 20 June 2004].

Nelson, D., and Lien, J. 1996. The status of the long-finned pilot whale, *Globicephala melas*, in Canada. Can. F. Nat. **110**(3): 511–524.

Nielsen, J., Hedeholm, R.B., Heinemeier, J., Bushnell, P.G., Christiansen, J.S., Olsen, J., Ramsey, C.B., Brill, R.W., Simon, M., Steffensen, K.F., and Steffensen, J.F. 2016. Eye lens radiocarbon reveals centuries of longevity in the Greenland shark (Somniosus microcephalus).supplement. Science **353**(6300): 702–4. doi:10.1126/science.aaf1703.

Nielsen, J., Hedeholm, R.B., Simon, M., and Steffensen, J.F. 2014. Distribution and feeding ecology of the Greenland shark (Somniosus microcephalus) in Greenland waters. Polar Biol. **37**(1): 37–46. doi:10.1007/s00300-013-1408-3.

Packer, D.B., Cargnelli, L.M., Griesbach, S.J., and Shumway, S. 1999. Essential fish habitat Source Document: Sea Scallop, <i>Placopecten magellanicus<i/> Life history and habitat characteristics. NOAA Tech. Memo. **NMFS-NE-13**.

Packer, D.B., Watling, L., and Langton, W. 1994. The population structure of the brittle star Ophiura sarsi Lotken in the Gulf of Maine and its trophic relationship to American plaice (Hippoglossoides platessoides Fabricius). J. Exp. Mar. Bio. Ecol. **179**: 207–222.

Parsons, D.M., Morgan, J., Brodie, B., and Power, D. 2013. Assessment of NAFO Div 3LNO Yellowtail Flounder. NAFO Sci. Counc. Stud. **13/37**: 1–37.

Paulsen, M.L., Riisgaard, K., John, M.S., Thingstad, T.F., and Nielsen, T.G. 2017. Heterotrophic nanoflagellate grazing facilitates subarctic Atlantic spring bloom development. Aquat. Microb. Ecol. **78**(3): 161–176. doi:10.3354/ame01807.

Pauly, D., Christensen, V., and Walters, C.J. 2000. Ecopath, Ecosim, and Ecospace as tools for evaluating ecosystem impact of fisheries. ICES J. Mar. Sci. **57**: 697–706. doi:10.1006/jmsc.2000.0726.

Pepin, P., Colbourne, E., and Maillet, G. 2011. Seasonal patterns in zooplankton community structure on the Newfoundland and Labrador Shelf. Prog. Oceanogr. **91**(3): 273–285. Elsevier Ltd. doi:10.1016/j.pocean.2011.01.003.

Pepin, P., Maillet, G.L., Fraser, S., Lane, D., and Shears, T. 2015. Biological and chemical oceanographic conditions on the Newfoundland and Labrador Shelf during 2006. Can. Sci. Advis. Secr. Res. Doc. **2015/027**: 37.

Pepin, P., Petrie, B., Therriault, J.-C., Narayanan, S., Harrisson, W.G., Frank, K.T., Chassé, J., Colbourne, E.B., Gilbert, D., Gregory, D., Harvey, M., Maillet, G.L., Mitchell, M., and Starr, M. 2005. The Atlantic Zone Monitoring Program (AZMP): Review of 1998-2003. Can. Tech. Rep. Hydrogr. Ocean Sci. **242**: 1–87.

Pierce, R.W., and Turner, J.T. 1992. Ecology of planktonic ciliates in marine food webs. Rev. Aquat. Sci. **6**(January 1992): 139–181.

Polovina, J.J. 1984. Model of a coral reef ecosystem - I. The ECOPATH model and its application to French Frigate Shoals. Coral Reefs **3**(1): 1–11. doi:10.1007/BF00306135.

Rajasilta, M. 1980. Food consumption of the three-spined stickleback. Ann. Zool. Fennici **17**(2): 123–126.

Rideout, R.M., Ings, D.W., Brattey, J., and Dwyer, K. 2015. An Assessment of the Cod Stock in NAFO Divisions 3NO. Northwest Atl. Fish. Organ. Sci. Counc. Meet. **N6460**(Table 2): 1–51.

Rideout, R.M., Morgan, M.J., Maddock Parsons, D., Brodie, W.B., Healy, B.P., Power, D., and Dwyer, K.S. 2011. An assessment of American plaice in NAFO Div. 3LNO. NAFO Sci. Counc. Stud. **SCR 11/032**: 1–19. doi:10.1021/jo00129a046.

Rodriguez-Marin, E., Punzon, A., and Paz, J. 1995. Feeding patterns of Greenland halibut (*Reinhardtius hippoglossoides*) in Flemish Pass (northwest Atlantic). NAFO Sci. Counc. Stud. **23**(February 2014): 43–54.

Rose, K.A., Allen, J.I., Artioli, Y., Barange, M., Blackford, J., Carlotti, F., Cropp, R., Daewel, U., Edwards, K., Flynn, K., Hill, S.L., HilleRisLambers, R., Huse, G., Mackinson, S., Megrey, B., Moll, A., Rivkin, R., Salihoglu, B., Schrum, C., Shannon, L., Shin, Y.-J., Smith, S.L., Smith, C., Solidoro, C., St. John, M., and Zhou, M. 2010. End-To-End Models for the Analysis of Marine Ecosystems: Challenges, Issues, and Next Steps. Mar. Coast. Fish. **2**(1): 115–130. doi:10.1577/C09-059.1.

Saether, O., Ellingsen, T.E., and Mohr, V. 1986. Lipids of North Atlantic krill. J. Lipid Res. **27**(3): 274–85. Available from http://www.ncbi.nlm.nih.gov/pubmed/3734626.

Sameoto, D.D. 1976. Respiration Rates, Energy Budgets, and Molting Frequencies of Three Species of Euphasiids Found in the Gulf of St. Lawrence. J. Fish. Res. Board Canada **33**(Sameoto): 2568–2576. doi:10.1139/f76-301.

Schmoker, C., Hernandez-Leon, S., and Calbet, A. 2013. Microzooplankton grazing in the oceans : impacts, data variability, knowledge gaps and future directions. J. pl **35**(4): 691–706. doi:10.1093/plankt/fbt023.

Scott, J.S. 1973. Food and Inferred Feeding Behavior of Northern Sand Lance (*Ammodytes dubius*). J. Fish. Res. Board Canada **30**(3): 451–454. doi:10.1139/f73-075.

Scott, W.B., and Scott, M.G. 1988. Atlantic fishes of Canada. Can. Bull. Fish. Aquat. Sci. **219**: 731.

Sims, D.W. 2008. Chapter 3 Sieving a Living. A Review of the Biology, Ecology and Conservation Status of the Plankton-Feeding Basking Shark Cetorhinus Maximus. Adv. Mar. Biol. **54**(08): 171–

220. doi:10.1016/S0065-2881(08)00003-5.

Smith, B.E., and Link, J.S. 2010. The Trophic Dynamics of 50 Finfish and 2 Squid Species on the Northeast US Continental Shelf. Woods Hole, MA. USA.

Squires, H.J., and Dawe, E.G. 2003. Stomach contents of snow crab (Chionoecetes opilio, Decapoda, Brachyura) from the Northeast Newfoundland Shelf. J. Northwest Atl. Fish. Sci. **32**(October): 27–38. doi:10.2960/J.v32.a2.

Stenson, G.B. 2002. Harbour porpoise (Phocoena phocoena) in the North Atlantic: Abundance, removals, and sustainability of removals. NAMMCO Sci. Publ. **5**: 271–302. doi:10.7557/3.2830.

Sullivan, B.K. 1980. In situ feeding behavior of Sagitta elegans and Eukrohnia hamata (Chaetognatha) in relation to the vertical distribution and abundance of prey at Ocean Station "P." Limnol. Oceanogr. **25**(2): 317–326. doi:10.4319/lo.1980.25.2.0317.

Tam, J.C., Link, J.S., Large, S.I., Andrews, K., Friedland, K.D., Gove, J., Hazen, E., Holsman, K., Karnauskas, M., Samhouri, J.F., Shuford, R., Tomilieri, N., and Zador, S. 2017. Comparing Apples to Oranges: Common Trends and Thresholds in Anthropogenic and Environmental Pressures across Multiple Marine Ecosystems. Front. Mar. Sci. **4**: 282. doi:10.3389/fmars.2017.00282.

Tittensor, D.P. et al. 2017. A protocol for the intercomparison of marine fishery and ecosystem models: Fish-MIP v1.0. Geosci. Model Dev.: 1421–1442. doi:https://www.geosci-model-dev-discuss.net/gmd-2017-209/.

Travers, M., Shin, Y.J., Jennings, S., and Cury, P. 2007. Towards end-to-end models for investigating the effects of climate and fishing in marine ecosystems. Prog. Oceanogr. **75**(4): 751–770. doi:10.1016/j.pocean.2007.08.001.

Trites, A.W., and Pauly, D. 1998. Estimating mean body masses of marine mammals from maximum body lengths. Can. J. Zool. **76**(5): 886–896. doi:10.1139/cjz-76-5-886.

Vermeer, K. 1984. The Diet and Food Consumption of Nestling Cassin's Auklets during Summer and a Comparison with Other Plankton-Feeding Alcids. The Murrelet **65**(3): 65–77.

Vesin, J.-P., Leggett, W.C., and Able, K.W. 1981. Aquatic Sciences. Can. J. Fish. Aquat. Sci. **38**(56142).

Virtue, P., Mayzaud, P., Albessard, E., and Nichols, P. 2000. Use of fatty acids as dietary indicators in northern krill, *Meganyctiphanes norvegica* , from northeastern Atlantic, Kattegat, and Mediterranean waters. Can. J. Fish. Aquat. Sci. **57**(S3): 104–114. doi:10.1139/f00-182.

Walters, C., Christensen, V., Walters, W., and Rose, K. 2010. Representation of Multistanza Life Histories in Ecospace Models for Spatial Organization. Bull. Mar. Sci. **86**(2): 439–459. doi:papers3://publication/uuid/F835554D-9C95-4A26-AA0B-31166058CC5B.

Walters, C., Pauly, D., and Christensen, V. 1999. Ecospace: Prediction of mesoscale spation patterns in trophi relatiohsips of exploited ecosystem, with empahsis on the impacts of marine protected areas. Ecosystems **2**: 539–554.

Warkentin, I., Newton, S., and Peterson, R. 2013. Birds of Newfoundland: Field Guide. Boulder Publications, St. John's NL.

Wenner, C.A. 1983. Biology of the Longfin Hake, <i>Phycis chesteri<i/> , in the Western North Atlantic. Biol. Oceanogr. **3**(1): 41–75.

Winters, G.H. 1983. Analysis of the biological and demographic parameters of the northern sand lance, Ammodytes dubius, from the Newfoundland Grand Bank. Can. J. Fish. Aquat. Sci. **40**(Pitt 1976):

409–419. doi:10.1139/f83-059.

Yano, K., Stevens, J.D., and Compagno, L.J.V. 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.

Zamarro, J. 1992. Feeding behaviour of the American Plaice (*Hippoglossoides platessoides* on the Southern Grand Bank of Newfoundland. Netherlands J. Sea Res. **29**: 229–238.